XVI MEĐUNARODNI SIMPOZIJUM
INŽENJERSKI MENADŽMENT I KONKURENTNOST
EMC 2026

EMC 2026

16th International Symposium
"Engineering Management and
Competitiveness" 2026

UNIVERZITET U NOVOM SADU
TEHNIČKI FAKULTET "MIHAJLO PUPIN"
ZRENJANIN

University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

Budapest University of Economics and Business, Faculty of Finance and Accountancy, Budapest, Hungary

Voronezh State University, Department of Economics and Organization Management, Russia

16th International Symposium

ENGINEERING MANAGEMENT AND COMPETITIVENESS 2026 (EMC 2026)

Proceedings

19-20th of June 2026, Zrenjanin, Serbia

Organizer of the Symposium:
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

Partners:
Budapest University of Economics and Business, Faculty of Finance and Accountancy, Budapest, Hungary
Voronezh State University, Department of Economics and Organization Management, Russia

Publisher: University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Đure Đakovića bb, 23000 Zrenjanin, Serbia

For publisher: Milan Nikolić, Ph.D, Professor, Dean of Technical faculty

Editor: Edit Terek Stojanović, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Reviewers:
Ivana Berković, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia
Nemanja Berber, Ph.D, Professor, University of Novi Sad, Faculty of Economics Subotica, Subotica, Serbia

Technical treatment:
Dragan Ćoćkalo, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia
Mihalj Bakator, Ph.D, Assistant Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia
Verica Gluvakov, M.Sc, Assistant, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia
Stefan Ugrinov, M.Sc, Assistant, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Cover design:
Dragan Ćoćkalo, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Lecturer:
Katarina Ivanović, Ph.D, Assistant Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

ISBN: 978-86-7672-396-6

CIP - Каталогизација у публикацији
Библиотеке Матице српске, Нови Сад

62:005(082)(0.034.2)

INTERNATIONAL Symposium Engineering Management and Competitiveness (16 ; 2026 ; Zrenjanin)
Proceedings [Elektronski izvor] / 16th International Symposium Engineering Management and Competitiveness (EMC 2026), 19-20th of June 2026, Zrenjanin, Serbia ; [organizer] Technical Faculty "Mihajlo Pupin", Zrenjanin ; [editor Edit Terek Stojanović]. - Zrenjanin : Technical Faculty "Mihajlo Pupin", 2026. - 1 elektronski optički disk (CD ROM) : tekst, slika ; 12 cm

Dostupno i na: http://www.tfzr.rs/emc/index.aspx. - Nasl. sa naslovnog ekrana. - Elektronska publikacija u formatu pdf opsega 330 str. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-7672-396-6

a) Инжењерски менаџмент -- Зборници

COBISS.SR-ID 195794953

©2026 University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia. This Proceedings is a part of the internal informational materials of EMC 2026.

Program Committee:

Edit Terek Stojanović, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia - President of the Program Committee

Dragan Ćoćkalo, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia – Vice President of the Program Committee

Ješa Kreiner, Ph.D, Professor, California State University, Department of Engineering, Fullerton, CA, USA

Poór József, Ph.D, Professor, Szent István University, Gödöllő, Hungary

Ali Reza Afshari, Ph.D, Assistant professor, Islamic Azad University, Iran

Mohammad Anisseh, Ph.D, Assistant professor, Imam Khomeini International University, Qazvin, Iran

Ioannis Filippopoulos, Ph.D, Professor, University of Thessaly, Department of Computer Science, Lamia, Greece

Boštjan Antončič, **Ph.D**, Professor, University of Ljubljana, Faculty of Economics, Ljubljana, Slovenia

Larisa Nikitina, Ph.D, Professor, Voronezh State University, Department of Economics and Organization Management, Russia

Robert Minovski Ph.D, Professor, "Ss. Cyril and Methodi" University in Skopje, Faculty of Mechanical Engineering, Skopje, North Macedonia

Bojan Jovanovski, Ph.D, Associate professor, "Ss. Cyril and Methodi" University in Skopje, Faculty of Mechanical Engineering, Skopje, North Macedonia

Maša Magzan, Ph.D, Assistant Professor, University of Rijeka, Croatia

Zoran Filipi, Ph.D, Professor, Clemson University, Department of Automotive Engineering, South Carolina, USA

Zdenek Dvořák, Ph.D, Professor, University of Žilina, Faculty of Special Engineering, Slovakia

Vesna Spasojević Brkić, Ph.D, Professor, University of Belgrade, Mechanical faculty, Serbia

Cariša Bešić, Ph.D, Professor, University of Kragujevac, Faculty of Technical Sciences, Čačak, Serbia

Matej Černe, Ph.D, Associate Professor, University of Ljubljana, Faculty of Economics, Ljubljana, Slovenia

Milan Delić, Ph.D, Associate Professor, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia

László Szabó, Ph.D, Professor, Budapest University of Economics and Business, Faculty of Marketing and Business Communication, Budapest, Hungary

Jasna Auer Antončič, **Ph.D,** Assistant Professor, University of Primorska, Faculty of Management, Koper, Slovenia

Violeta Cvetkoska, Ph.D, Associate professor, "Ss. Cyril and Methodius" University, Faculty of Economics, Skopje, North Macedonia

Bruno Završnik, Ph.D., Professor, University of Maribor, Faculty of Economics and Business, Slovenia

László Buics, Ph.D., Associate Professor, Széchenyi István University, Krautz Gyula Faculty of Economics, Gőr, Hungary

Miroslava Petrevska, Ph.D, Lecturer, The College of Tourism, Belgrade, Serbia

Srđan Bogetić, Ph.D., Belgrade Business and Arts Academy of Applied Studies, Belgrade, Serbia

Miloš Vorkapić, Ph.D., Scientific associate, University of Belgrade, Institute of Chemistry, Technology and Metallurgy (ICTM) - Center of Microelectronic Technologies, Belgrade, Serbia

Milan Nikolić, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Sanja Stanisavljev, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Mila Kavalić, Ph.D, Assistant Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Mihalj Bakator, Ph.D, Assistant Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Organizing Committee:

Sanja Stanisavljev, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia – President of the Organizing Committee

Milan Nikolić, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia – Vice President of the Organizing Committee

Dragan Ćoćkalo, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Edit Terek Stojanović, Ph.D, Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Mila Kavalić, Ph.D, Assistant Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Mihalj Bakator, Ph.D, Assistant Professor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Dragana Kovač, M.Sc, Assistant, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Verica Gluvakov, M.Sc, Assistant, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

Stefan Ugrinov, M.Sc, Assistant, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia

INTRODUCTION

Department of Management and Technical faculty "Mihajlo Pupin" from Zrenjanin have started the organization of International Symposium Engineering Management and Competitiveness (EMC) in 2011. Since 2013 the organization of the EMC symposium has been supported by the following foreign partners: Szent István University, Faculty of Economics and Social Sciences, Gödöllő, Hungary, Voronezh State University, Faculty of Economics, Voronezh, Russia and University of Montenegro, Maritime Faculty, Kotor, Montenegro. Since 2025 the partners are: Budapest University of Economics and Business, Faculty of Finance and Accountancy, Budapest, Hungary and Voronezh State University, Department of Economics and Organization Management, Russia.

The objectives of the Symposium EMC are: presentation of current knowledge and the exchange of experiences from the field of Engineering management, consideration of development tendencies and trends in Serbia and the world as well, gathering researchers from this field with the aim of expanding regional and international cooperation, raising the level of professional and scientific work at Technical faculty "Mihajlo Pupin" from Zrenjanin, expanding cooperation with economic and educational institutions and encouraging young researchers within this field. Taking into account that this Symposium is international, the importance of this event is obvious for the town of Zrenjanin, Banat region, Vojvodina and Serbia. Organization of EMC by the Technical faculty "Mihajlo Pupin" from Zrenjanin represents this scientific-educational institution as one of the major representatives of economic and social development in Banat.

Over the years, the EMC Symposium has evolved into a recognized international symposium for the dissemination of scientific achievements and professional experiences in the fields of engineering management, competitiveness, innovation, and sustainable development. The multidisciplinary nature of the Symposium encourages dialogue among researchers, academics, industry professionals, and policymakers, creating opportunities for the development of new ideas, collaborative projects, and practical solutions to contemporary managerial and technological challenges. The papers presented in these Proceedings reflect the diversity of current research topics and contribute to the advancement of knowledge and practice in engineering management, both regionally and internationally.

Within this Proceeding all accepted papers received for the 16th International Symposium Engineering Management and Competitiveness 2026 (EMC 2026) are presented. This year at the symposium we have 52 papers. The authors come from 11 countries: Bosnia and Herzegovina, Canada, Croatia, Hungary, Iran, North Macedonia, Russia, Slovenia, Serbia, Turkey and the United States. The papers are divided into six sessions: Plenary, Management and operation management, Human resource management, Marketing management, Economy, and IT Management.

We wish to thank the Technical faculty "Mihajlo Pupin" from Zrenjanin and the dean Prof. Ph.D Milan Nikolić for their active role concerning the organization of the Symposium. We are also expressing our gratitude to all authors who have contributed with their papers to the organization of our fifteenth Symposium EMC.

The EMC Symposiums become a traditional meeting of researchers in June, every year. We are open and thankful for all useful suggestions which could contribute that the next International Symposium Engineering Management and Competitiveness become better in an organizational and program sense.

President of the Programm Committee
Professor Edit Terek Stojanović, Ph.D.

Zrenjanin, June 2026.

Word of Thanks

We wish to thank
Provincial Secretary for Higher Education and Scientific Research,
Autonomous Province of Vojvodina, Republic of Serbia
for donating financial means which supported the organization of
16th International Symposium
Engineering Management and Competitiveness 2026
(EMC 2026).

CONTENTS

Plenary session ...1

Dragan Ćoćkalo, Mihalj Bakator, Sanja Stanisavljev, Milan Nikolić,
Edit Terek Stojanović, Mila Kavalić, Stefan Ugrinov, Verica Gluvakov
ENTREPRENEURSHIP 5.0 ORIENTED STRATEGIES FOR SUSTAINABLE
COMPETITIVE ADVANTAGE ...3

Zoran Čepić, Julka Petrović
IMPLEMENTATION OF THE MONITORING, REPORTING AND VERIFICATION
SYSTEM FOR GREENHOUSE GAS EMISSIONS IN THE REPUBLIC OF SERBIA:
FROM REGULATORY FRAMEWORK TO THE FIRST REPORTING YEAR ...10

Igor Grubišić, Ivana Denčić
OBSERVABILITY BEYOND MONITORING: QUANTIFYING
THE IMPACT OF IT ON ENTERPRISE VALUE ...16

Larisa Nikitina, Ulyana Dubinkina, Irina Maleva
STUDENTS' ENTREPRENEURIAL INTENTIONS IN CONTEXT OF
MACROECONOMIC INSTABILITY: AN EMPIRICAL ANALYSIS
USING THE CASE OF VORONEZH STATE UNIVERSITY ...22

Sanela Ravlić
ARTIFICIAL INTELLIGENCE AND THE REDEFINITION OF THE DIKW
PYRAMID: CHALLENGES OF THE POSTDIGITAL AGE ...28

Marija Stanojeska, Stefan Dimovski
VALUATION OF THE EFFECTS OF EMERGING TECHNOLOGIES:
SURVEY-BASED EVIDENCE FROM THE IT SECTOR ...35

Jun Todorovic, Zelimir Todorovic
ENTREPRENEURIAL UNIVERSITY SCALE (ENTRE-U)
VALIDATION AT CHINESE UNIVERSITIES ...41

Session A: MANAGEMENT AND OPERATION MANAGEMENT ...47

Muhammed Ernur Akiner
WATER SCARCITY CHALLENGE FOR TURKEY: RECOGNITION OF REGIONAL
DISCREPANCIES AND URGENT SOLUTION FOR SUSTAINABILITY ...49

İlknur Akiner, Büşra Selin Kepenek
A SYSTEMATIC REVIEW OF CRITICAL FACTORS AFFECTING COMPANY
SUCCESS IN INTERNATIONAL CONTRACTING SERVICES ...56

Dušan Jovanić, Valentina Mladenović
RISK ANALYSIS OF INFRARED THERMOGRAPHIC EQUIPMENT ...65

Dušan Jovanić, Valentina Mladenović
RISK ASSESSMENT AND RISK REDUCTION MEASURES FOR
ELECTROPNEUMATIC EQUIPMENT ...71

Natalija Nikolić, Milka Bubalo Živković, Tamara Lukić,
Bojan Đerčan, Dajana Bjelajac
INTERNET COVERAGE AND SMART RURAL DEVELOPMENT:
THE CASE STUDY OF VOJVODINA, SERBIA ...77

Ivan Palinkaš, Eleonora Desnica, Jasmina Pekez, Bogdana Vujić,
Ljiljana Radovanović, Borko Bulajić ANALYSIS OF THE CONDITION OF
HISTORICAL BUILDINGS IN SERBIA – LITERATURE REVIEW ...83

Adriana Radosavac, Oliver Momčilović
STRATEGIC SELECTION OF A LOGISTICS CENTER LOCATION USING
A HYBRID MCDM MODEL BASED ON PIPRECIA AND SAW METHODS:
AN EMPIRICAL STUDY ...87

László Szabó
INNOVATION AND TECHNOLOGICAL CHANGES IN SUPPLY CHAINS ...94

Vesna Spasojević Brkić, Branislav Tomić, Iva Savić,
Martina Perišić Jokić, Abdulghder Alsharif
LINKING ORGANIZATIONAL CULTURE, QUALITY AND AGILITY TO
BUSINESS PERFORMANCE: A CROSS-COUNTRY CLUSTER ANALYSIS
OF A TRANSPORTATION SUPPLY CHAIN ...99

Stefan Ugrinov, Edit Terek Stojanović, Sanja Stanisavljev, Mila Kavalić,
Verica Gluvakov, Mića Đurđev
MANAGING THE STRATEGIC LOGISTICS POSITION OF THE REPUBLIC OF
SERBIA IN REGIONAL AND EUROPEAN SUPPLY CHAINS ...106

Session B: HUMAN RESOURCE MANAGEMENT ...111

Ali Reza Afshari, Dragan Ćoćkalo
IDENTIFYING AND PRIORITIZING BEHAVIORAL COMPETENCIES OF
PROJECT MANAGERS IN MASHHAD METRO PROJECTS ...113

Milica Bogdanov, Jasmina Poštin
COMPARATIVE ANALYSIS OF HR PROFESSIONALS' COMPETENCIES
IN DIFFERENT SECTORS BETWEEN DEVELOPED AND
DEVELOPING COUNTRIES ...120

Aneta Guteša, Dijana Vašaš Kuručev, Milica Bogdanov, Jasmina Poštin
SUSTAINABLE HUMAN RESOURCE PRACTICES AND EMPLOYEE
WELLBEING IN DIGITALIZED WORK ENVIRONMENTS ...126

Mirjana Jokanović Đajić, Brankica Čomić, Obrad Spaić, Mirjana Miljanović
BETWEEN FAILURE AND SUCCESS: THE ROLE OF PROJECT MANAGER'S
LEADERSHIP IN ACHIEVING PROJECT SUCCESS DIMENSIONS ...132

Dragana Kovač, Edit Terek Stojanović, Stefan Ugrinov,
Melita Ćoćkalo-Hronjec, Milovan Cvjetković
THE IMPORTANCE OF CREATIVITY IN HIGHER EDUCATION FOR
THE DEVELOPMENT OF MODERN BUSINESS ...138

Ljubiša Malešev, Jasmina Pekez, Mila Kavalić,
Nikola Jerković, Nadežda Ljubojev
HUMAN RESOURCES AS A DETERMINANT OF THE SUCCESSFUL
INTEGRATION OF CBAM REQUIREMENTS INTO THE PRODUCT
CARBON FOOTPRINT MANAGEMENT SYSTEM ...144

Leontina Pap
ETHICAL MANAGEMENT OF ARTIFICIAL INTELLIGENCE IN
GLOBAL BUSINESS: COMPETITIVENESS, RISKS AND
REGULATORY FRAMEWORKS ...151

Marko Pavlović, Dragana Đurić, Marija Perić,
Mirjana Dunić, Miodrag Simić
HUMAN RESOURCES MANAGEMENT IN INSURANCE COMPANIES:
CASE STUDY WIENER STADTISCHE ...157

Ana-Marija Vukić, Dragana Sajfert, Marko Kihler
THE IMPACT OF DIGITAL COMPETENCIES ON HUMAN RESOURCE
MANAGEMENT PRACTICES ...163

Session C: MARKETING MANAGEMENT ...169

Nurdan Akiner
THE ALGORITHMIC EMPIRE: ALPHABET INC. AND THE INFRASTRUCTURAL
HEGEMONY OF PLATFORM CAPITALISM ...171

Marija Bugarski
IMPORTANCE OF BRAND DEVELOPMENT IN THE FASHION INDUSTRY ...179

Nenad Djokic, Nikola Milicevic, Ines Djokic, Branimir Kalas
THE IMPLEMENTATION OF A/B TESTING TECHNIQUE ...185

Dijana Vašaš Kuručev, Aneta Guteša
DIGITAL TOOLS AS DRIVERS OF MICRO-INNOVATIONS IN SME BUSINESS
MODELS IN THE CONTEXT OF ENTREPRENEURSHIP 5.0 ...191

Peko Lakatuš, Mihalj Bakator, Miloš Vorkapić
OPTIMIZATION OF MARKETING MANAGEMENT IN INDUSTRIAL (B2B)
COMPANIES: A LITERATURE REVIEW AND MODEL PROPOSAL ...197

Peko Lakatuš, Uroš Šarenac
INTEGRATED MARKETING MANAGEMENT MODEL FOR IMPROVING
BUSINESS AND MARKET PERFORMANCE OF
CONTEMPORARY ENTERPRISES ...202

Ljiljana Stošić Mihajlović, Marija Mihajlović
ORGANIZATIONAL AND FINANCIAL CONSTRAINTS OF MARKETING
MANAGEMENT IN SMALL AND MEDIUM ENTERPRISES ...208

Ljiljana Stošić Mihajlović, Marija Mihajlović
DETERMINANTS OF EFFECTIVE MARKETING MANAGEMENT ...214

Bruno Završnik
OMNICHANNEL RETAILING STRATEGY ...220

Session D: ECONOMY ...227

Mohammad Anisseh, Rohullah Sajed
EVALUATING THE IMPACT OF DOLLAR AUCTION POLICY ON EXCHANGE
RATE STABILITY IN AFGHANISTAN: AN ARDL APPROACH ...229

Marijana Dukić Mijatović, Andrea Ivanišević, Otilija Sedlak,
Aleksandra Marcikić Horvat, Biljana Pajin
DIGITALIZATION AS A DRIVER OF CIRCULAR ECONOMY TRANSITION:
A CONCEPTUAL FRAMEWORK FOR EMERGING ECONOMIES ...236

Branimir Kalaš, Ines Đokić
FINANCIAL CONSIDERATIONS OF AI ADOPTION IN HIGHER EDUCATION ...241

Mila Krivokuća
ENTREPRENEURSHIP AND CORPORATE SOCIAL RESPONSIBILITY ...245

Mila Krivokuća
ENTREPRENEURSHIP AND THE CONCEPT OF SUSTAINABLE DEVELOPMENT ...251

Vladimir Marković
HYPERCOMPETITIVE RELATIONS AND THE NECESSITY OF
BENCHMARKING IN DOMESTIC ENTERPRISES ...257

Vladimir Milošev, Dubravko Marić, Ali Reza Afshari
NETWORK MODEL OF REGIONAL ENTREPRENEURIAL
ECOSYSTEMS IN SERBIA ...262

Miloš Pjanić, Jelena Andrašić, Milica Inđić, Mirela Mitrašević
FACTORS IN THE DEVELOPMENT OF THE LIFE INSURANCE MARKET
IN THE REPUBLIC OF SERBIA ...267

Session E: IT MANAGEMENT ...273

Ivana Denčić, Sanja Stanisavljev
NO BORDERS FOR COMPLIANCE: EU AI ACT OBLIGATIONS FOR
NON-EU DIGITAL AGENCIES AND TECH COMPANIES ...275

Aleksandar Kupusinac
THE SMART CITY: TECHNOLOGY, FUNCTIONALITY AND CHALLENGES ...281

Tamara Milić, Biljana Radulović, Igor Vecštejn, Vuk Amižić
RISK ANALYSIS OF MICROSERVICES ARCHITECTURE FOR A BANK'S
INFORMATION SYSTEM ...285

Branislava Radu, Ljubica Kazi
MAPPING BUSINESS PROCESS MODELS INTO SOFTWARE
DESIGN DIAGRAMS ...291

Branislava Radu, Ljubica Kazi
TOOLS FOR AUTOMATED SOFTWARE CODE GENERATION WITH
PROMPT ENGINEERING, EFFICIENCY AND THE EDUCATIONAL
UTILIZATION POTENTIALS: A BRIEF REVIEW ...297

Jelena Slavić, Željko Stojanov
IMPACT OF TECHNOLOGICAL DRIVERS ON JOB TRANSFORMATION
WITH IMPLICATIONS FOR RESKILLING AND UPSKILLING ...303

Ivana Vasić, Ivana Berković, Veselinka Lejić
TEACHERS' PERCEPTIONS OF AI TOOL ADOPTION IN SERBIAN
SCHOOLS: IMPLICATIONS FOR EDUCATIONAL MANAGEMENT ...309

Igor Vecstejn, Tamara Milić, Vuk Amižić,
Ninoslava Tihi, Mohammad Anisseh
ONBOARDING AS KNOWLEDGE MANAGEMENT IN REMOTE
SOFTWARE TEAMS: A LITERATURE REVIEW ...315

Ana-Marija Vukić, Biljana Radulovic, Dragana Sajfert
MANAGING DIGITAL COMPETENCIES TO IMPROVE THE QUALITY OF
INFORMATICS TEACHING IN PRIMARY SCHOOLS ...321

Author Index ...327

16th International Symposium Engineering Management and Competitiveness 2026 (EMC 2026)
June, 19-20, 2026, Zrenjanin, Serbia

Plenary session

Papers (pp. 3-46):

Dragan Ćoćkalo, Mihalj Bakator, Sanja Stanisavljev, Milan Nikolić,
Edit Terek Stojanović, Mila Kavalić, Stefan Ugrinov, Verica Gluvakov
ENTREPRENEURSHIP 5.0 ORIENTED STRATEGIES FOR SUSTAINABLE
COMPETITIVE ADVANTAGE ...3

Zoran Čepić, Julka Petrović
IMPLEMENTATION OF THE MONITORING, REPORTING AND VERIFICATION
SYSTEM FOR GREENHOUSE GAS EMISSIONS IN THE REPUBLIC OF SERBIA:
FROM REGULATORY FRAMEWORK TO THE FIRST REPORTING YEAR ...10

Igor Grubišić, Ivana Denčić
OBSERVABILITY BEYOND MONITORING: QUANTIFYING
THE IMPACT OF IT ON ENTERPRISE VALUE ...16

Larisa Nikitina, Ulyana Dubinkina, Irina Maleva
STUDENTS' ENTREPRENEURIAL INTENTIONS IN CONTEXT OF
MACROECONOMIC INSTABILITY: AN EMPIRICAL ANALYSIS
USING THE CASE OF VORONEZH STATE UNIVERSIT ...22

Sanela Ravlić
ARTIFICIAL INTELLIGENCE AND THE REDEFINITION OF THE DIKW
PYRAMID: CHALLENGES OF THE POSTDIGITAL AGE ...28

Marija Stanojeska, Stefan Dimovski
VALUATION OF THE EFFECTS OF EMERGING TECHNOLOGIES:
SURVEY-BASED EVIDENCE FROM THE IT SECTOR ...35

Jun Todorovic, Zelimir Todorovic
ENTREPRENEURIAL UNIVERSITY SCALE (ENTRE-U)
VALIDATION AT CHINESE UNIVERSITIES ...41

ENTREPRENEURSHIP 5.0 ORIENTED STRATEGIES FOR SUSTAINABLE COMPETITIVE ADVANTAGE

DOI: 10.5937/EMC26003C

Dragan Ćoćkalo
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Mihalj Bakator
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
E-mail: mihalj.bakator@uns.ac.rs
Sanja Stanisavljev
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Milan Nikolić
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Edit Terek Stojanović
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Mila Kavalić
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Stefan Ugrinov
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Verica Gluvakov
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia

ABSTRACT

This study examines the influence of Entrepreneurship 5.0 oriented strategies on sustainable competitive advantage. The research focuses on digital technology integration, collaborative innovation and ecosystem engagement, and human-centric entrepreneurial orientation. Data were collected from 64 enterprise managers using a structured survey with a seven-point Likert scale. The analysis includes descriptive statistics, correlation analysis, and linear regression. The results show positive and statistically significant relationships between all independent variables and sustainable competitive advantage. Human-centric entrepreneurial orientation shows the strongest effect, followed by digital technology integration and collaborative innovation. The model explains a substantial portion of variance in the dependent variable, which confirms its explanatory strength. The findings indicate that enterprises that combine technological adoption, external collaboration, and internal orientation toward employees achieve more stable competitive outcomes. The study contributes to the understanding of Entrepreneurship 5.0 and offers a basis for further research and practical application in modern business environments.

Key words: Entrepreneurship 5.0, Sustainable competitive advantage, Collaborative innovation, Ecosystem engagement.

INTRODUCTION

Modern business environments are characterized by complexity, uncertainty, and continuous change. Enterprises adjust strategies to maintain competitiveness over longer periods. The concept of sustainable competitive advantage has gained importance, since organizations focus on long-term positioning in addition to short-term performance (Abbasi Kamardi et al., 2025; Hossain et al., 2022;). Traditional approaches to competitiveness are often insufficient because they neglect the integration of technological and human-oriented elements. New frameworks combine digital transformation with broader organizational and societal considerations. Entrepreneurship 5.0 represents such a framework. It integrates digital technologies, collaboration, and human-centered values into entrepreneurial practice (Putra et al., 2024). This approach emphasizes alignment between technological development

and human needs, as well as cooperation within innovation ecosystems. Enterprises integrate digital technologies, engage in collaborative innovation, and develop orientations that consider employees and stakeholders. Digital technology integration improves processes, decision making, and communication (Huang et al., 2025). Collaborative innovation and ecosystem engagement enable access to external knowledge and support value co-creation (Abazi-Alili et al., 2024; Abbate et al., 2022). Human-centric entrepreneurial orientation focuses on employee well-being, creativity, and organizational culture, which supports adaptability and long-term outcomes (Irawan et al., 2023).

This study investigates the relationships between digital technology integration, collaborative innovation and ecosystem engagement, and human-centric entrepreneurial orientation. Through empirical analysis, the research explores how these factors influence sustainable competitive advantage. This research contributes to the understanding of how Entrepreneurship 5.0 approaches can be implemented for long-term competitiveness in the turbulent modern business environment.

THEORETICAL BACKGROUND

The concept of sustainable competitive advantage is grounded in resource-based theory and dynamic capability perspectives. It refers to the ability of an enterprise to achieve and maintain superior performance relative to competitors over time. This outcome depends on the possession and effective use of resources that are valuable, rare, and difficult to imitate (Hossain et al., 2022; Iriani et al., 2024). Enterprises are not limited to static resource conditions, since changing environments require continuous adjustment of internal structures and strategies. Dynamic capabilities describe the capacity to integrate, reconfigure, and renew internal and external competences in line with market conditions (Alrub & Sánchez-Cañizares, 2025; Hsiao, 2024). These perspectives indicate that long-term competitiveness depends on both resource quality and the ability to adapt organizational processes and decisions. Digital technology integration has been widely examined as a determinant of firm performance and competitiveness. It includes the adoption and use of technologies such as data analytics, cloud computing, and digital communication systems. These technologies support more efficient information processing, coordination of activities, and data-based decision making (Shah et al., 2024; Huang et al., 2025). Organizations that integrate digital tools into their operations are able to improve process transparency and reduce operational inefficiencies. In addition, digital technologies enable new forms of value creation through improved customer interaction and service delivery (Su et al., 2022). However, the effects of digital integration are not uniform across firms. The benefits depend on the alignment between technological investments and existing organizational capabilities, including employee skills and managerial practices (Nasution et al., 2026). Without such alignment, digital tools may remain underutilized and fail to contribute to performance outcomes.

Collaborative innovation and ecosystem engagement are based on open innovation and network theory. Open innovation assumes that firms rely on both internal and external sources of knowledge to develop innovations (Nguyen et al., 2025). Ecosystem engagement extends this perspective by including a wider set of actors such as suppliers, customers, institutions, and strategic partners. Enterprises that actively participate in innovation networks gain access to diverse knowledge bases and complementary resources. This interaction supports joint problem solving and shared value creation across organizational boundaries (Abbate et al., 2022). Empirical findings indicate that firms engaged in collaborative innovation achieve improved innovation outputs and stronger competitive positions (Abazi-Alili et al., 2024). At the same time, effective collaboration requires coordination mechanisms, trust, and clear communication among participants. Human-centric entrepreneurial orientation is derived from entrepreneurship theory and organizational behavior research. It reflects a focus on people within the enterprise, including employees, managers, and stakeholders. This orientation includes support for creativity, openness to new ideas, and attention to employee well-being. It also involves responsible decision making and consideration of broader social outcomes. Organizations that develop such orientations create internal environments that support knowledge sharing and continuous improvement (Irawan et al., 2023). These conditions contribute to higher levels of employee motivation and adaptability. As a result, enterprises are better prepared to respond to changes and maintain stable performance over time.

The integration of digital technology, collaborative innovation, and human-centric orientation aligns with the broader framework of Entrepreneurship 5.0. This framework connects technological development with collaboration and human-centered values (Putra et al., 2024). It suggests that competitiveness emerges from the interaction of multiple elements rather than isolated practices. Digital capabilities provide the infrastructure for data-driven operations and communication. Collaborative networks expand access to knowledge and resources. Human-oriented practices support internal cohesion and adaptability. When these elements are aligned, enterprises are able to create more stable and sustainable competitive outcomes. Empirical evidence indicates that firms that combine digital capabilities with innovation and organizational alignment achieve higher levels of performance and long-term competitiveness (Van Hoang et al., 2025).

METHODOLOGY

The study was conducted to analyze the influence of digital technology integration, collaborative innovation and ecosystem engagement and human-centric entrepreneurial orientation on sustainable competitive advantage. A total of 64 respondents (enterprise managers) participated in the survey. The survey included seven-point Likert scale items, ranging from "strongly disagree" to "strongly agree". The data was collected via online survey, which was distributed via e-mail. Data analysis included descriptive statistics, correlation analysis and regression analysis.

Based on the analyzed literature and the research goals, the following hypotheses are noted:

H1: Digital technology integration (DIT) has a statistically significant and positive effect on Sustainable competitive advantage (SCA).

H2: Collaborative innovation and ecosystem engagement (CIE) has a statistically significant and positive effect on Sustainable competitive advantage (SCA).

H3: Human-centric entrepreneurial orientation (HCE) has a statistically significant and positive effect on Sustainable competitive advantage (SCA).

RESULTS

The results of the descriptive statistics are presented in Table 1.

Table 1: Results of the descriptive statistics

Variable	Mean	Standard deviation	Cronbach's alpha
Sustainable competitive advantage (SCA)	5.32	1.14	0.875
Digital technology integration (DTI)	4.88	1.34	0.905
Collaborative innovation and ecosystem engagement (CIE)	5.44	1.24	0.865
Human-centric entrepreneurial orientation (HCE)	5.76	1.26	0.798

(*Source:* Authors)

The results of descriptive statistics presented in Table 1 indicate relatively high average values across all analyzed variables, which suggests that respondents generally perceive a strong presence of the observed constructs within their enterprises. Human-centric entrepreneurial orientation shows the highest mean value, followed by collaborative innovation and ecosystem engagement, and sustainable competitive advantage. Digital technology integration has a slightly lower mean, which may indicate uneven levels of adoption across enterprises. The values of standard deviation suggest moderate variability in responses, which points to differences in managerial perceptions. The reported Cronbach's alpha coefficients exceed acceptable thresholds for all variables, which confirms the internal consistency and reliability of the measurement scales used in the study. The results of the correlation analysis are presented in Table 2.

Table 2: Results of the correlation analysis

	SCA	DTI	CIE	HCE
Sustainable competitive advantage (SCA)	1.000			
Digital technology integration (DTI)	0.605	1.000		
Collaborative innovation and ecosystem engagement (CIE)	0.510	0.536	1.000	
Human-centric entrepreneurial orientation (HCE)	0.487	0.598	0.622	1.000

(*Source:* Authors)

The results of the correlation analysis presented in Table 2 indicate positive relationships among all analyzed variables. Sustainable competitive advantage is positively correlated with digital technology integration (r = 0.605), collaborative innovation and ecosystem engagement (r = 0.510), and human-centric entrepreneurial orientation (r = 0.487). The strongest relationship among independent variables is observed between collaborative innovation and human-centric entrepreneurial orientation (r = 0.622), followed by the relationship between human-centric orientation and digital technology integration (r = 0.598), and between collaborative innovation and digital technology integration (r = 0.536). These values indicate moderate positive associations, which suggest that higher levels of one construct are associated with higher levels of others. The correlation coefficients remain below commonly accepted thresholds, which indicates that multicollinearity is not present and supports the use of regression analysis. The results of the linear regression are presented in Table 3.

Table 3: Results of linear regression analysis

Dep. variable Y	Indep. variables X	β intercept: 1.856	p-value	R^2	F	F Sig.	MSE	RMSE	DW
SCA	DTI	0.414	<0.0001	0.642	187.704	<0.0001	0.187	0.389	1.865
	CIE	0.364	<0.0001						
	HCE	0.432	<0.0001						

(*Source:* Authors)

The results of the linear regression analysis presented in Table 3 indicate that all independent variables have a positive and statistically significant effect on sustainable competitive advantage. Digital technology integration shows a positive effect ($\beta = 0.414$, $p < 0.0001$), which indicates that higher levels of technology use are associated with higher levels of competitive advantage. Collaborative innovation and ecosystem engagement also show a positive effect ($\beta = 0.364$, $p < 0.0001$), which suggests that cooperation and external interaction contribute to improved outcomes. Human-centric entrepreneurial orientation has the strongest effect among the analyzed variables ($\beta = 0.432$, $p < 0.0001$), which indicates the importance of internal organizational orientation toward people. The overall model shows a coefficient of determination of $R^2 = 0.642$, which means that 64.2 percent of the variance in sustainable competitive advantage is explained by the included variables. The F-statistic ($F = 187.704$, $p < 0.0001$) confirms that the model is statistically significant. The values of MSE (0.187) and RMSE (0.389) indicate an acceptable level of prediction error. The Durbin–Watson statistic (DW = 1.865) suggests that there is no issue with autocorrelation in the residuals. These results support all proposed hypotheses and confirm that the selected variables contribute to explaining sustainable competitive advantage. Next, based on conducted research and the analyzed literature a theoretical model for improving sustainable competitive advantage in the context of Entrepreneurship 5.0.

The model is presented on Figure 1.

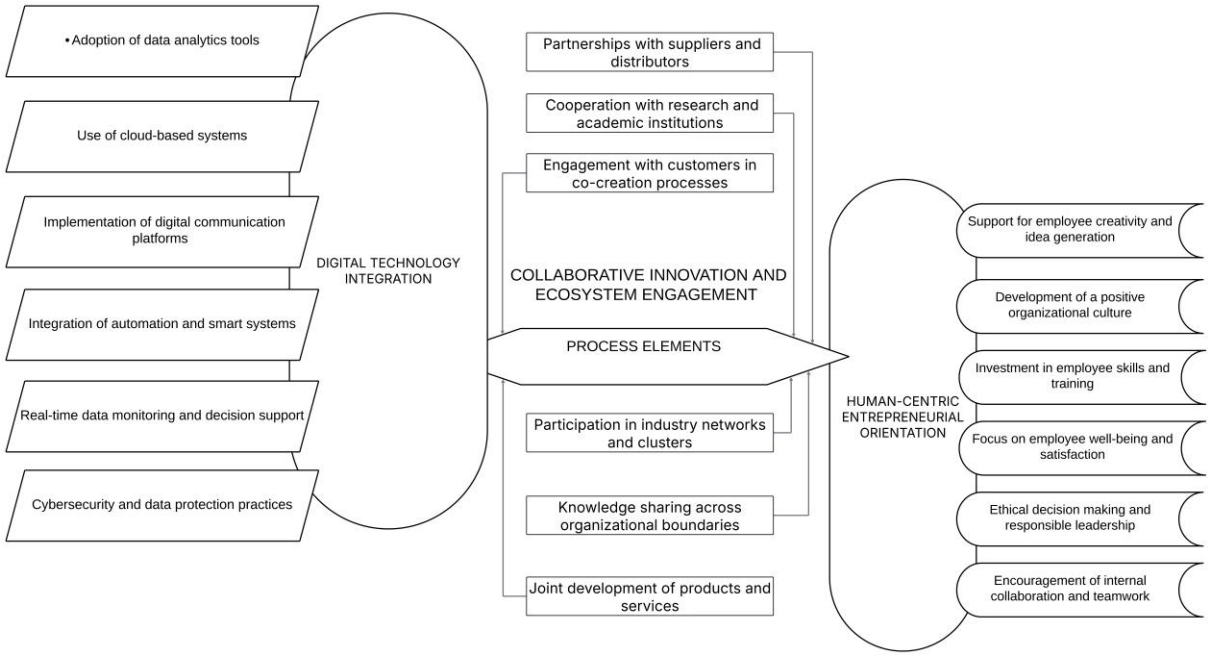


Figure 1: Model for improving sustainable competitive advantage

Digital technology integration includes sub-elements that support structured operations and data use. Adoption of data analytics tools enables better decision making based on available information. Use of cloud-based systems improves access to data and supports coordination across units. Implementation of digital communication platforms enables faster information exchange with internal and external actors. Integration of automation and smart systems improves process consistency and reduces manual work. Real-time data monitoring allows timely responses to changes. Cybersecurity and data protection ensure system reliability and data safety. Collaborative innovation and ecosystem engagement connect enterprises with external knowledge and resources. Partnerships with suppliers and distributors improve coordination in value chains. Cooperation with research and academic institutions provides access to new knowledge. Engagement with customers in co-creation aligns products and services with market needs. Participation in industry networks supports exchange of experiences and practices. Knowledge sharing across organizational boundaries improves problem solving. Joint development of products and services combines capabilities from different actors. Human-centric entrepreneurial orientation focuses on internal organizational conditions. Support for employee creativity encourages new ideas and improvements. Development of a positive organizational culture supports communication and stability. Investment in employee skills ensures readiness for technological and organizational changes. Focus on employee well-being increases engagement and retention. Ethical decision making supports trust and consistent behavior. Encouragement of teamwork improves coordination and knowledge use.

These elements are interconnected. Digital technology provides support for collaboration and internal processes. Collaborative innovation connects external inputs with internal capabilities. Human-centric orientation ensures that employees use technologies and participate in collaboration.

SUGGESTION AND GUIDELINES

Based on the analyzed literature and obtained results, the following suggestions and guidelines for improving sustainable competitive advantage in the context of Entrepreneurship 5.0:

– Enterprises can establish partnerships with external stakeholders such as suppliers, customers, and academic institutions. Such cooperation can lead to shared resources and improved innovation outcomes.

- Individuals within organizations can develop digital skills and adapt to new technologies through continuous learning. Employees can also contribute ideas that support process improvement and organizational development.
- Enterprises can create internal environments that support employee well-being and open communication. This approach can increase motivation and support knowledge sharing across teams.
- Governments can promote education programs that combine technical knowledge with entrepreneurial skills. These initiatives can prepare future workforce participants for complex business environments.
- Enterprises can implement structured training programs that improve employee competencies and adaptability. Regular evaluation of skills can ensure alignment with organizational needs.
- Enterprises can monitor performance through data-driven systems and adjust strategies based on measurable outcomes. Continuous assessment can support long-term stability and competitiveness.

CONCLUSION

The study examined the influence of digital technology integration, collaborative innovation and ecosystem engagement, and human-centric entrepreneurial orientation on sustainable competitive advantage. The results indicate that all analyzed variables have a positive and statistically significant effect on the dependent variable. The regression analysis confirms that the model explains a substantial share of variance in sustainable competitive advantage, which supports the selected research framework. The findings are consistent with theoretical assumptions that link technological, collaborative, and human-oriented factors with long-term competitiveness. The first hypothesis, which assumes a positive effect of digital technology integration on sustainable competitive advantage, is supported. The obtained coefficient indicates that enterprises that use digital technologies more extensively achieve higher levels of competitive outcomes. The second hypothesis, which refers to collaborative innovation and ecosystem engagement, is also supported. The results show that cooperation with external actors and participation in broader networks are associated with improved performance. The third hypothesis, which relates to human-centric entrepreneurial orientation, is supported as well. This variable shows the strongest effect, which indicates that internal organizational practices focused on people are strongly connected with sustainable outcomes. The obtained results suggest that sustainable competitive advantage depends on the combined influence of technological capabilities, external collaboration, and internal organizational orientation. Each of these elements contributes to performance, while their joint presence provides a more stable basis for long-term competitiveness. The proposed theoretical model offers a structured view of these relationships and can support both academic analysis and practical application in enterprise environments.

ACKNOWLEDGEMENT

This paper has been supported by the Provincial Secretariat for Higher Education and Scientific Research of the Autonomous Province of Vojvodina, number: 003897158 2025 09418 003 000 000 001 04 004. Project name: Analysis of key factors for implementing the Entrepreneurship concept in the AP Vojvodina.

REFERENCES

Abazi-Alili, H., Hashi, I., Rexhepi, G., Ramadani, V., & Kallmuenzer, A. (2024). Unravelling open innovation determinants and firm performance relationships in CEE and SEE countries. *International Journal of Entrepreneurial Behavior & Research, 30*(5), 1224-1248. https://doi.org/10.1108/IJEBR-10-2023-1112

Abbasi Kamardi, A., Amoozad Mahdiraji, H., Masoumi, S., & Jafari-Sadeghi, V. (2025). Developing sustainable competitive advantages from the lens of resource-based view: evidence from IT sector of an emerging economy. *Journal of Strategic Marketing, 33*(6), 775-797. https://doi.org/10.1080/0965254X.2022.2160485

Abbate, T., Codini, A., Aquilani, B., & Vrontis, D. (2022). From knowledge ecosystems to capabilities ecosystems: When open innovation digital platforms lead to value co-creation. *Journal of the Knowledge Economy, 13*(1), 290-304. https://doi.org/10.1007/s13132-021-00720-1

Alrub, Y. A., & Sánchez-Cañizares, S. M. (2025). Dynamic capabilities and digital transformation: Toward strategic planning in the digital age—Evidence from palestine. *Administrative Sciences, 15*(1), 21. https://doi.org/10.3390/admsci15010021

Hossain, M. S., Hussain, K., Kannan, S., & Kunju Raman Nair, S. K. (2022). Determinants of sustainable competitive advantage from resource-based view: implications for hotel industry. *Journal of Hospitality and Tourism Insights, 5*(1), 79-98. https://doi.org/10.1108/JHTI-08-2020-0152

Hsiao, M. H. (2024). Resource integration and firm performance through organizational capabilities for digital transformation. *Digital Transformation and Society*. https://doi.org/10.1108/DTS-07-2023-0050

Huang, J., Raja Yusof, R. N., Abd Rahman, A., & Ab Rahman, R. (2025). Determinants of digital technology adoption and its impact on firm performance in manufacturing firms. *Journal of Manufacturing Technology Management, 36*(5), 1003-1025. https://doi.org/10.1108/JMTM-08-2024-0475

Irawan, T. T., Mansor, M. N. B., & Ramlee, A. A. (2023). Entrepreneurial orientation and firm performance: A systematic review. *European Business & Management, 9*(3), 51-62. https://doi.org/10.11648/j.ebm.20230903.12

Iriani, S. S., Anita, N. D., Farid, P., Sari, S. P., Dwiarko, N., & Dwi, J. R. (2024). Harnessing competitive advantage: A resource-based perspective on sustainable business performance in tourism villages. *Jurnal Siasat Bisnis,* 263-274. https://doi.org/10.20885/jsb.vol28.iss2.art8

Nasution, M. D. T. P., Rossanty, Y., Harahap, R., Tanjung, A. R., & Nasution, T. A. M. (2026). Technology-Driven Resource Utilization and Integration to Enhance Firm Performance. *Aptisi Transactions on Technopreneurship (ATT), 8*(1), 268-283. https://doi.org/10.34306/att.v8i1.472

Nguyen, T. P. T., Huang, F., & Tian, X. (2025). A meta-analysis of the impact of open innovation on performance. *Journal of Management & Organization, 31*(2), 830-847. https://doi.org/10.1017/jmo.2021.38

Putra, J. M., Karundeng, D. R., Gofur, A., Tresnadjaja, R., Suhara, A., Sukmayadi, S., & Sopyan, A. (2024). Entrepreneurship in the era of society 5.0: Navigating digitalization for innovation and growth. *Journal of Sustainable Tourism and Entrepreneurship, 6*(1), 1-13. https://doi.org/10.35912/joste.v6i1.2224

Shah, N., Zehri, A. W., Saraih, U. N., Abdelwahed, N. A. A., & Soomro, B. A. (2024). The role of digital technology and digital innovation towards firm performance in a digital economy. *Kybernetes, 53*(2), 620-644. https://doi.org/10.1108/K-01-2023-0124

Su, X., Zeng, W., Zheng, M., Jiang, X., Lin, W., & Xu, A. (2022). Big data analytics capabilities and organizational performance: the mediating effect of dual innovations. *European Journal of Innovation Management, 25*(4), 1142-1160. https://doi.org/10.1108/EJIM-10-2020-0431

Van Hoang, D., Thi Hien, N., Van Thang, H., Nguyen Truc Phuong, P., & Thi-Thuy Duong, T. (2025). Digital capabilities and sustainable competitive advantages: The case of emerging market manufacturing SMEs. *Sage Open, 15*(2), 21582440251329967. https://doi.org/10.1177/21582440251329967

IMPLEMENTATION OF THE MONITORING, REPORTING AND VERIFICATION SYSTEM FOR GREENHOUSE GAS EMISSIONS IN THE REPUBLIC OF SERBIA: FROM REGULATORY FRAMEWORK TO THE FIRST REPORTING YEAR

DOI: 10.5937/EMC26010C

Zoran Čepić
University of Novi Sad, Faculty of Technical Sciences, Republic of Serbia
E-mail: zorancepic@uns.ac.rs
Julka Petrović
Public Utility Company "Novosadska toplana", Novi Sad, Republic of Serbia

ABSTRACT

The establishment of the monitoring, reporting and verification (MRV) system for greenhouse gas emissions in the Republic of Serbia represents an important step towards the future implementation of an emissions trading framework and the harmonization of national climate policy with the European Union acquis. Following the adoption of the national monitoring and reporting regulation, operators were required to apply for greenhouse gas emission permits and submit monitoring plans with supporting documentation. This paper presents the implementation process from the adoption of the regulatory framework and preparation of operators to the completion of the first reporting year. Special attention is given to practical challenges identified during the preparation and implementation of monitoring plans, including the identification of emission sources and source streams, selection of activity data sources, application of monitoring tiers, development of internal procedures and assessment of data uncertainty. Experiences from the first reporting year are illustrated through the example of a category B district heating operator with annual emissions of approximately 95.000 t CO_2. The results indicate that the first reporting cycle provided valuable experience for operators, verifiers and competent authorities, while highlighting the need for further capacity building and methodological clarification.

Key words: MRV system, greenhouse gas emissions, monitoring plan, EU ETS, Serbia

INTRODUCTION

The European Union Emissions Trading System (EU ETS) is one of the central instruments of European climate policy. It was established as a greenhouse gas allowance trading scheme within the European Union and has become a key mechanism for reducing emissions from energy-intensive sectors (European Parliament and Council, 2003). The system has been further revised in the context of strengthened EU climate targets and the broader Fit for 55 policy package (European Parliament and Council, 2023).

Although the Republic of Serbia has not yet established a full emissions trading system in the sense of allowance allocation and trading, the introduction of a national monitoring, reporting and verification (MRV) system represents the first operational step towards such a mechanism. A reliable MRV system creates the basis for transparent emissions data, consistent reporting, independent verification and future integration with carbon pricing or emissions trading mechanisms.

The implementation of the MRV system is particularly important for candidate countries and economies in the process of harmonizing their climate legislation with the European Union acquis. For installation operators, however, the introduction of MRV requirements represents a complex technical, organizational and administrative process.

In Serbia, the first reporting year for installation operators started on 1 January 2025, while reporting and verification of annual greenhouse gas emissions for 2025 were carried out during the first quarter of 2026. This period provided the first practical insight into the readiness of operators, verifiers and competent authorities to implement the new requirements. The paper therefore focuses on the transition from the adopted regulatory framework to the practical experience gained during the first reporting cycle.

The objective of this paper is to analyse the implementation of the MRV system for greenhouse gas emissions in the Republic of Serbia, with emphasis on the regulatory framework, preparation of operators, practical implementation challenges and lessons learned from the first reporting year. The experience is additionally illustrated through the example of a district heating operator, which demonstrates typical technical and methodological issues faced by operators during the preparation and implementation of monitoring plans.

REGULATORY FRAMEWORK FOR THE IMPLEMENTATION OF THE MRV SYSTEM IN SERBIA

The legal basis for the establishment of the MRV system in the Republic of Serbia is provided by the Law on Climate Change, which introduced obligations related to greenhouse gas emission permits, monitoring plans, annual emission reports and verification (Republic of Serbia, 2021a). The Law established the general framework for monitoring, reporting and verification of greenhouse gas emissions from installations and aviation activities, thereby creating the basis for further harmonization with the EU climate policy framework.

The scope of installations subject to MRV obligations was further defined by the Regulation on Types of Activities and Greenhouse Gases, which specifies covered activities, activity capacity thresholds and greenhouse gases included in the national MRV system (Republic of Serbia, 2022). On this basis, the competent ministry identified installations that were required to enter the system. This step was particularly important because the initial coverage of the MRV system depended not only on general legal obligations, but also on the correct interpretation of activity categories, capacity thresholds and applicable greenhouse gases.

The most important by-law for the practical implementation of the MRV system is the Rulebook on Monitoring and Reporting of Greenhouse Gas Emissions, adopted in December 2023 (Republic of Serbia, 2023). The Rulebook started to apply in 2024 and defined detailed requirements for the preparation of monitoring plans, monitoring methodologies, determination of activity data, calculation factors, monitoring tiers, data flow activities, control activities and reporting. In this respect, the Serbian MRV framework follows the main principles of the EU monitoring and reporting system, particularly regarding the need for transparent, accurate, complete, consistent and verifiable emissions data (European Commission, 2018a).

After the Rulebook entered into application, installation operators were given a six-month period, until July 2024, to submit applications for greenhouse gas emission permits. The application had to be accompanied by a monitoring plan and supporting documentation. During the second half of 2024, the competent ministry reviewed the submitted documentation and issued greenhouse gas emission permits. The obligation of operators to monitor and report greenhouse gas emissions started on 1 January 2025. Figure 1 presents the key milestones in the implementation of the MRV system in Serbia, from the adoption of the monitoring and reporting regulation to the first reporting and verification cycle.

The verification component of the MRV system is based on the principle that annual emission reports should be independently assessed by competent and accredited verification bodies (European Commission, 2018b). In Serbia, the obligations of verification bodies and the requirements for verification and accreditation are defined by the national Rulebook on Verification and Accreditation of Verifiers of Greenhouse Gas Emission Reports (Republic of Serbia, 2021b).

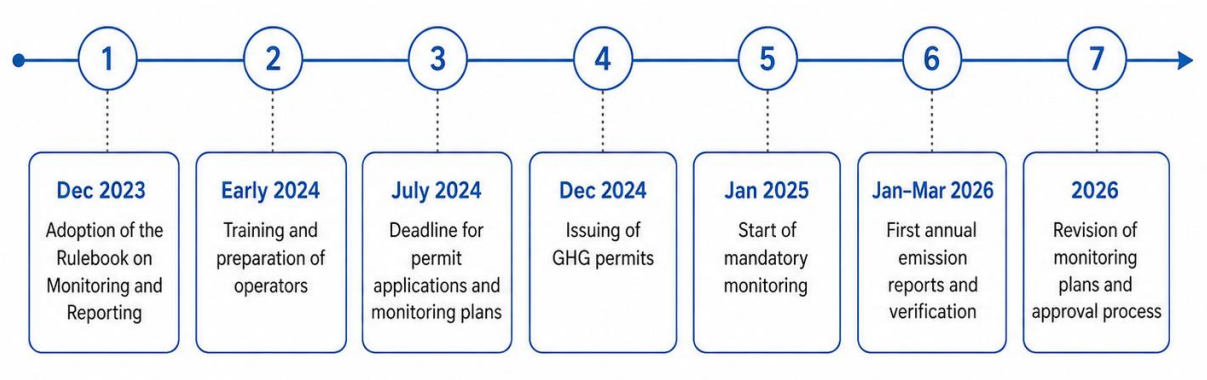


Figure 1: Timeline of the implementation of the MRV system in Serbia

Although the national system is often discussed in the broader context of the EU ETS, it is important to emphasize that Serbia has introduced the MRV component, not a complete emissions trading system. Therefore, the current stage should be understood as the establishment of a reliable emissions monitoring and reporting infrastructure, which may serve as a foundation for future carbon pricing or allowance trading mechanisms.

PREPARATION OF OPERATORS FOR THE INTRODUCTION OF THE MRV SYSTEM

The preparation of operators began with the introduction of the new MRV requirements in early 2024. Operators had to become familiar with the concept of greenhouse gas emission permits, monitoring plans, annual emission reports and independent verification. For many operators, this represented the first systematic encounter with EU ETS-type monitoring requirements, even though some facilities had previous experience with environmental reporting or energy management.

A key element of the preparation process was the development of monitoring plans. The monitoring plan is the central document of the MRV system, as it defines emission sources, source streams, monitoring methodologies, activity data sources, calculation factors, monitoring tiers, data flow activities and control procedures. In practice, the preparation of monitoring plans required operators to analyse their technological processes in detail and to translate existing operational, metering and accounting practices into the format required by the MRV regulation.

Training activities were therefore essential during the initial phase. Operators had to be trained not only to complete formal templates, but also to understand the underlying logic of the MRV system. This included the distinction between emission sources and source streams, the classification of source streams, selection of monitoring methodologies, documentation of data sources and preparation of written procedures. The quality of the submitted monitoring plans depended significantly on the operator's understanding of these concepts.

The greenhouse gas emission permit created direct obligations for operators from the beginning of the first reporting year. Operators were required to monitor emissions in accordance with the approved monitoring plan, maintain appropriate records, apply data flow and control activities, prepare annual emission reports and submit them for verification. This meant that the monitoring plan was not only an administrative document prepared for permitting purposes, but also the operational basis for annual monitoring and reporting.

IMPLEMENTATION CHALLENGES

The first phase of implementation revealed several practical challenges. These challenges were expected, considering that the MRV system was introduced within a relatively short timeframe and required operators to establish new technical and administrative practices.

One of the most important challenges was the identification of emission sources and source streams. In many installations, existing internal documentation was not structured in the same way as required by the

MRV system. Operators therefore had to identify all relevant emission sources, define source streams and classify them according to their contribution to total emissions. This was particularly important for installations using several fuels, auxiliary materials or backup systems.

The selection of activity data sources was another significant issue. Activity data may be based on invoices, operator measurements, stock changes, conservative estimates or other documented sources, depending on the nature of the source stream and the applicable monitoring methodology. Operators had to demonstrate that the selected source of activity data was appropriate, traceable and consistent with the monitoring plan. In practice, the difference between commercial documentation, internal measurements and auxiliary estimates required careful explanation.

The determination of calculation factors also required attention. For standard commercial fuels, default values may be used under certain conditions, while for some fuels calculation factors may be based on supplier data, quality reports or laboratory analyses. Operators had to identify the correct source of information for net calorific value, emission factor, oxidation factor and other relevant parameters. In some cases, the challenge was not the absence of data, but the correct interpretation and documentation of the available data.

The application of monitoring tiers represented an additional methodological challenge. Operators needed to understand the relationship between installation category, source stream category, monitoring methodology and required tiers. This was particularly important for major source streams, where higher accuracy requirements generally apply. At the same time, simplified approaches could be used for minor and de minimis source streams, but these approaches also had to be properly justified and documented.

A further challenge was the preparation of written procedures and supporting documentation. Monitoring plans required references to procedures related to data flow activities, control activities, responsibilities, record keeping, quality assurance, data gaps and internal reviews. For many operators, the number and level of detail of these procedures were new. As a result, the preparation of monitoring documentation required cooperation between technical personnel, environmental departments, accounting departments, metering services and management.

The assessment of data uncertainty was also among the main implementation challenges. Operators had to evaluate the uncertainty of activity data, especially where metering systems were used. This required information on measuring instruments, maximum permissible errors, calibration or verification records, correction devices and, in some cases, the combination of uncertainty contributions from several measurement lines. The practical difficulty was that operators often possessed metrological documentation, but had not previously used it for the purpose of greenhouse gas monitoring.

Laboratory analyses were another area requiring methodological clarification. Where calculation factors are determined through analyses, operators need to ensure that sampling, laboratory competence, analytical methods and frequency of analysis are appropriate. In the first implementation phase, it was important to distinguish between cases where laboratory analysis was required and cases where default values, supplier data or regulatory values could be used.

Finally, organizational challenges were significant. The MRV system requires clearly assigned responsibilities, stable data flows, internal checks and management awareness. The first reporting year showed that MRV implementation is not only a technical task, but also a management process. Operators that established internal coordination between technical, financial and environmental functions were generally better positioned to prepare consistent monitoring documentation and annual reports.

FIRST REPORTING YEAR - EXPERIENCES AND LESSONS LEARNED

The first reporting year started on 1 January 2025, while annual emission reports for 2025 were prepared and verified by 31 March 2026. This first reporting cycle provided the first practical test of the Serbian MRV system. Available implementation information indicates that approximately 120 installations were identified as subject to MRV obligations, while around 90 installations have been included in the system so

far. The difference between identified and included installations indicates the need for further clarification of coverage, communication with operators and enforcement of obligations.

The first reporting cycle also required the establishment of a national verification infrastructure. This represented an additional challenge because accreditation of verification bodies according to SRPS EN ISO/IEC 17029:2020 had not previously been applied in this field in Serbia. The Accreditation Body of Serbia therefore had to develop the necessary accreditation process and ensure competent assessors for organizations seeking accreditation as greenhouse gas verification bodies. For the first reporting year, five verification bodies obtained temporary accreditation, while additional safeguards were introduced through the engagement of experienced foreign verifiers, whose role was to support, train and supervise domestic verifiers until sufficient national experience was developed. This approach contributed to the credibility of the first verification cycle, but also demonstrated that the development of verifier competence is one of the key elements of a functioning MRV system.

During verification of the first annual emission reports, operators received recommendations related to monitoring plans and supporting documentation. In some cases, verifiers identified the need to correct or clarify certain elements of the monitoring plan, such as data sources, procedures, monitoring methodologies or source stream descriptions. As a result, operators prepared new versions of monitoring plans and submitted them to the competent ministry for approval. This process is an expected part of the initial implementation phase and may contribute to the gradual improvement of monitoring documentation.

The experience of a district heating operator can be used to illustrate typical issues in the first reporting year. The operator belongs to category B and has annual emissions of approximately 95.000 t CO_2. Its combustion activities are based primarily on natural gas, with additional source streams including light fuel oil, urea used for DeNOx in gas engines and diesel fuel for an emergency generator. Natural gas is combusted in five boilers and three gas engines and is supplied through three gas lines, each equipped with a flow meter and volume corrector.

Table 1 presents a simplified overview of the main source streams, activity data sources, calculation factor sources and implementation challenges in this example.

Table 1: Example of source streams and monitoring approach for a district heating operator

Source stream	**Type of source stream**	**Activity data source**	**Calculation factor source**	**Main implementation challenge**
Natural gas	Major source stream	Supplier invoices	Gas quality report; NCV and EF calculated according to national regulation	Consistency between commercial data, several gas lines and monitoring documentation
Light fuel oil	Minor source stream	Operator flow meter	Default values from national regulation	Documentation of internal measurement and data flow
Urea	De minimis source stream	Conservative estimate	Default values from national regulation	Methodological interpretation and simplified monitoring approach
Diesel fuel	De minimis source stream	Conservative estimate	Default values from national regulation	Justification of simplified monitoring for very small emissions

The example shows that even installations with relatively conventional combustion processes may face complex MRV issues. Natural gas, although a standard commercial fuel, required clear documentation of the relationship between invoices, metering lines, gas quality data and calculation factors. Minor and de minimis source streams required proportional approaches, but also sufficient justification in the monitoring plan. The use of urea for DeNOx in gas engines additionally demonstrated the importance of correctly identifying all materials that may result in greenhouse gas emissions.

Several lessons can be drawn from the first reporting year. First, the quality of monitoring plans depends on the operator’s ability to understand and document existing technical and administrative practices in MRV terms. Second, data sources must be clearly defined and consistently used throughout the reporting process.

Third, written procedures are essential for ensuring continuity and traceability of data. Fourth, uncertainty assessment requires better integration of metrological documentation into emissions monitoring. Finally, the first verification cycle plays an important role in identifying weaknesses and improving the quality of monitoring documentation.

CONCLUSIONS

The introduction of the MRV system for greenhouse gas emissions in the Republic of Serbia represents an important step in the development of national climate policy and future alignment with emissions trading mechanisms. Although a full emissions trading system has not yet been established, the MRV framework provides the necessary foundation for reliable emissions data, annual reporting and independent verification.

The first implementation phase showed that Serbia established the basic regulatory and procedural framework within a relatively short period. Operators submitted permit applications and monitoring plans, the competent authority issued greenhouse gas emission permits, and the first reporting and verification cycle was completed for the 2025 reporting year. At the same time, the process revealed several practical challenges, particularly in the identification of emission sources and source streams, selection of data sources, application of monitoring tiers, preparation of procedures and assessment of data uncertainty.

The experience of the first reporting year should therefore be understood as a learning phase for all participants in the system. Further improvement should focus on capacity building, clearer methodological guidance, consistent interpretation of regulatory requirements and strengthening of internal MRV procedures at operator level. These improvements will be important for increasing the reliability of emissions data and preparing the Serbian system for possible future development towards carbon pricing or emissions trading.

ACKNOWLEDGEMENT

This research has been supported by the Ministry of Science, Technological Development and Innovation through Contract No. 451-03-33/2026-03/200156.

REFERENCES

European Commission. (2018a). *Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601/2012*. *Official Journal of the European Union, L*334, 1–93.

European Commission. (2018b). *Commission Implementing Regulation (EU) 2018/2067 of 19 December 2018 on the verification of data and on the accreditation of verifiers pursuant to Directive 2003/87/EC of the European Parliament and of the Council*. *Official Journal of the European Union, L*334, 94–134.

European Parliament and Council. (2003). *Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC*. *Official Journal of the European Union, L*275, 32–46.

European Parliament and Council. (2023). *Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814*. *Official Journal of the European Union, L*130, 134–202.

Republic of Serbia. (2021a). *Law on Climate Change*. *Official Gazette of the Republic of Serbia*, No. 26/2021.

Republic of Serbia. (2021b). *Rulebook on Verification and Accreditation of Verifiers of Greenhouse Gas Emission Reports*. *Official Gazette of the Republic of Serbia*, No. 107/2021.

Republic of Serbia. (2022). *Regulation on Types of Activities and Greenhouse Gases*. *Official Gazette of the Republic of Serbia*, No. 13/2022.

Republic of Serbia. (2023). *Rulebook on Monitoring and Reporting of Greenhouse Gas Emissions*. *Official Gazette of the Republic of Serbia*, No. 118/2023.

OBSERVABILITY BEYOND MONITORING: QUANTIFYING THE IMPACT OF IT ON ENTERPRISE VALUE

DOI: 10.5937/EMC26016G

Igor Grubišić
Harvard University, Faculty of Arts and Sciences, Cambridge, Massachusetts, USA
E-mail: igor.grubisic@dynatrace.com
Ivana Denčić
Tehnički fakultet „Mihajlo Pupin“, Zrenjanin, Republic of Serbia

ABSTRACT

This paper introduces Business Observability, a subset of observability, as a strategic tool for quantifying IT's impact on Enterprise Value. In today's digital economy, IT plays a pivotal role in driving revenue, innovations, operational efficiency, and risk management. However, quantifying this impact on business processes and enterprise outcomes is not straightforward. Business Intelligence and time sheets track historical performance, but do not correlate metrics with Enterprise Value. Drawing on practitioner experience across Fortune Global 500 companies, we introduce how companies can use observability to create a value lineage between the Digital Estate and the overarching Enterprise Value. The paper presents a four-level Enterprise Value Lineage framework that maps observability signals to four value drivers (efficiency, quality, productivity, and risk), which drive enterprise outcomes. We have validated this lineage through enterprise-scale implementations, enabling near-real-time insights into how the technology stack impacts Enterprise Value. As a result, we are seeing an increase in use cases in which companies experiment with positioning observability as an integral function of the business, protecting their competitive advantage rather than treating it as just an IT-confounded application and infrastructure performance monitoring tool.

Keywords: Observability, Enterprise Value, IT Performance, MTTR, Business Observability, Value Realization

INTRODUCTION

The rapid expansion of digital ecosystems has fundamentally altered how organizations create and sustain value. Technology is no longer a supporting function; it is the primary enabler that powers every process across the value chain (Porter & Millar, 1985; Brynjolfsson & Hitt, 2000). Yet, recognizing the full financial impact of technology investments remains one of the most persistent challenges in enterprise management. This paper is grounded in practitioner experience across global enterprise IT operations and value strategy at Dynatrace, the leading observability platform (Gartner, 2025). The two vantage points converge on an observation that this paper takes as a central claim: the gap is not an instrumentation problem, but the disjointed impact measurement approach with no common ownership and accountability structure. To close it, this paper introduces a framework that elevates observability from a tactical engineering practice to a strategic governance instrument. We argue that observability must be utilized to continuously correlate technical signals and business events with organizational Service Level Objectives (SLOs) jointly owned by technology and business leadership. By doing so, organizations can quantify how their digital estate impacts enterprise value drivers, thereby determining its contribution to Enterprise Value.

THEORETICAL BACKGROUND

Enterprise Value and the Role of IT as Enabling Infrastructure

Digital transformation is reshaping value creation by steering organizations toward an ecosystem of stakeholder co-creation, where Information Technology serves as the enabling layer powering every

activity in the value chain (Zhang et al., 2026). Porter and Millar (1985) were among the first to articulate IT's role as a source of competitive advantage embedded across the value chain. Brynjolfsson and Hitt (2000) later demonstrated empirically that the economic value of IT investment is captured in the organizational transformations it enables, which are often intangible and difficult to measure.

Billi and Bernardo (2025) show that the combination of digital transformation, IT innovation, and operational strategy produces measurable effects on Tobin's Q. Ran et al. (2024) confirm that digital technology impacts value by driving productivity and profitability, but the mechanism remains unclear. To understand it, organizations need a consistent value framing that links financial goals to the technological capabilities that drive them (Smith et al., 2024). The framework in this paper seeks to enable such linkage. Recent empirical evidence confirms that digital activities are associated with a market-to-book ratio 8–26 percent higher than industry peers, but only a fraction of this value is captured in financial reporting (Chen & Srinivasan, 2024).

The Evolution of Observability: From Monitoring to Strategic Instrument

In its original context, observability refers to the ability to infer a system's internal state from its external outputs (Majors et al., 2022). It leverages runtime telemetry to diagnose anomalies and accelerate remediation. Second generation emerged with the cloud, utilizing Application Performance Monitoring to correlate signals across microservices and containers to understand why failures occur and accelerate recovery. The third generation is qualitatively different; it is about understanding consequences. Introduced by Saha et al. (2024), Business Process Observability is a cross-layer topology that links processes to the underlying IT, making the business impact visible alongside the technical signal. Building on the authors' empirical experience (Grubisic, 2026), it is visible that most organizations still operate at generation two. They are using observability as an application monitoring tool. As the underlying reason, we see the limitations of existing platforms in establishing composite value metrics and in correlating business and technical observability signals with top-level business outcomes (Gartner, 2025).

METHODOLOGY AND MEASUREMENT APPROACH

The measurement approach proposed in this paper operationalizes the Enterprise Value Lineage by systematically correlating captured observability signals with customer business outcomes. To illustrate the approach, we will describe how eliminating tool sprawl protects revenue. The primary measurement chain runs as follows: Tools Consolidation to Faster Root Cause Analysis to lower MTTx to Improved Asset Efficiency to NPS to Revenue and Operational Efficiency. The practical application of this approach, linking MTTR and NPS to IT investment decisions, has been pivoted in complex operational environments, which we will present below.

CONCEPTUAL FRAMEWORK: BUSINESS OBSERVABILITY FOR ENTERPRISE VALUE

Observing a business process as the driving force of Enterprise Value, we characterize each process along four dimensions: efficiency, quality, productivity, and risk. The underlying Digital Estate, comprising hardware infrastructure, applications, data, and digital services, impacts each dimension. Business Observability allows us to measure the impact that the Digital Estate has on the characterizing dimensions, the business processes, and the affected value drivers along the Enterprise Value map.

Business Observability, as defined in this paper, is the real-time measurement of the impact of technology-driven value drivers on business and technology processes and overall Enterprise Value. This framework was developed through enterprise-scale practice, operationalized across selected Fortune 500 engagements, and is presented here as a formalized contribution to the engineering management literature (Grubisic, 2026). It requires three things to work in concert: the right observability signals from the Digital Estate, organizational SLOs that management has defined as

measures of success, and the Enterprise Value Lineage that maps them to one another, up to the top-level business objectives.

The Enterprise Value Lineage

The Enterprise Value Lineage describes a four-step process through which technical telemetry is transformed into strategic business insight (Figure 2).

- Step 1 — Ingestion. Observability solutions capture the signals produced by the Digital Estate: logs, metrics, traces, events, and other raw data points and composite metrics.
- Step 2 — Real-Time Correlation. Signals are mapped to operational dimensions (Efficiency, Quality, Productivity, and Risk), adding business and technical interpretations. An increase in MTTR for payment processing is not a reliability statistic in isolation; it is a quality degradation event with a calculable effect on transaction completeness, customer satisfaction, and revenue. This is where the framework diverges from conventional observability, which presents technical metrics without business context.
- Step 3 — Outcome Quantification. Operational performance is translated into financial impact: the captured signals are correlated with Outcome Levers, and the impact is compared against the baseline. MTTR is one of the most consistent predictors of organizational performance (Forsgren et al., 2018; DORA, 2024). Rapid resolution preserves service value and customer satisfaction (Najjar et al., 2022). Net Promoter Score (NPS) captures that perception as a predictor of future sales (Baehre et al., 2022).
- Step 4 — Strategic Value Alignment. The result is a shared view for executives and technology teams: a direct line from what is happening in the technology stack to its implications for the business.

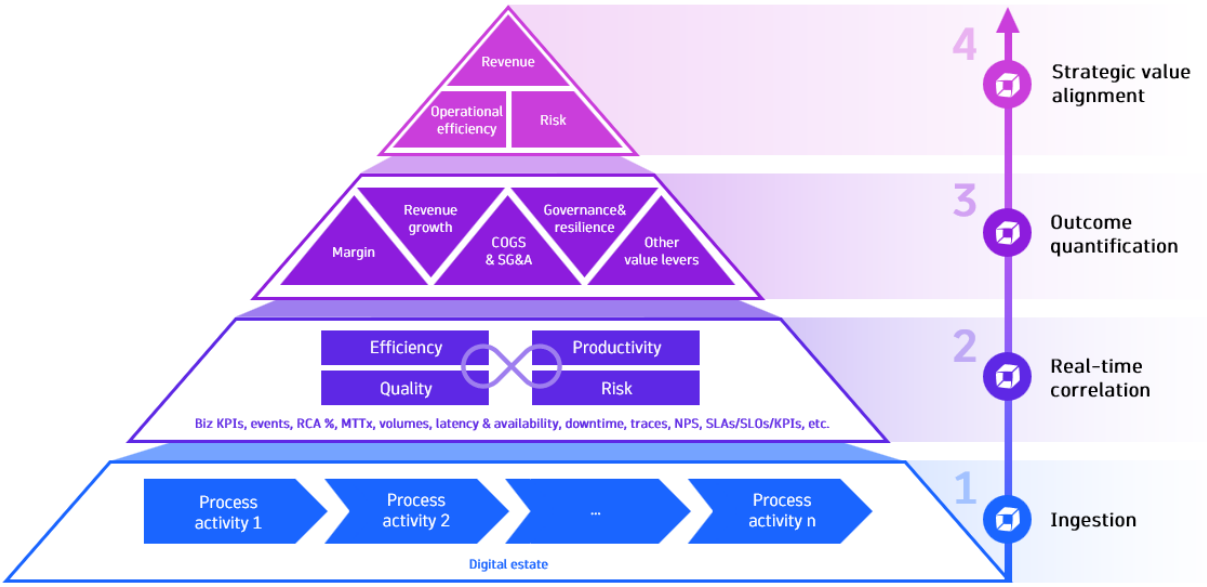


Figure 2: Enterprise Value Lineage: Digital Estate to Strategic Value Alignment
Source: Grubisic (2026)

The Enterprise Observability Value Map

To operationalize the Value Lineage across the entire value chain, the framework leverages an Enterprise Observability Value Map (Figure 3), a structured taxonomy that connects IT signals to strategic business outcomes through a hierarchy of outcome levers and value drivers (Grubisic, 2026). The map is organized around three strategic pillars of the Enterprise Value, where each value driver builds on the lower ones. For example, accelerating technology-related M&A expedites new customer integration and acquisition, increases revenue volume, and drives overall revenue and innovation.

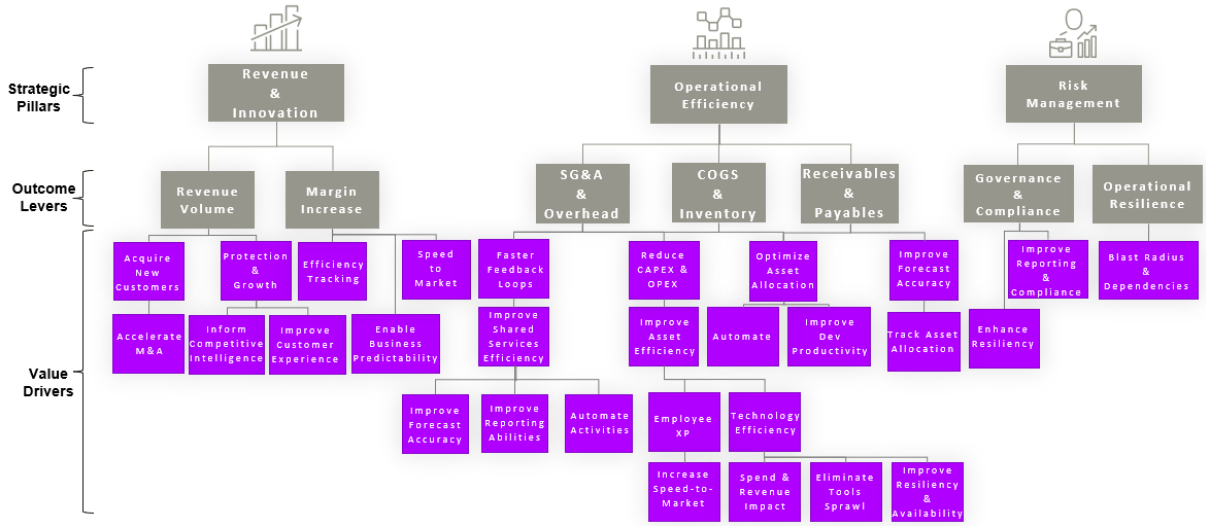


Figure 3: Enterprise Observability Value Map: Strategic Pillars, Outcome Levers, and Value Drivers
Source: Grubisic (2026)

The Value Map provides organizations with a structured starting point for prioritizing observability investments based on the value levers most material to their strategic context.

Empirical Validation

Customer-serving business processes rely on a multitude of connected digital systems that are often monitored separately. Unifying observability by eliminating tool sprawl significantly lowers MTTx. Per our empirical findings across over 5000 deployments, consolidated observability reduces MTTx by as much 99% (Dynatrace, 2026). Reduced detection and resolution times enable a near-frictionless customer experience, improving NPS and driving revenue protection and growth. Figure 4 shows a real-life example of how tool consolidation at one of the largest US airlines increased asset efficiency (coverage of monitored hosts), resulting in an 88% reduction in MTTR and, consequently, a 3-point improvement in NPS.

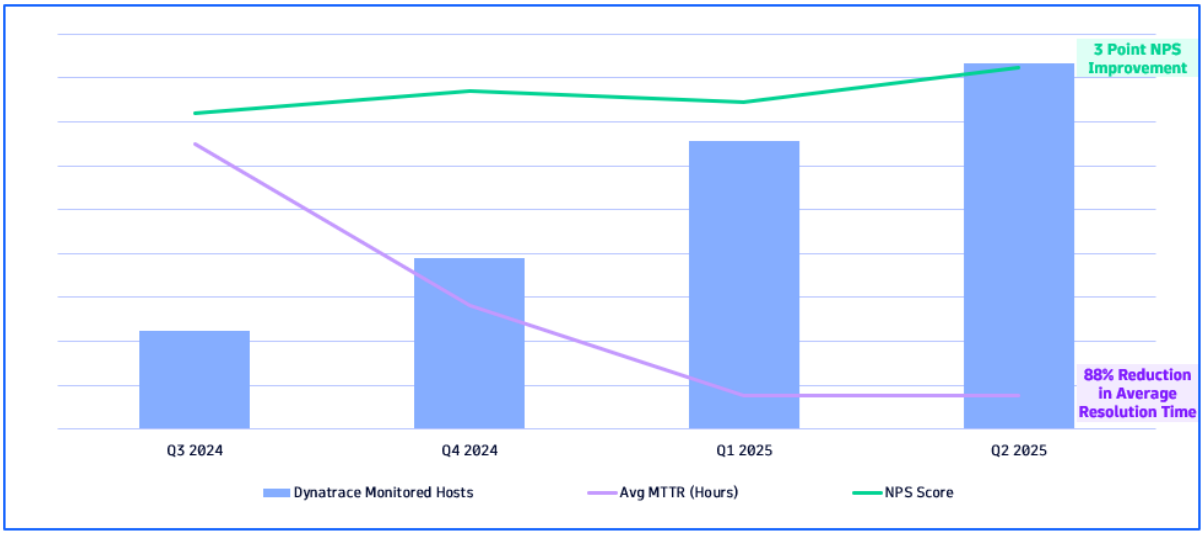


Figure 4: Correlation Between Tools Consolidation, MTTR, and NPS.
Source: Dynatrace Perform, 2026

This empirical evidence demonstrates that the measurement chain proposed in this paper has been validated in practice, producing measurable improvements in both operational efficiency and customer outcomes.

DISCUSSION

What this framework changes most is a power dynamic, not a process. Leveraging our framework through observability, concretely Business Observability, we can establish a near-real-time quantification of how changes across the Digital Estate impact Enterprise Value. A Chief Information Officer (CIO) who operates with Business Observability does not arrive at a board meeting with retrospective business impact that the Chief Financial Officer (CFO) will discount. They arrive with real-time correlations between the IT investments, performance of enterprise-wide SLOs, and enterprise value drivers. This is a shift in who holds informational power in the room, and that shift changes the nature of technology investment decisions in ways that improved tooling and IT processes alone cannot achieve.

This realization points to the single critical prerequisite for the framework to function: joint SLO ownership between technology and business stakeholders. Without it, the value lineage has no anchor. Only 52% of companies currently have a technology investment decision-making process that is jointly owned by IT and the business (Smith et al., 2024). The other 48% are failing because the organizational structure does not create the conditions for the correlation to be acted upon. Implementing observability without resolving this gap produces dashboards without business context and value lineage.
Technology and business leaders need to co-author SLOs that carry financial consequences for both sides and review them at the same cadence as financial reporting. The specific governance structure that makes this durable across organizational contexts is beyond the scope of this paper.

Two limitations of the framework as presented deserve explicit acknowledgment. First, correlation is not causation. An MTTR reduction that coincides with an NPS improvement does not, by itself, establish a causal relationship. The measurement chain given in Section 3 is a well-evidenced directional model, not a deterministic formula. Correlations stemming from this framework are decision-support signals that need to be put into a valid business context. Second, the accuracy of the framework depends on the completeness of the instrumentation across the Digital Estate.

CONCLUSIONS

This paper contributes to the engineering management literature at the intersection of IT governance, Enterprise Value creation, and observability practice. We have argued that observability, when elevated beyond its traditional operational role and governed as a shared accountability structure, functions as a real-time strategic instrument for quantifying the impact of technology on Enterprise Value. The Business Observability framework, grounded in practitioner experience and supported by evidence from academic research and large-scale industry studies, provides a structured approach to this quantification through a four-step Enterprise Value Lineage and a comprehensive Observability Value Map.

The framework has been piloted through Proof of Concept implementations in two global enterprise organizations, demonstrating a measurable impact of IT performance on Enterprise value. Broader empirical validation across industries and organizational contexts remains a direction for future research, along with further refinement of the standardized value measurement protocols for the Digital Estate-to-Outcomes correlation chains and governance models that drive joint SLO ownership at enterprise scale. The challenge for enterprises is no longer whether observability can quantify technology’s business value, but whether the organizations are structured to leverage observability as a function of Enterprise Value and act on insights in real time.

REFERENCES

Baehre, S., O'Dwyer, M., O'Malley, L., & Lee, N. (2022). The use of Net Promoter Score (NPS) to predict sales growth: Insights from an empirical investigation. *Journal of the Academy of Marketing Science, 50*(1), 67–84.

Billi, A., & Bernardo, A. (2025). The effects of digital transformation, IT innovation, and sustainability strategies on firms' performances: An empirical study. *Sustainability, 17*(3), 823.

Brynjolfsson, E., & Hitt, L. M. (2000). Beyond computation: Information technology, organizational transformation and business performance. *Journal of Economic Perspectives, 14*(4), 23–48.

Chen, W., & Srinivasan, S. (2024). Going digital: Implications for firm value and performance. *Review of Accounting Studies, 29*(2), 1619–1665.

Dynatrace. (2026). *SAP case study: Consolidated observability reduces MTTx by 99%*. Dynatrace. https://www.dynatrace.com/customers/sap/

Forsgren, N., Humble, J., & Kim, G. (2018). *Accelerate: The science of lean software and DevOps: Building and scaling high-performing technology organizations*. IT Revolution.

Grubisic, I. (2026). *Business outcomes observability for enterprise value*. Dynatrace.

Majors, C., Fong-Jones, L., & Miranda, G. (2022). *Observability engineering: Achieving production excellence*. O'Reilly Media.

MoghadasNian, S., & Moslehi, Z. (2024). Optimizing IT solutions in the airline industry: A KPI-driven strategic approach. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.6279258

Najjar, M. S., et al. (2022). IS incident recovery and service value: A service-dominant logic view. *European Journal of Information Systems, 31*(4), 492–524.

Porter, M. E., & Millar, V. E. (1985). How information gives you competitive advantage. *Harvard Business Review, 63*(4), 149–160.

Ran, L., Zhang, Q., & Li, X. (2024). Can digital technology innovation contribute to firms' market value? *PLoS ONE, 19*(9), e0309993.

Saha, A., et al. (2024). Towards business process observability. In *Proceedings of the 7th Joint International Conference on Data Science & Management of Data (CODS-COMAD 2024)* (pp. 1–9). ACM.

Gartner. (2025). *Magic Quadrant for Observability Platforms (G00821166)*. Gartner Research. https://www.gartner.com/doc/reprints?id=1-2LFAL8EW&ct=250710&st=sb

Smith, T., et al. (2024). *Enterprise value from technology*. Deloitte Insights.

Zhang, C., Sun, Y., Xu, D., & Liu, Q. (2026). Digital transformation and enterprise value creation: A study based on both human capital upgrading and pay gap optimization. *International Review of Economics & Finance*.

STUDENTS' ENTREPRENEURIAL INTENTIONS IN CONTEXT OF MACROECONOMIC INSTABILITY: AN EMPIRICAL ANALYSIS USING THE CASE OF VORONEZH STATE UNIVERSITY

DOI: 10.5937/EMC26022N

Larisa Nikitina
Voronezh State University, Russian Federation
E-mail: nikitina@econ.vsu.ru
Ulyana Dubinkina
Voronezh State University, Russian Federation
Irina Maleva
Voronezh State University, Russian Federation

ABSTRACT

The paper analyzes the dynamics of entrepreneurial intentions and career preferences among students at Voronezh State University (VSU) in a context of macroeconomic and geopolitical instability. The study highlights the role of the university environment in shaping students' entrepreneurial attitudes. The empirical base is comprised of data from the Russian segment of the international GUESSS project for 2018 and 2025. The study design combines longitudinal analysis (comparing VSU indicators at two time points) and cross-sectional comparative analysis (comparing VSU data with national data). The results show that students' career strategies have significantly shifted over the period under review. Over the short-term planning horizon, the proportion of those wanting to start their own business increased, whereas over the five-year horizon, entrepreneurial intentions declined, with a sharp increase in the proportion of undecided students. A regional characteristic of VSU is the higher proportion of students without long-term career plans and lower entrepreneurial environment compared to the Russian average. In a context of external instability, students demonstrate increased uncertainty about their professional futures. It is concluded that universities need to strengthen their support for students' entrepreneurial intentions to ensure the reproduction of entrepreneurial potential.

Key words: entrepreneurial intentions, university, students, macroeconomic instability.

INTRODUCTION

In recent years, Russia has been developing amid economic and geopolitical instability. Restrictions caused by the pandemic and the Ukrainian crisis have led to difficulties in selling export products, a shortage of imported equipment, and the disruption of supply chains and economic ties. Many foreign companies and brands have left the Russian market. The opening of market niches, despite the presence of macroeconomic obstacles, has opened up a unique opportunity for the development of Russian entrepreneurship (Nikitina et al., 2024). The study "Monitoring Entrepreneurial Activity 2024/2025" (Verkhovskaya, 2025) also showed that, according to respondents, starting in 2022, there has been an increase in the number of those who agree that Russia offers favorable conditions for developing their own business: 33,7% in 2022, 38,4% in 2023, and 39,8% in 2024. Moreover, starting in 2022, the number of respondents who believe that starting a business in Russia is easy has averaged 54,6%, while in 2016–2019 this figure was at an average of 23,6%.

However, despite improved survey respondents' assessments of the business climate, data from the Russian Federal Tax Service indicates the beginning of a reversal. In 2025, the number of legal entities established in Russia was the lowest in the past 14 years – 192 883 companies. Moreover, the number of liquidated legal entities exceeded newly created ones by 36,45%, reaching 263 201 companies. The decline in the number of legal entities in small and medium-sized businesses is offset by an increase in the number of sole proprietors (1 076 747 opened, 748 889 closed).

This growth in the number of individual entrepreneurs is largely driven by young people. The desire to start a business peaks at a young age, according to the report "Monitoring Entrepreneurial Activity 2024/2025" (Verkhovskaya, 2025). Thus, in 2024, 45,9% of respondents aged 18 to 24 stated their intention to become an entrepreneur in Russia, 40,2% of those aged 25 to 35, 36,2% of those aged 35 to 44, 16,5% of those aged 46 to 55, and 12,4% of those over 55. Among respondents who are not entrepreneurs, students (51,5%) expressed the highest desire to start their own business in the next three years. This is due to the younger generation being more entrepreneurial, innovative, flexible, and willing to take risks.

Overall, the youth entrepreneurship sector in Russia is steadily growing. By 2025, the number of individual entrepreneurs under 35 reached 1,17 million. Young entrepreneurs are shifting from retail to industries with greater intellectual and innovative potential. The largest relative growth compared to the previous year was recorded in education – 59,8%. Administrative activities grew by 27,6%, scientific and professional activities by 19,9%, and the number of IT companies increased by 14,5%. Public administration, healthcare, culture, sports, and leisure also experienced rapid growth. Among Russian regions, Moscow and the Moscow region remain the absolute leaders in the number of young entrepreneurs (over 200 000). More than 61 000 young founders are registered in the Krasnodar Krai, over 54 000 in St. Petersburg, and over 35 500 in the Republic of Tatarstan. The Republic of Dagestan demonstrated unique growth, with the number of young entrepreneurs in this region increasing by 24% to 4 300.

The growth of youth entrepreneurship is driven by government support. Grant support, provided through various government agencies and development institutions, plays a particularly important role. For example, the Foundation for Assistance to Small Innovative Enterprises (FASIE) offers targeted programs for young technology entrepreneurs, including a grant of up to 1 million rubles under the Student Startup program for students. Projects in IT and the creative industries are eligible for support from the Presidential Creative Industries Fund. Also in 2024, the Russian Ministry of Education and Science, together with the Russian Ministry of Economic Development, launched the "Startup as a Diploma" competition for graduates, allowing young people to present their business project as a final qualifying thesis.

The current level of youth entrepreneurship development is undoubtedly linked to the educational sector's ability to nurture entrepreneurial potential. Universities foster not only professional competencies but also the value-motivational structure of young professionals' career strategies. In the context of macroeconomic instability, there is an objective need to analyze and evaluate the dynamics of students' entrepreneurial intentions, as this indicator serves as a proxy for graduates' actual economic activity.

The theoretical basis for this analysis is the theory of planned behavior (Ajzen, 1991), according to which an individual's intentions are shaped by three factors: individual attitudes toward behavior, subjective norms, and perceived behavioral control. Since starting a business is considered a planned action by an individual preceded by intention, entrepreneurship is often studied from the perspective of entrepreneurial intentions (Bird, 1988). These intentions, in turn, are determined by the individual's personal motives, which are influenced by family, the university environment, and the socio-cultural context (Berman et al., 2008; Shirokova et al., 2015). Universities play a key role in shaping and intensifying entrepreneurial intentions (Ustinova and Koemets, 2024).

Thus, identifying the degree and nature of the influence of the university environment (including educational programs, start-up support infrastructure, informal entrepreneurial communities) on the intensification of students' entrepreneurial intentions, including in conditions of macroeconomic instability, is of great theoretical and practical significance. Without understanding this connection, any measures to stimulate youth entrepreneurship risk remaining mere declarative measures. Therefore, the goal of our study is to assess the dynamics of entrepreneurial intentions among students at a regional classical university (using Voronezh State University as an example) in a context of macroeconomic instability.

MATERIALS AND METHODS

The empirical basis of the study was data from the international research project "Global Student Entrepreneurial Spirit Study" (GUESSS). GUESSS is conducted biennially under the leadership of the Swiss Universities of St. Gallen and Bern. It focuses on studying the career intentions, entrepreneurial activity, and attitudes toward entrepreneurship among students worldwide. Anonymous online surveys conducted in over 50 countries and thousands of universities make it possible to analyze the dynamics of student entrepreneurial spirit over time, compare indicators across universities and countries, and assess the influence of the university environment on the formation of entrepreneurial intentions. The National Research University Higher School of Economics (HSE – St. Petersburg) is a partner in the project and is responsible for collecting data from students across Russia.

The study utilized a mixed-methods approach to data analysis, including secondary analysis of GUESSS project data for 2018 and 2025 (Russian segment), analytical reports (Global study of students' entrepreneurial spirit. National report. Russia 2018), and scientific publications. The study design combines longitudinal analysis (assessing data dynamics for Voronezh State University in 2018 and 2025) and cross-sectional comparative analysis (comparison of Voronezh State University data with national data). The choice of the 2018 and 2025 time points is due to the fact that this interval allows us to capture two qualitatively different macroeconomic regimes: 2018 serves as a starting point characterized by relative stability and the absence of systemic external shocks, while 2025 reflects the state of entrepreneurial intentions after the cumulative effect of the COVID-19 pandemic, sanctions pressure, and the structural restructuring of the Russian economy.

In 2018, 93 students from Voronezh State University were surveyed, accounting for 3,3% of the total sample for Russia. In 2025, the number of respondents increased to 104, accounting for 6,1% of the total sample for Russia. Respondents were distributed by education level as follows: in 2018, 91% held bachelor's degrees, 8% held master's degrees, and 1% held doctoral degrees. In 2025, the share of bachelor's degrees was 44%, master's degrees 17%, specialist degrees 38%, and doctoral degrees 1%.

RESULTS AND DISCUSSION

The study asked participants to answer two questions: where they see themselves immediately after graduating and five years later. The near- and long-term career expectations of students at Voronezh State University (VSU) and across Russia for 2018 and 2025 are presented in Table 1.

An analysis of the career preferences of VSU students and those in Russia as a whole in 2018 revealed that, in the short term, respondents primarily considered employment as employees. The largest share of VSU and Russian students surveyed were focused on large companies (with 250 or more employees) – 27,96% and 24,6%, respectively – and medium-sized organizations (with 50 to 249 employees) – 26,88% and 22,8%. With a five-year planning horizon, a general trend was also observed in 2018, but the majority of students already envisioned themselves as future entrepreneurs (68,82% at VSU and 50,4% across Russia). Moreover, Voronezh students are characterized by lower uncertainty in both the short- and long-term perspectives – 4,3% and 3,23%, compared to 12,4% and 13,3% in Russia, respectively.

A comparison of Voronezh students' career intentions with the Russian national average for 2025 reveals similar trends. Immediately after graduation, the leading career path is working for large companies (28,85% at VSU and 27,62% nationally), followed by being a founder (entrepreneur) of their own company (20,19% at VSU and 22,67% nationally). Third place goes to students who have not yet decided on their career preferences, representing 21,15% at VSU and 19,38% nationally. In the long term, despite similar career choice trends to those observed in the Russian national average, students from Voronezh demonstrate more cautious behavior. For example, the proportion of those who see themselves as the founder (entrepreneur) of their own company in five years at VSU is 6,48%

lower than the national average (38,46% versus 44,94%). Voronezh students are characterized by a higher degree of uncertainty when predicting their career trajectory. At Voronezh State University, a quarter of respondents were unable to decide on their career path five years after graduation, compared to 15,49% across Russia. The 9,51% gap can be explained by Voronezh's proximity to the Special Military Operations Zone, which poses additional risks to economic activity. Under these circumstances, the shortening of Voronezh State University students' planning horizons is a natural response to the aggressive external environment.

Table 1: Career expectations of VSU and Russian students for the near and long term for 2018 and 2025.

Your Career Choice Intentions	**VSU**				**Russia**			
	Right after studies, %		**5 years later, %**		**Right after studies, %**		**5 years later, %**	
	2018	**2025**	**2018**	**2025**	**2018**	**2025**	**2018**	**2025**
1. An employee in a small company (1-49 employees)	13,98	4,81	0,00	0,00	14,00	4,77	1,70	1,53
2. An employee in a medium-sized business (50-249 employees)	26,88	11,54	2,15	5,77	22,80	13,43	3,70	4,65
3. An employee in a large business (250 or more employees)	27,96	28,85	15,05	21,15	24,90	27,62	17,80	20,91
4. An employee in a non-profit organization	1,08	0,96	1,08	0,00	3,10	0,65	1,80	0,65
5. An employee in academia (academic career path)	2,15	2,88	2,15	3,85	6,20	4,42	3,40	4,30
6. An employee in public service	1,08	0,96	0,00	0,00	3,00	2,53	1,80	2,12
7. A founder (entrepreneur) working in my own business	15,05	20,19	68,82	38,46	9,00	22,67	50,40	44,94
8. A successor in my parents'/family's business	7,53	3,85	3,23	2,88	3,00	2,71	2,20	2,36
9. A successor in another business	0,00	4,81	4,30	2,88	1,60	1,83	3,90	3,06
10. Other / do not know yet	4,30	21,15	3,23	25,00	12,40	19,38	13,30	15,49
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

An analysis of the career preferences of VSU and Russian students for 2018 and 2025 revealed the following general trends:

- there has been a steady increase in student interest in working as employees at large companies. At the same time, the number of those seeking employment at small and medium-sized companies has declined;
- the dynamics of students' entrepreneurial intentions are mixed. In the short term, the number of students wanting to start their own business has increased (from 15,05% to 20,19% at VSU and from 9% to 22,67% across Russia). In the five-year planning horizon, the number of respondents who see themselves as entrepreneurs has decreased (from 68,82% to 38,46% at VSU and from 50,4% to 44,94% across Russia).
- the proportion of students who have not yet decided on their career preferences is growing.

A comparison of the career preferences of VSU and Russian students for 2018 and 2025 also revealed regional differences. The preferences of Voronezh students, while reflecting overall Russian trends, are subject to more rapid fluctuations. VSU students show a more pronounced decline in entrepreneurial intentions over the long term. Furthermore, respondents from Voronezh are characterized by greater uncertainty.

To further assess students' entrepreneurial intentions and the factors shaping them, the study included statements that required students to express their level of agreement on a 7-point scale (1 = strongly

disagree, 7 = strongly agree). The university plays a key role in supporting and developing entrepreneurial potential, so we analyzed students' assessments of its entrepreneurial environment separately and present them in Table 2.

Table 2: Assessment of the entrepreneurial environment of universities for 2018 and 2025.

Assertion	2018				2025			
	Average rating	Response rate in %			Average rating	Response rate in %		
		+	—	+ —		+	—	+ —
Voronezh State University								
The atmosphere at my university inspires me to develop ideas for new businesses.	4,20	36,56	36,56	26,88	4,07	40,38	39,42	20,19
There is a favorable climate for becoming an entrepreneur at my university.	4,12	42,58	37,95	27,41	4,14	39,60	35,29	25,49
My university encourages students to engage in entrepreneurial activities.	4,63	38,04	33,70	28,26	4,17	43,14	37,25	18,63
Russia								
The atmosphere at my university inspires me to develop ideas for new businesses.	4,44	49,24	30,66	20,10	4,81	60,74	22,26	17,00
There is a favorable climate for becoming an entrepreneur at my university.	4,57	52,62	27,80	19,57	5,00	64,50	17,13	18,37
My university encourages students to engage in entrepreneurial activities.	4,70	55,02	26,75	18,23	5,25	69,57	15,90	14,53

Note. "+" is the proportion of respondents who agree with the judgment (scores of 5, 6 and 7 points in total), "—" is the proportion who disagree (scores of 1, 2 and 3 points in total), "+ —" is the proportion who are neutral (score of 4 points).

Positive dynamics were recorded at VSU in two indicators. The share of positive ratings for the statement "The atmosphere at my university inspires me to develop ideas for new businesses" increased from 36,56% in 2018 to 40,38% in 2025, while for the statement "My university encourages students to engage in entrepreneurial activity" it increased from 38,04% to 43,14%. At the same time, positive ratings for the statement "My university has a favorable climate..." decreased from 42,58% to 39,6%. This suggests that VSU has become more proactive in encouraging student entrepreneurship by expanding its educational programs to include new disciplines and engaging in entrepreneurship activities.

VSU students are more pessimistic about the entrepreneurial environment at their university than the Russian average. In 2025, the proportion of VSU students who positively assessed the university's atmosphere was 20,36% lower than the national average (40,38% versus 60,74%). 39,6% of VSU students agreed with the statement that the university's climate was favorable, compared to 64,5% nationally. When assessing student involvement in entrepreneurship, the proportion of positive responses at VSU (43,14%) was 26,43% lower than the national average (69,57%).

At the same time, students became less likely to avoid answering questions. The proportion of those who rated the university entrepreneurship environment as 4 points in 2025 across all dimensions decreased compared to 2018 in both samples. This indicates that the university environment is becoming more visible to students in matters of entrepreneurship. Moreover, there is a qualitative shift toward an increase in the average scores across Russia for all three indicators – from 4,47 in 2018 to 5,02 in 2025.

A regional characteristic is the inverse relationship between assessments related to entrepreneurial intentions and the entrepreneurial environment at the university. Throughout the period under review,

VSU students, on the one hand, were characterized by a higher intention to start their own business immediately after graduation compared to Russian students, while on the other hand, they tended to underestimate the state of the entrepreneurial environment at the university compared to Russian students.

CONCLUSIONS

The study found that the turbulent external environment in Russia in recent years has led to a transformation in established patterns of behavior among students when formulating career plans. These behavioral shifts are most pronounced with long-term planning horizons. The number of students declaring their intention to start their own business is declining. Students are shifting from potential entrepreneurs to employees at large companies. The share of undecided students has increased significantly. In 2018, only three VSU students surveyed were unsure what they would do five years after graduation; by 2025, one in four had not yet decided. The abandonment of long-term planning is a consequence of an adaptive response to external shocks.

Several regional differences in students' entrepreneurial intentions can be noted. The number of undecided students at Voronezh State University over a five-year horizon is 1,6 times higher than the national average. The most likely explanation for these differences is Voronezh's geographic proximity to a zone of heightened military and political risks, which creates additional uncertainty regarding personal safety and the stability of the socioeconomic environment. In the short-term planning period, student preferences changed less. Working for a large company remains the leading option immediately after graduation. Overall, VSU students rate the entrepreneurial environment at the university lower than the national average.

The results of the study on entrepreneurial intentions among VSU students largely reflect national trends. Minor regional differences are consistent with established trends in Russia and serve as indicators of the sensitivity of students' perceptions of the future during a period of macroeconomic instability.

REFERENCES

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211.

Berman, D., Kletzer, L., McPherson, M., & Shapiro, M. O. (2008). College choice, career, and wage formation: A microeconomic approach. *Educational Issues*, (2), 108–121.

Bird, B. (1988). Implementing entrepreneurial ideas: The case for intention. *Academy of Management Review, 13*(3), 442–453.

Global survey of students' entrepreneurial spirit: National report Russia 2018. (2019). Graduate School of Management, St. Petersburg State University. https://gsom.spbu.ru/files/folder_11/GUESSS_report_2019_RUS.pdf

Nikitina, L. M., Dubinkina, U. A., & Maleva, I. A. (2024). Analysis of changes in economic results of industrial enterprises of the Voronezh Region under sanctions. In *Current issues of sustainable development of the state, society and economy: Collection of scientific articles of the 3rd All-Russian Scientific and Practical Conference* (Vol. 2, pp. 106–109).

Shirokova, G. V., Kapirskaia, E. O., Veksler, K. A., & Dvorkina, D. V. (2023). *Global study of students' entrepreneurial spirit: National report Russia 2022*. Graduate School of Management, St. Petersburg State University.

Shirokova, G. V., Tsukanova, T. V., & Bogatyreva, K. A. (2015). Factors in the formation of entrepreneurial intentions of Russian students. *Bulletin of St. Petersburg University. Management*, (3), 21–46.

Ustinova, O. V., & Koemets, S. R. (2024). The role of the university environment in students' development of entrepreneurial culture. *Human Progress, 10*(8), 10.

Verkhovskaya, O. R. (2025). *Monitoring of entrepreneurial activity: Russia 2024/2025*. Graduate School of Management, St. Petersburg State University.

ARTIFICIAL INTELLIGENCE AND THE REDEFINITION OF THE DIKW PYRAMID: CHALLENGES OF THE POSTDIGITAL AGE

DOI: 10.5937/EMC26028R

Sanela Ravlić
University of Slavonski Brod, Department of Social Sciences and Humanities,
Slavonski Brod, Republic of Croatia
E-mail: sravlic@unisb.hr

ABSTRACT

In an era where artificial intelligence generates texts, recommends decisions, shapes markets, and actively participates in the construction of social reality, the classical DIKW hierarchy (Data-Information-Knowledge-Wisdom) faces significant challenges. Never in human history has more data and information been produced, yet at the same time it has never been more difficult to distinguish knowledge from the illusion of knowledge, truth from persuasiveness, and wisdom from statistical prediction. This paper examines the relationship between information and knowledge in the context of generative artificial intelligence, with a particular focus on the phenomenon of the "simulation of knowledge" in a postdigital society. The research aims to investigate whether trust in artificial intelligence is related to the ability to distinguish accurate from inaccurate information, as well as whether discrepancies exist between perceived and actual knowledge. The survey for this paper was conducted using a questionnaire on a sample of 97 respondents, combining elements of validated instruments such as the Misinformation Susceptibility Test (MIST) and self-assessment measures. The results indicate that respondents demonstrate a relatively good ability to recognize accurate and inaccurate information; however, no statistically significant relationship was found between self-assessed competence and actual performance. This finding suggests the presence of a potential "illusion of knowledge," where individuals overestimate their ability to evaluate information. These findings highlight the importance of critical information literacy in the context of artificial intelligence and suggest that generative AI may contribute to the blurring of boundaries between information and knowledge in postdigital society.

Key words: Artificial intelligence[1], DIKW model, information, knowledge, information literacy

INTRODUCTION

In today's digital environment, the volume of available information is growing exponentially, while the development of artificial intelligence further accelerates the processes of its production, distribution, and interpretation. Within this context, generative artificial intelligence occupies a particularly significant role, as it enables the creation of content that is linguistically coherent and persuasive, yet not necessarily factually accurate. Such systems are transforming the ways in which users access information and construct knowledge, raising important questions about the reliability, understanding, and validity of information in the digital age.

Traditionally, the relationship between data, information, and knowledge has been conceptualized through the DIKW model (data-information-knowledge-wisdom), which assumes a hierarchical and linear progression between these levels. However, in the context of emerging technologies, and artificial intelligence in particular, this assumption becomes increasingly problematic. Generative AI systems are capable of producing content that resembles knowledge without genuine understanding, thereby blurring the boundaries between information and knowledge. As a result, a phenomenon increasingly described in the literature as "simulated" or "false knowledge" begins to emerge.

At the same time, contemporary society is often characterized as postdigital, a condition in which digital technologies are no longer a separate domain but are deeply embedded in everyday life and

social processes. Within such a context, users continuously interact with technological systems, including artificial intelligence. These technologies no longer function merely as tools but as active participants in the production and interpretation of knowledge, further emphasizing the need for a critical approach to information and the development of information literacy.

Despite the growing body of research on artificial intelligence and information behavior, there remains a lack of empirical studies addressing the relationship between trust in artificial intelligence and users' actual ability to distinguish information from knowledge, and to recognize accurate and inaccurate information. Of particular interest is the extent to which generative AI shapes subjective perceptions of knowledge and contributes to a discrepancy between perceived and actual abilities in evaluating information. Accordingly, the aim of this paper is to examine the perception of the relationship between information and knowledge in the context of artificial intelligence, with a particular focus on trust in AI systems and the ability to recognize misinformation. The study is based on the assumption that the contemporary digital environment may foster an "illusion of knowledge," a situation in which individuals believe they possess knowledge that is not grounded in genuine understanding.

In line with this aim, the study addresses the following research questions: Is there a relationship between trust in artificial intelligence and the ability to distinguish knowledge from misinformation? And does generative artificial intelligence contribute to a discrepancy between the subjective perception of knowledge and the actual ability to recognize accurate and inaccurate information?

THEORETICAL BACKGROUND

The DIKW model (data-information-knowledge-wisdom) represents one of the fundamental theoretical frameworks in the field of information science, describing the relationship between data, information, knowledge, and wisdom through a hierarchical structure. Within this model, data are defined as raw facts without inherent meaning, which become information once contextualized. Through further interpretation and understanding, they evolve into knowledge, and through experience and judgment, into wisdom (Rowley, 2007). The DIKW model has been widely adopted in fields such as management, information systems, and education, where it serves as a framework for understanding the transformation of information into knowledge. Despite its popularity, however, the model is based on the assumption of a linear and unidirectional progression between its levels; an assumption that is increasingly challenged in contemporary digital environments. In the context of ongoing digital transformation, the model continues to function as an important analytical tool, although its meaning has expanded considerably. Grieves (2024) emphasizes that DIKW should not be viewed solely as a theoretical hierarchy, but also as an operational framework applicable in digital environments, particularly within data-driven systems and digital twin technologies. This perspective highlights the functional interconnectedness of the model's levels and their relevance in technological contexts.

One of the main critiques of the DIKW model concerns its hierarchical and linear assumptions. Authors such as Frické (2008) and Baškarada & Koronios (2013) argue that the distinction between data, information, and knowledge is not clear-cut, but rather exists along a continuum shaped by interpretation and context. In contemporary digital environments, this issue becomes even more pronounced, as artificial intelligence contributes to misinformation and reshapes how knowledge is perceived (Baker et al., 2025).

The development of generative artificial intelligence has significantly transformed the ways in which information is produced and perceived. Such systems generate linguistically coherent and persuasive content based on probabilistic patterns rather than genuine understanding, which may result in so-called "hallucinations", i.e. plausible but factually incorrect information (Dierickx et al., 2026). In this sense, AI does not replace the DIKW model, but reshapes it by accelerating the transformation processes between its levels while simultaneously producing outputs that resemble knowledge without being grounded in actual comprehension (Peters et al., 2024). Consequently, users may interpret such outputs as knowledge, contributing to the phenomenon of "simulated knowledge" and further blurring the distinction between information and knowledge. These developments highlight the need for a

human-centered approach to artificial intelligence, emphasizing critical interpretation, transparency, and responsibility in evaluating information (Verma, 2025).

The role of artificial intelligence must be understood within the postdigital context, where the boundaries between digital and non-digital are increasingly blurred and technology is deeply embedded in social processes (Veletsianos et al., 2024). In such an environment, artificial intelligence is no longer merely a tool, but an active participant in the production and interpretation of knowledge, emerging through interactions between users and technological systems. This transformation reinforces the need for new approaches to understanding human–technology relationships, particularly in order to avoid uncritical reliance on algorithmically generated information (Hayes et al., 2024).
The integration of the DIKW model, artificial intelligence, and the postdigital context points to profound changes in how knowledge is produced, interpreted, and perceived. While the DIKW model assumes a linear progression from data to knowledge, generative AI produces content that simultaneously exhibits characteristics of both information and knowledge.

In such an environment, the phenomenon of perceiving knowledge without actual understanding; referred to as "false" or "simulated knowledge"; becomes increasingly prominent. This phenomenon represents a key challenge for modern information systems and the development of information literacy. It is precisely within this theoretical framework that the need arises for empirical research on the relationship between trust in artificial intelligence, understanding of knowledge, and the ability to distinguish accurate from inaccurate information.

RESEARCH

The study was conducted with the aim of examining the perception of the relationship between information and knowledge within the context of the contemporary digital environment, with a particular focus on the role of artificial intelligence in shaping knowledge. In an era marked by the increasing availability of information and the rapid development of generative AI systems, an important question arises: do users distinguish between information and knowledge, and to what extent are they able to recognize accurate and inaccurate information?

The questionnaire was designed based on existing validated instruments commonly used in research on information behavior and misinformation. Specifically, part of the questionnaire was based on the Misinformation Susceptibility Test - MIST (Maertens et al., 2024), which measures respondents' ability to distinguish between accurate and inaccurate information by evaluating the truthfulness of various statements. In addition, elements of the Online Misinformation Susceptibility Scale - OMISS (Katsiroumpa et al., 2025) were incorporated to assess the tendency to trust information without verification, as well as the subjective perception of one's ability to recognize misinformation.

Given the specific focus of this study on the relationship between data, information, and knowledge (as conceptualized in the DIKW model), as well as the influence of artificial intelligence, the questionnaire was further adapted by including items that examine perceptions of artificial intelligence, trust in its outputs, and understanding of the distinction between information and knowledge. This approach—combining validated instruments with newly developed questions tailored to the research context—is a common and widely accepted practice in social science research.

Sample Description

A total of 97 respondents participated in the study. The sample was heterogeneous; however, younger participants predominated. The most represented age group was 18 to 24 years, indicating a substantial presence of young individuals and students. In terms of gender, the sample was predominantly female, while male respondents were represented to a lesser extent. With regard to educational background, the majority of respondents had completed secondary education or were currently enrolled in, or had completed, higher education (undergraduate or graduate studies), which corresponds to a digitally active user population. Considering employment status, the largest group consisted of students,

followed by employed individuals, while other categories (such as unemployed participants and retirees) were represented to a smaller extent.

Questionnaire Structure

The questionnaire consisted of four thematic sections:

- Perception of artificial intelligence – items assessing trust in AI, perception of information accuracy, and the perceived ability of AI to generate knowledge (Block A)
- Understanding the relationship between information and knowledge (DIKW) – items examining the ability to distinguish between data, information, and knowledge (Block B)
- Susceptibility to misinformation – self-assessment of critical attitudes toward information (Block C)
- Assessment of statement accuracy (MIST principle) – evaluation of the truthfulness of both accurate and inaccurate statements (Block D)

The collected data enabled an analysis of perceptions of knowledge in a digital environment, as well as a comparison between respondents' subjective assessments of their ability to distinguish information and their actual performance in recognizing accurate and inaccurate statements.

RESULTS

Statistical data analysis was performed using SPSS 23.0 software. The analysis of means and standard deviations reveals certain patterns in the respondents' perceptions of artificial intelligence and knowledge. Respondents demonstrate a high awareness of AI's ability to simulate knowledge and produce convincing but inaccurate information (M = 4.09 - 4.35), while rejecting the idea that speed implies accuracy (M = 2.18). Trust in AI remains moderate (M = 2.94), indicating a cautious but not entirely negative attitude. Respondents clearly distinguish knowledge from information (M = 4.71), although mid-range values for related statements (M ≈ 3.3–3.5) indicate some conceptual ambiguity.
Respondents also express uncertainty, as reflected in agreement that it is increasingly difficult to distinguish real knowledge from the illusion of knowledge (M = 3.91).

Respondents perceive themselves as critical users who tend to verify information sources and avoid uncritical acceptance. However, their confidence in evaluating information remains moderate (M ≈ 3.49), indicating some uncertainty.

Results indicate that respondents are generally successful in distinguishing accurate from inaccurate information, although occasional errors and neutral responses suggest that this ability is not entirely consistent

.

Overall, findings indicate a gap between the subjective perception of information literacy and actual performance in evaluating information accuracy.

Hypothesis Testing

H1: There is a statistically significant difference between student and employed respondents in their perception of artificial intelligence, understanding of the relationship between information and knowledge, and the ability to distinguish accurate from inaccurate information.

The t-test results (Table 1.) indicate that a statistically significant difference between students and employed respondents exists only in the perception of artificial intelligence ($t = -2.77$; $p = 0.007$). Employed respondents show slightly higher mean values, suggesting a higher level of trust or a different perception of artificial intelligence compared to students. On the other hand, no statistically significant differences were found in understanding the relationship between information and knowledge (DIKW), susceptibility to misinformation, or the ability to distinguish between accurate and inaccurate information ($p > 0.05$). This suggests that students and employed respondents are

relatively similar in these aspects. Therefore, Hypothesis H1 is partially confirmed, as the difference is observed only in the perception of AI, but not in other variables.

Table 1: Differences between students and employed respondents in AI perception, DIKW understanding, susceptibility to misinformation, and MIST scores (t-test)

Variable	M (students)	M (employed)	t	p
AI perception	3.31	3.58	-2.77	**0.007**
DIKW	3.79	3.78	0.07	0.943
Misinformation	3.21	3.24	-0.31	0.76
MIST	3.05	3.01	0.62	0.538

Source: Author's calculation

H2: There is a statistically significant relationship between the level of trust in artificial intelligence and susceptibility to misinformation.

Table 2: Relationship between trust in artificial intelligence and susceptibility to misinformation (Pearson correlation)

Variable	r	Sig. (p)
AI trust - misinformation	0.19	> 0.05

Source: Author's calculation

The results of Pearson's correlation analysis show a weak positive relationship between trust in artificial intelligence and susceptibility to misinformation ($r = 0.19$). However, this relationship is not statistically significant ($p > 0.05$). This indicates that respondents who have higher trust in artificial intelligence do not necessarily show a higher tendency to believe misinformation. In other words, trust in AI is not statistically associated with uncritical acceptance of information. Accordingly, Hypothesis H2 is rejected, as no statistically significant relationship was found.

H3: There is a statistically significant relationship between subjective self-assessment of the ability to distinguish information and actual performance in identifying accurate and inaccurate statements.

Table 3: Relationship between self-assessed ability and actual performance in recognizing accurate and inaccurate information (Pearson correlation)

Variable	r	Sig. (p)
Self-assessed ability - MIST	0.08	> 0.05

Source: Author's calculation

The analysis of the relationship between subjective self-assessment and actual performance in distinguishing accurate from inaccurate information reveals a very weak positive correlation ($r = 0.08$), which is not statistically significant. This result indicates that respondents who perceive themselves as more confident in their ability to evaluate information do not necessarily achieve better results in the truth-assessment test. In other words, there is no clear relationship between perceived and actual ability. Therefore, Hypothesis H3 is rejected. However, the findings suggest a potential discrepancy between subjective perception and actual performance, which may indicate elements of an "illusion of knowledge."

H4: There is a positive relationship between understanding the difference between information and knowledge and the ability to distinguish accurate from inaccurate information.

The results of Pearson's correlation (Table 4.) analysis show a weak positive relationship between understanding the distinction between information and knowledge and the ability to distinguish accurate from inaccurate information ($r = 0.08$). However, this relationship is not statistically significant. This means that respondents who better understand the difference between knowledge and

information do not necessarily perform better in identifying accurate and inaccurate statements. Consequently, Hypothesis H4 is rejected.

Table 4: Relationship between understanding the distinction between information and knowledge (DIKW) and the ability to distinguish accurate from inaccurate information (Pearson correlation)

Variable	r	Sig. (p)
DIKW - MIST	0.08	> 0.05

Source: Author's calculation

The results of hypothesis testing indicate that only the first hypothesis was partially confirmed, with a significant difference found between students and employed respondents in the perception of artificial intelligence. The remaining hypotheses were not supported, as no statistically significant relationships were identified among the analyzed variables.

A particularly important finding is the lack of a relationship between subjective self-assessment and actual performance, suggesting a potential discrepancy between perceived and actual knowledge in the digital environment.

DISCUSSION

The findings provide insight into how individuals perceive the relationship between information and knowledge in a digital environment shaped by artificial intelligence, highlighting both awareness of AI limitations and uncertainty in evaluating information. Regarding H1, a partial difference was observed between students and employed respondents in their perception of artificial intelligence, while no differences were found in understanding the relationship between information and knowledge or in the ability to evaluate information. In relation to H2, no significant relationship was found between trust in artificial intelligence and susceptibility to misinformation, suggesting that users may trust AI while still maintaining a certain level of critical distance. With regard to H3, no significant relationship was found between self-assessed and actual ability, indicating a discrepancy consistent with the concept of the "illusion of knowledge". Concerning H4, understanding the distinction between information and knowledge does not appear to translate into better performance in evaluating information accuracy.
These findings support critiques of the DIKW model, suggesting that the transformation of information into knowledge is neither linear nor automatic. In the context of AI, persuasive but not necessarily accurate content may contribute to the emergence of "false knowledge".

From a postdigital perspective, the findings point to a complex relationship between users and technology, where AI acts as an active participant in knowledge production. This reinforces the importance of critical information literacy. Artificial intelligence is no longer merely a tool but an active participant in the production and shaping of knowledge. In such an environment, the importance of critical information literacy; defined as the ability to evaluate, interpret, and verify information; becomes increasingly evident.

Although respondents expressed strong agreement with statements emphasizing the importance of understanding and a critical approach to information in the descriptive part of the study, the results of the tests and correlation analyses show that this awareness is not always consistently applied in practice. This further highlights the gap between theoretical understanding and actual behavior in digital environments.

CONCLUSION

This study examined the relationship between information and knowledge in the context of artificial intelligence, with a focus on trust in AI and the ability to evaluate information accuracy.Results show that respondents recognize both the capabilities and limitations of AI and understand the conceptual difference between information and knowledge. However, a discrepancy between perceived and actual

ability indicates the presence of the "illusion of knowledge".No significant relationships were found between trust in AI, understanding of knowledge, and the ability to evaluate information, highlighting the complexity of information behavior in digital environments. This supports contemporary critiques of the DIKW model, which argue that the transformation of information into knowledge is neither linear nor automatic.In the context of AI and postdigital society, these findings emphasize the importance of developing critical information literacy. Generative AI systems produce content that is persuasive and easily accessible, but not necessarily accurate, which may contribute to the blurring of boundaries between information and knowledge and the emergence of a perception of "false knowledge."This research is limited by a non-representative sample dominated by younger respondents, the use of self-assessment measures, and the integration of multiple constructs within a single research instrument.Despite these limitations, the study contributes to understanding the relationship between artificial intelligence, information, and knowledge. Future research should include more diverse samples and additional methods for assessing actual information literacy.

REFERENCES

Baker, A., Chakraborty, D., & McAdams, A. C. (2025). Revisiting the information hierarchy in the AI era: Implications of misinformation, ignorance, and imprudence. *Communications of the Association for Information Systems, 57*(1), Article 5.

Baskarada, S., & Koronios, A. (2013). Data, information, knowledge, wisdom (DIKW): A semiotic theoretical and empirical exploration of the hierarchy and its quality dimension. *Australasian Journal of Information Systems, 18*(1).

Dierickx, L., Opdahl, A. L., Bjerknes, F., & Lindén, C. G. (2026). What is a fact in the age of generative AI? Fact-checking as an epistemological lens. *Information, Communication & Society*, 1–18.

Frické, M. (2009). The knowledge pyramid: A critique of the DIKW hierarchy. *Journal of Information Science, 35*(2), 131–142.

Grieves, M. (2024). DIKW as a general and digital twin action framework: Data, information, knowledge, and wisdom. *Knowledge, 4*(2), 120–140.

Hayes, S., Jandrić, P., & Green, B. J. (2025). Towards a postdigital social contract for higher education in the age of artificial intelligence. In *Postdigital education for development* (pp. 115–134). Springer Nature Switzerland.

Katsiroumpa, A., Moisoglou, I., Mangoulia, P., Konstantakopoulou, O., Gallos, P., Tsiachri, M., & Galanis, P. (2025). The online misinformation susceptibility scale: Development and initial validation. *Healthcare, 13*(17), Article 2252.

Maertens, R., Götz, F. M., Golino, H. F., Roozenbeek, J., Schneider, C. R., Kyrychenko, Y., ... & van der Linden, S. (2024). The Misinformation Susceptibility Test (MIST): A psychometrically validated measure of news veracity discernment. *Behavior Research Methods, 56*(3), 1863–1899.

Peters, M. A., Jandrić, P., & Green, B. J. (2025). The DIKW model in the age of artificial intelligence. *Postdigital Science and Education, 7*(4), 1150–1159.

Rowley, J. (2007). The wisdom hierarchy: Representations of the DIKW hierarchy. *Journal of Information Science, 33*(2), 163–180.

Veletsianos, G., Jandrić, P., MacKenzie, A., & Knox, J. (2024). Postdigital research: Transforming borders into connections. *Postdigital Science and Education, 6*(2), 643–662.

Verma, J. (2025). From data to wisdom: Human-centered AI for ethical and transparent decision-making. *International Journal for Multidisciplinary Research (IJFMR), 7*(5).

[1] *Artificial intelligence was used to translate the paper from Croatian to English and proofread it, which may result in certain parts of the paper being flagged as AI-generated in case of verification.*

VALUATION OF THE EFFECTS OF EMERGING TECHNOLOGIES: SURVEY-BASED EVIDENCE FROM THE IT SECTOR

DOI: 10.5937/EMC26035S

Marija Stanojeska
UACS, School of Computer Science and Information Technology, Skopje, Republic of North Macedonia
E-mail: marija.stanojeska@uacs.edu.mk
Stefan Dimovski
MA, Ministry of Defense, Skopje, Republic of North Macedonia

ABSTRACT

Understanding the potential of emerging technologies to accelerate economic growth, competitiveness, and sustainability, this paper evaluates their effects on business performance within the Information Technology (IT) sector. Additionally, the study investigates the level of integration of these technologies into the business operations of IT companies in North Macedonia. A quantitative survey was conducted using a structured questionnaire distributed among selected IT companies. The research findings indicate that the integration of new technologies significantly enhances business performance and operational efficiency in the Macedonian IT sector, with Cloud Computing and Cybersecurity showing the highest level of adoption maturity, while AI, ML, Big Data, and IoT demonstrate varying levels of implementation and impact. The present study is a contribution to building a knowledge base on what is currently taking place in the IT sector with respect to embedding emerging technologies into its business models. As innovations continue to alter business operations, marking a new era in which emerging technologies effortlessly integrate with traditional practices, their influence remains a determinant of success.

Keywords: Emerging technologies; Effect; Integration; IT Companies.

INTRODUCTION

Emerging technologies present unparalleled opportunities for a prosperous future, now and in times to come, by rewiring the way businesses operate. These developments refer to a chain of technologically advanced factors alongside Internet of Things (IoT), Artificial Intelligence (AI), Cybersecurity, Machine Learning (ML), and Cloud Computing, which allow organizations to redesign their business models. As important participants in economic progress, companies are able to utilize these opportunities to improve efficiency and productivity, thereby becoming more competitive, especially within in the IT sector (Dimovski et al., 2026). By embracing emerging technologies, IT companies have the opportunity to optimize processes, minimize costs, and provide customers with more personalized goods (Bakator et al., 2024). Generally speaking, organizations that have embedded innovative technologies experience success in the digital era (Agustian et al., 2023).

Although the positive effects of emerging technologies have been well documented, their implementation and level of integration are not sufficiently understood or widely applied, especially in developing countries. Therefore, investigating driving technologies and their impact on specific businesses' performances, emerges as a major research incentive of this paper. Exactly, the research problem focuses on the following goal:

G1: To evaluate the effects of embraced emerging technologies on the specific businesses' performances in the Macedonian IT sector."

The additional research goal in this paper is:

G2: To investigate the level of integration of these technologies in the current operations within the IT companies."

In fulfilling the research goal, the proposed research design combines a qualitative approach (literature review) with a quantitative method (survey). The paper is structured into several sections, the literature review, methodological framework, findings and discussion, and the final section offers the conclusion.

LITERATURE BACKGROUND

Apparently, companies that integrate emerging technologies in their organizational structure are more competitive on the market (Perifanis and Kitsios, 2023; Lindström et al., 2023). More than a few studies have suggested that the adoption of advanced technologies has a positive influence on performance (Agustian et al., 2023; Yuniarto, 2023). Consequently, organizations become flexible enough to face any changes in the marketplace, particularly in the case of IT companies, which belong to fast-growing industries (Ibrahim and Ali, 2023; Stanojeska, 2024).

As stated by Sharma et al. (2023), the importance of Cloud Computing is determined by its scalability, flexibility, and efficiency due to being less expensive. Likewise, Khatib et al. (2019) acknowledge the cost-efficiency of the technology along with the opportunities for having access to computing services whenever necessary. The application of Big Data is crucial because of the need for data transformation into valuable information and the ability to develop forecasts and make decisions, as underlined by Rane et al. (2024). Moreover, the role of IoT is associated with efficiency and automation due to the ability to collect and process information in real time from connected devices (Rocha & Kissimoto, 2022). It can be concluded that the combination of AI and IoT allows for predictive maintenance and improved decision-making (Gajić et al., 2024; Reim et al., 2020). Additionally, ML and AI enable predictive analytics, automation, and personalization (Brocal et al., 2019; Stanojeska, 2025; Waqar et al., 2024). AI provides more value to customers via personalized services and smarter decision-making, while ML algorithms improve efficiency by automating mundane tasks and optimizing resource consumption (Chowdhury, 2024). According to Rocha & Kissimoto (2022), the full potential of both AI and ML technologies remains unexplored, thus necessitating empirical research in this area. Aspects of Cybersecurity have been identified as one of the most important elements in facilitating digital transformation in today's world, as they ensure data privacy, system integrity, and organizational sustainability (Hasan et al., 2021; Lezzi et al., 2018). Thus, the effective Cybersecurity measures can be useful in securing information assets (Denkovski et al, 2024; Hasani et al., 2023).

In conclusion, it has been proven that all the technological innovations that define emerging technologies help increase efficiency and innovation while improving competitiveness. At the same time, their benefits are best achieved through integration instead of implementation separately. Although the literature review has provided valuable information, a significant deficiency has been noted in the number of studies examining the level of integration of emerging technologies and their effects on business models in Macedonian IT companies.

RESEARCH METHODOLOGY

In line with the research goals, the applied methodology employs a qualitative research method and quantitative analysis. In terms of the qualitative research, a comprehensive research of the literature based upon Emerald, Scopus, EBSCO, and other relevant bases, was conducted in the period from 1st Januray 2025 to 15th February 2025. A total of 22 papers in the treated areas, published in English, have been found, according to keywords: emerging technologies, effect, business performances, and IT industry. The quantitative research was conducted through a survey using a structured questionnaire.

Questionnaire design

The survey conduction includes the design of a structured questionnaire composed of questions reffering to the determined specific criteria, offering multiple categories of optional answers in accordance with the research objectives and allowing the selection of more than one answer.

The questionnaire encompasses 18 questions positioned in 3 sections: (I) referring to general data about respondents, (II) covering benefits, and challenges of emerging technologies implementation in the IT companies and (III) referring to effects of emerging technologies on specific business performances and the level of integration of new technologies in the current operations. General data were gathered at the start of the questionnaire in the first section, including company name, type of company activity, number of employees in the organization and responder position.

The second section addresses benefits and challenges before and during the implementation of emerging technologies in IT companies. The findings regarding the second section were published in the paper titled *"Industry 4.0 in Practice - Exploring the challenges of adoption in the IT sector,"* in Journal of TERUM (Dimovski et al., 2026). The third section includes questions concerning the effects of emerging technologies on specific business performances and the level of integration of new technologies in existing processes. Actually, the research in this paper embraces the findings regarding the third section of the questionnaire.

Data collection

The data were collected from 40 reputable IT companies in North Macedonia, that were actively involved in software development and digital technology services. Companies were identified based on their market presence, operational activity, and relevance to the research topic. Invitations to participate in the survey were distributed to representatives of 40 selected IT companies during the period from 1st February, 2025 to 1st March, 2025. The response rate was 78%. The participation of the surveyed organizations according to the number of employees' criterion: 22% were small organizations (less than 50 employees), 41% medium-sized organizations (between 50 and 251 employees), and 22% for large organizations (with up to 251 employees). Specifically, this survey contains a wider scope of job positions of the respondents, 36% were software developers, followed by managers with 24%, 12% software engineers, 12% business owners, 4% for software testers, 4% web developers, and finally, 4% team leaders. This research and its findings are limited to the Macedonian IT companies (as a representative example of a small developing country), but can still indicate the general directions concerning its research goals.

RESULTS AND DISCUSSION

In more detail, the specific effects of six technologies on certain criteria were explored throughout the survey conducted in the IT sector. Thus, respondents were challenged to evaluate (1) the impact of using Cloud Compututing from a resource management perspective, (2) the effect of Big Data technology on data-driven decision making, (3) the impact of using IoT in businesses process automation and optimization, (4) the usability of ML to predict customer needs, (5) the integration of AI technology in customization and personalization efforts, and finally (6) the effect of using Cybersecurity technology to address the risk of data privacy and security infringes. The collected data are explicitly presented in Table 1.

The general conclusion is that the claims listed in Table 1 are more or less confirmed by the respondents included in the survey. It is clear that *Cybersecurity* and *AI* are the highest-ranked technologies according to the criterion of application and understanding of their effects in terms of information protection and automation of operations, respectively. This proves a strong awareness among companies of the importance of cybersecurity and its main role in reducing company vulnerabilities and preventing potential attacks. In the same context, the power of AI is recognized by

as many as 92% of the surveyed companies, according to which AI is the driver of automation in performing complex operations and personalization in response to individual customer requests. A minor number of respondents chose the option of *"lack of information",* which leads to the conclusion that Cybersecurity and AI are well understood in domestic IT companies.

Table 1: Overview of data collected throughout the survey

Research question: *Effect of…*	**Collected data (%)**			
	Significantly positive impact	Slightly positive impact	No impact	Lack of information
...Cloud Computing on resource management	44	41	0	15
...Big Data on data-based decision making	46	15	0	39
...IoT on automation and optimization	46	35	0	19
...ML on customers needs prediction	54	27	8	11
…AI on customization and personalization	54	38	4	4
...Cybersecurity on data privacy protection	80	16	0	4

A lower portion of respondents (under 20%) stated that they are not familiar with the functionalities and effects of *ML*, *Cloud Computing* and *IoT*, which leads to the conclusion that employees have not yet had the opportunity to gain work experience in the application of this type of advanced technologies.

More critical findings were obtained regarding the impact of *Big Data* on data-driven decision-making. The fact that as many as 39% of the respondents stated that they do not have enough information to assess the effects of Big Data in practice is impressive. This finding is significant and indicates a serious need for employee education and raising their knowledge, through organizing specialized training programs for systematized development, in order to recognize the role of advanced technologies and their effects in improving organizational performance.

The next research goal concerns the investigation of the degree of support of current operations in IT companies enabled by specific emerging technology (Cloud Computing, Cybersecurity, IoT, AI, ML, and Big Data). For the purpose of data simplification, the support levels are divided into five intervals (0-20%, 20-40%, 40-60%, 60-80%, and 80-100%). Analyzing each specific technology, presented in Figure 1, the following conclusions were reached.

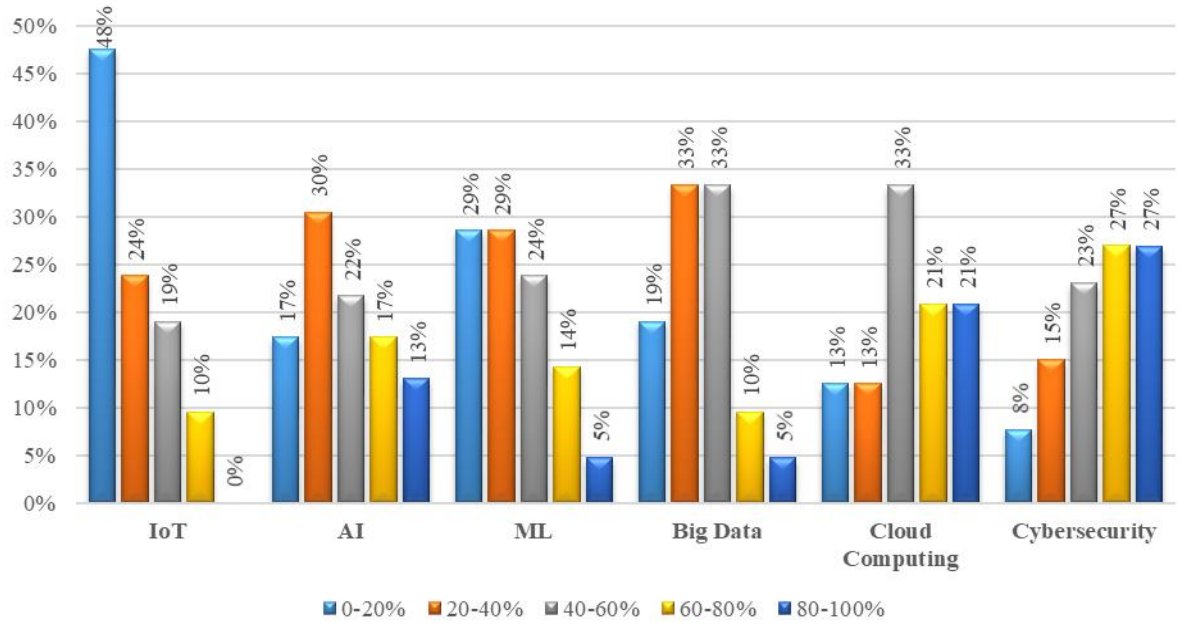


Figure 1: Level of integration of emerging technologies within IT companies

According to the given findings, none of the respondents confirmed that IoT supports current operations to a significant extent, at the highest level of integration (80-100%). In contrast, the majority of the responses are addressed to the lowest level of integration (0-20%). It is more than clear that IoT is poorly adopted in the IT sector.

Regarding AI, at the highest level of integration, only 13% of respondents consider AI vital for personalization in meeting customer requirements. Accordingly, the integration of AI is on the rise, but is not yet at an enviable level. A similar view can be confirmed for ML and Big Data. In other words, as the level of integration increases, the application of ML and Big Data in current operations decreases. Hence, the conclusion is that these technologies have moderate application in the IT sector and their potential is not yet fully utilized in current operations.

In contrast to AI, Big Data, and IoT, the data analysis leads to the conclusion that Cloud Computing is adopted to the greatest extent in IT companies (in the range of 40-100%). In terms of Cybersecurity, it is worth emphasizing that as many as 27% of the surveyed companies have a very high level of protection that varies in the range of 60-100%, and only 8% of the companies apply it for security and data protection that are at the first level of integration. This implies the claim that, as the level of integration of new technologies into companies' business models increases, so does the awareness of the need to practice Cybersecurity.

Overall, the data presented in Figure 1 confirms that Cloud Computing is the leading technology in terms of the level of integration of emerging technologies into the current operations of IT companies. Cybersecurity is second in line, while other technologies, such as AI, ML, and Big Data, are utilized, but only partially. Compared to other emerging technologies, it is notable that the use of IoT as a technology that enables automation and optimization of business operations is the least adopted in IT companies.

CONCLUSION

The adoption of emerging technologies offers significant benefits and improvement in overall business performance, which is confirmed by the findings of the conducted research. The significantly positive effect of the application of emerging technologies in resource management, automation and optimization, personalization and customization, protection of private data, as well as the prediction of customer needs, is clearly confirmed by the majority of the analyzed data. The survey showed that the application and integration of new technologies in Macedonian IT companies are at different levels, depending on the type of technology and the level of understanding of its effects on organizational operations. As the results indicate that the degree of adoption of new technologies is not equally distributed, there are technologies that already have strong practical application, like Cloud Computing and Cybersecurity, while others are still in the phase of partial adoption or limited integration. These findings emphasize the need for strategic investments in staff training, technological infrastructure and the development of innovative business models, in order to more fully exploit the potential of new technologies and improve organizational performance and competitiveness of the IT sector. Thus, it can be concluded that the adoption of emerging technologies cannot be taken as an option but must be done out of necessity, because of the significant possibility for sustainable development and global competitiveness in the IT industry.

REFERENCES

Agustian, K., Mubarok, E. S., Zen, A., Wiwin, W., & Malik, A. J. (2023). The impact of digital transformation on business models and competitive advantage. *Technology and Society Perspectives, 1*(2), 79–93.

Bakator, M., Ćoćkalo, D., Makitan, V., Stanisavljev, S., & Nikolić, M. (2024). The three pillars of tomorrow: How Marketing 5.0 builds on Industry 5.0 and impacts Society 5.0. *Heliyon, 10*(17), e36543. https://doi.org/10.1016/j.heliyon.2024.e36543

Brocal, F., González, C., Komljenovic, D., Katina, P. F., & Sebastián, M. A. (2019). Emerging risk management in Industry 4.0: An approach to improve organizational and human performance in complex systems. *Complexity, 2019*, Article 2089763. https://doi.org/10.1155/2019/2089763

Chowdhury, N. R. H. (2024). The evolution of business operations: Unleashing the potential of artificial intelligence, machine learning, and blockchain. *World Journal of Advanced Research and Reviews, 22*(3), 2135–2147. https://doi.org/10.30574/wjarr.2024.22.3.1746

Denkovski, V., Stojmenovska, I., Gavrilov, G., Radevski, V., & Trajkovik, V. (2024). Exploring current challenges on security and privacy in an operational eHealth information system. *Advances in Science, Technology and Engineering Systems Journal, 9*(2), 45–53. https://doi.org/10.25046/aj090206

Dimovski, S., Stanojeska, M., Hristova, S., & Ivanovski, F. (2026). Industry 4.0 in practice: Exploring the challenges of adoption in the IT sector. *Theoretical and Empirical Researches in Urban Management, 21*(1), 94–111.

Gajić, T., Petrović, M. D., Pešić Milanović, A., Ćonić, M., & Gligorijević, N. (2024). Innovative approaches in hotel management: Integrating artificial intelligence (AI) and the Internet of Things (IoT) to enhance operational efficiency and sustainability. *Sustainability, 16*(17), 7279. https://doi.org/10.3390/su16177279

Hasan, S., Ali, M., Kurnia, S., & Thurasamy, R. (2021). Evaluating the cyber security readiness of organizations and its influence on performance. *Journal of Information Security and Applications, 58*, 102726. https://doi.org/10.1016/j.jisa.2021.102726

Hasani, T., O'Reilly, N., Dehghantanha, A., Rezania, D., & Levallet, N. (2023). Evaluating the adoption of cyber security and its influence on organizational performance. *SN Business & Economics, 3*(5), Article 62. https://doi.org/10.1007/s43546-023-00462-7

Ibrahim, A. M., & Ali, H. (2023). Factors affecting human resource information systems: IT infrastructure, management support, and market competition. *Dinasti International Journal of Management Science, 5*(1), 136–141. https://doi.org/10.31933/dijms.v5i1

Khatib, M. M. E., Al-Nakeeb, A., & Ahmed, G. (2019). Integration of cloud computing with artificial intelligence and its impact on the telecom sector: A case study. *iBusiness, 11*(1), 1–10. https://doi.org/10.4236/ib.2019.111001

Lezzi, M., Lazoi, M., & Corallo, A. (2018). Cybersecurity for Industry 4.0 in the current literature: A reference framework. *Computers in Industry, 103*, 97–110. https://doi.org/10.1016/j.compind.2018.09.004

Lindström, C. W. J., Maleki, V. B., & De Giovanni, P. (2023). Subscription-based business models in the context of tech firms: Theory and applications. *International Journal of Industrial Engineering and Operations Management, 8*, 1–19.

Perifanis, N. A., & Kitsios, F. (2023). Investigating the influence of artificial intelligence on business value in the digital era of strategy: A literature review. *Information, 14*(2), 85. https://doi.org/10.3390/info14020085

Rane, N. L., Paramesha, M., Choudhary, S. P., & Rane, J. (2024). Artificial intelligence, machine learning, and deep learning for advanced business strategies: A review. *Partners Universal International Innovation Journal, 1*(5), 151–186.

Reim, W., Åström, J., & Eriksson, O. (2020). Implementation of artificial intelligence (AI): A roadmap for business model innovation. *AI, 1*(2), 180–191. https://doi.org/10.3390/ai1020011

Rocha, I. F., & Kissimoto, K. O. (2022). Artificial intelligence and Internet of Things adoption in operations management: Barriers and benefits. *RAM. Revista de Administração Mackenzie, 23*(4), eRAMG220091. https://doi.org/10.1590/1678-6971/eRAMG220091.en

Sharma, M., Gupta, R., & Acharya, P. (2023). Systems approach to cloud computing adoption in an emerging economy. *International Journal of Emerging Markets, 18*(9), 3283–3308. https://doi.org/10.1108/IJOEM-11-2020-1385

Stanojeska, M. (2024). Personalized training for successful implementation of advanced technologies in the IT industry. In *Proceedings of the XIV International Symposium Engineering Management and Competitiveness 2024 (EMC 2024)* (pp. 84–90). Technical Faculty "Mihajlo Pupin".

Stanojeska, M. (2025). Applying DMAIC framework for designing personalized training programs in the IT industry. *Business Excellence and Management, 15*(2), 63–75.

Waqar, A., Bheel, N., & Tayeh, B. A. (2024). Modeling the effect of implementation of artificial intelligence-powered image analysis and pattern recognition algorithms in the concrete industry. *Data in Brief, 57*, 100349. https://doi.org/10.1016/j.dib.2024.100349

Yuniarto, D. (2023). Implementing cloud computing in companies to increase business efficiency. *Jurnal Info Sains: Informatika dan Sains, 13*(2), 145–154.

ENTREPRENEURIAL UNIVERSITY SCALE (ENTRE-U) VALIDATION AT CHINESE UNIVERSITIES

DOI: 10.5937/EMC26041T

Jun Todorovic
Purdue University Fort Wayne, The United States
E-mail: Ma@purdue.edu
Zelimir Todorovic
Purdue University Fort Wayne, The United States

ABSTRACT

The rapid rise of Chinese universities in global research rankings has raised important questions regarding the entrepreneurial orientation (EO) of engineering and research-intensive academic institutions in China. This study examines the EO of Chinese universities using the Entre-U scale and investigates its relationship with innovation performance. Data were collected from department heads and academic administrators across engineering, computer science, natural sciences, and related disciplines at Chinese universities.The findings confirm that the Entre-U scale is a reliable instrument for measuring entrepreneurial orientation within the Chinese higher education context. However, the results indicate that EO does not have a strong direct relationship with university performance when measured by patents and faculty-led startup activity. Among the four EO dimensions, only Industry Collaboration demonstrated a modest positive association with performance outcomes. The study suggests that traditional commercialization metrics may not fully capture the broader contributions of Chinese engineering departments to technological innovation and economic development. The findings highlight the need for more comprehensive measures of entrepreneurial university performance within engineering and technology-focused institutions.

Key Words: Entrepreneurial Orientation, Entre-U Scale, Engineering Departments, Chinese Entrepreneurial Universities, University Innovation

INTRODUCTION

The Centre for Science and Technology Studies (CWTS) at Leiden University published the Leiden Ranking Open Edition 2025, which evaluates universities worldwide based on their scientific publications and review output between 2020 and 2023. In the 2025 rankings, Chinese universities occupied the leading positions, surpassing many historically dominant American research institutions. Zhejiang University ranked first with 37,457 points, followed by Shanghai Jiao Tong University with 35,373 points, while Harvard University fell to third place. These rankings, which assessed the scientific performance of more than 1,500 universities globally, highlight China's growing influence in research productivity, engineering innovation, and technological development.

The prominence of Chinese universities in the CWTS rankings reflects decades of strategic national investment in higher education, advanced engineering research, industrial modernization, and innovation ecosystems. Engineering faculties and technology-oriented departments have played a particularly critical role in this transformation by contributing to scientific breakthroughs, patents, technology transfer, and startup development. Consequently, the rise of Chinese universities represents not only an academic achievement but also a broader shift in global technological leadership and industrial competitiveness.

The latest CWTS rankings have generated significant international attention and raised important questions regarding the entrepreneurial orientation of Chinese universities, particularly within engineering and applied science disciplines. Specifically, to what extent do engineering departments

within Chinese universities demonstrate entrepreneurial characteristics that support high-impact research and innovation? Furthermore, how effectively do research activities within these departments contribute to technological commercialization, intellectual property generation, and startup creation that support China's economic development and industrial competitiveness?

The remainder of this article is organized as follows. First, a review of the literature on Entrepreneurial Orientation (EO) and the development of the Entre-U scale is presented, with particular attention to its relevance for engineering and technology-focused academic units. This is followed by the research methodology and empirical results. The final section discusses the implications of the findings, identifies limitations of the study, and proposes future research directions for understanding entrepreneurial orientation within engineering-intensive higher education institutions.

LITERATURE REVIEW FOR ENTREPRENEURIAL ORIENTATION AND ENTRE-U SCALE

Entrepreneurial Orientation

Entrepreneurial Orientation (EO) is a foundational construct within entrepreneurship and strategic management research that explains how organizations adopt entrepreneurial behaviors to enhance innovation capability, technological competitiveness, and organizational performance (Miller, 1983). Miller (1983) characterized entrepreneurial organizations as those that engage in product-market innovation, undertake risk-oriented initiatives, and proactively introduce innovations ahead of competitors.

Building upon this foundational framework, Covin and Slevin (1989) conceptualized EO as a strategic posture characterized by innovativeness, risk-taking, and proactiveness, and subsequently developed one of the most influential measurement scales for empirical EO research. These three dimensions became central to early EO scholarship. Later, Lumpkin and Dess (1996) expanded the construct into a five-dimensional framework by incorporating competitive aggressiveness and autonomy. This multidimensional interpretation has become widely accepted because it enables researchers to evaluate EO either as an integrated construct or through its individual dimensions depending on the organizational context.

A substantial body of empirical research has demonstrated a positive relationship between EO and organizational performance. Firms exhibiting stronger entrepreneurial orientation frequently achieve superior growth, enhanced innovation output, and sustained competitive advantage (Rauch, Wiklund, Lumpkin, & Frese, 2009; Wiklund & Shepherd, 2005). More recent research has extended EO into contexts such as digital entrepreneurship, corporate entrepreneurship, and technology-intensive industries. Scholars argue that EO strengthens an organization's capacity to identify emerging technological opportunities, respond to dynamic market conditions, and maintain strategic flexibility in rapidly evolving innovation environments (Covin & Wales, 2019).

Within engineering and technology-oriented academic environments, EO is particularly relevant because engineering departments serve as primary generators of applied research, patents, technological innovation, and university-industry collaboration. Engineering faculties often operate at the intersection of scientific discovery and industrial application, making them critical contributors to technology transfer and entrepreneurial ecosystems within universities. Consequently, examining EO within engineering departments provides valuable insight into how universities transform scientific knowledge into economic and technological value.

Entre-U Scale

The transformation of traditional universities into entrepreneurial institutions has received extensive attention in the literature on innovation systems and higher education. Early theoretical frameworks emphasized the interaction among universities, industry, and government as a catalyst for innovation

and economic development (Etzkowitz & Leydesdorff, 2000). Within this framework, entrepreneurial universities were conceptualized as institutions that strategically adapt their organizational structures, funding models, and institutional cultures to promote innovation, commercialization, and entrepreneurial activities (Clark, 1989).

Although these foundational studies established important theoretical perspectives, they did not provide standardized quantitative instruments for assessing the entrepreneurial orientation of universities. To address this limitation, Todorovic et al. (2011) developed the Entre-U scale, which has since become one of the most widely utilized instruments for measuring entrepreneurial orientation in higher education institutions.

The Entre-U scale evaluates four principal dimensions of university entrepreneurial orientation: Research Mobilization, Unconventionality, Industry Collaboration, and University Policies. These dimensions are especially relevant to engineering and applied science departments, where research commercialization, interdisciplinary collaboration, and industry partnerships frequently drive innovation outcomes. Engineering faculties, in particular, depend heavily on effective industry engagement and supportive institutional policies to facilitate technology transfer, patent generation, and startup creation.

Subsequent studies have applied the Entre-U scale across diverse cultural and institutional settings to examine the relationship between university entrepreneurial orientation and performance outcomes. Building on this body of research, the present study applies the Entre-U scale within the Chinese higher education context to investigate the entrepreneurial orientation of engineering-focused university departments and its relationship with innovation performance.

METHODOLOGY

Measures

This study adopted the Entre-U scale developed by Todorovic et al. (2011) to assess the entrepreneurial orientation (EO) of Chinese universities, with particular emphasis on engineering as well as other technology-oriented departments. The Entre-U scale consists of 23 items measuring four dimensions of university EO: Research Mobilization (6 items), Unconventionality (8 items), Industry Collaboration (5 items), and University Policies (4 items). All items were measured using a seven-point Likert scale ranging from 1 (“Strongly Disagree”) to 7 (“Strongly Agree”).

Given that the study was conducted within the Chinese higher education context, the original English-language instrument was translated into Chinese by a bilingual Chinese graduate student proficient in both English and Chinese academic terminology. To ensure linguistic equivalence and conceptual accuracy, the Chinese version was subsequently back-translated into English following the procedures recommended by Brislin (1970). The back-translation process was completed by a bilingual professor based in the United States.

To improve the reliability and contextual appropriateness of the survey instrument, the Chinese questionnaire was pre-tested with a small group of faculty members and prospective respondents from engineering and science-related departments. Feedback regarding wording clarity, contextual relevance, and interpretability was incorporated into the final version of the survey instrument.

University performance was assessed through self-reported measures provided by departmental respondents. Performance indicators focused specifically on entrepreneurial and innovation-related outcomes generated within academic departments during the preceding three years. In particular, the survey measured the number of patents, intellectual property outputs, and faculty-led spin-offs or startup ventures originating from the department. These indicators were selected because they are especially relevant to engineering and technology-oriented disciplines, where applied research,

commercialization activities, and industry-driven innovation represent critical measures of institutional impact.

Sampling and Data Collection Method

Data collection for the study was conducted through an online survey administered to academic leaders across Chinese universities. Survey invitations containing the questionnaire link were distributed electronically to targeted respondents. The sampling frame primarily consisted of department heads and senior academic administrators from engineering, natural sciences, biochemistry, computer science, health sciences, aeronautical and astronautical sciences, and agricultural sciences. Particular emphasis was placed on engineering and technology-intensive departments because of their central role in research commercialization, innovation development, and university-industry collaboration within China's higher education system.

A total of 130 universities were selected based on the 2014 university rankings published by the Chinese University Alumni Association. The sample included the top 100 universities as well as an additional 30 universities selected from the lower range of the top 600 institutions in China. This sampling strategy enabled the study to capture variation in institutional prestige, research capacity, and entrepreneurial orientation across different tiers of Chinese universities.

The target population consisted of 4,578 academic administrators and department leaders. Engineering departments represented the largest proportion of the sample, reflecting their dominant role in Chinese research and innovation activities. Specifically, the sampling frame included 1,919 individuals from engineering disciplines, 715 from natural sciences, 724 from biochemistry, 404 from computer science, 662 from health sciences, 78 from aeronautical and astronautical sciences, and 76 from agricultural sciences.

Among the identified respondents, 1,013 individuals could not be reached because of invalid or inaccessible email and telephone contact information. During the data collection period, two reminder emails were distributed to improve participation rates. The first reminder was sent one week after the initial invitation, while the second reminder was distributed three weeks following the initial contact.

A total of 593 responses were received, yielding a response rate of 16.63%. Following data screening procedures, 253 responses were excluded because they contained substantial missing data, defined as more than 20% missing values across study variables. Subsequent outlier analysis resulted in the removal of an additional five observations, leaving a final sample of 335 valid responses for statistical analysis.

The demographic profile of respondents indicates substantial administrative and academic experience among participants. Of the final sample, 83.8% of respondents were male and 16.2% were female. Only one respondent was younger than 30 years of age, while 48.1% were 46 years or older. In addition, 81.2% of respondents had served as department chairs or academic administrators for three years or longer, suggesting a high degree of familiarity with departmental research activities, innovation initiatives, and institutional policies.

Engineering departments accounted for the largest proportion of respondents (43.6%), followed by biochemistry (18.8%), natural sciences (15.2%), health sciences (10.4%), and computer science (9%). The strong representation of engineering-related disciplines aligns with the study's objective of examining entrepreneurial orientation within research-intensive and innovation-driven academic environments.

Potential non-response bias was evaluated by comparing the mean responses of the earliest 25% of respondents with those of the latest 25% of respondents. The analysis revealed no statistically significant differences between the two groups, suggesting that non-response bias does not represent a major concern in the present study.

RESULTS

Confirmatory Factor Analysis

Amos was used to analyze the data. Confirmatory Factor Analysis was conducted to test the first-order model with four latent factors, and all latent factors are correlated. The preliminary results show that the factor loadings of UC8 and IC5 have factor loadings less than .5. The two items were dropped for further analysis. After dropping the two items, the confirmatory factor Analysis was conducted. The reliability analysis shows that all measures in the measurement model achieve good reliability. The model fit indices also show that the measurement model is acceptable (CFI=.841, RMSEA=.106).

Table 1: Reliability Analysis

Research Mobilization		**Unconventionality**		**Industry Collaboration**		**University Policy**	
Items	**Standardized Regression Coefficient**	**Items**	**Standardized Regression Coefficient**	**Items**	**Standardized Regression Coefficient**	**Items**	**Standardized Regression Coefficient**
RM1	0.565	UC1	0.696	IC1	0.788	UC1	0.725
RM2	0.648	UC2	0.547	IC2	0.669	UC2	0.75
RM3	0.756	UC3	0.717	IC3	0.794	UC3	0.825
RM4	0.784	UC4	0.736	IC4	0.696	UC4	0.577
RM5	0.709	UC5	0.756				
RM6	0.677	UC6	0.71				
		UC7	0.676				
CR=.846; AVE=.481; α=.85		CR=.866; AVE=.482; α=.861		CR=.827; AVE=.546; α=.819		CR=.813; AVE=.525; α=.805	

Relationship between EO and Performance

Using the number of IPs and the number of startups as performance measures, SEM was submitted to AMOS for analysis. The model fit indices show the model has a good fit to the data (CFI=.844, RMSEA=.096). The correlations between the four dimensions of EO and performance show that only industrial collaboration has a significant impact on performance at the .1 level. The other three dimensions do not have a significant impact on performance.

DISCUSSION AND FUTURE RESEARCH DIRECTIONS

The study examines the entrepreneurial orientation (EO) of Chinese universities, with a focus on engineering and technology-intensive environments, using the Entre-U scale. Results confirm that the scale is valid in the Chinese context, with its four dimensions—Research Mobilization, Unconventionality, Industry Collaboration, and University Policies—relevant for assessing university entrepreneurship in engineering-focused institutions.

However, EO shows little direct relationship with performance when measured by patents, intellectual property, and startup creation. Only Industry Collaboration exhibits a modest positive effect. This suggests that EO does not straightforwardly translate into commercialization outcomes in Chinese universities.

A key explanation is that China’s centralized, policy-driven innovation system and strong emphasis on research output and rankings may weaken the direct impact of EO on entrepreneurial results. Engineering departments may produce high levels of innovation while still facing structural barriers to commercialization and technology transfer.

Moreover, conventional indicators such as patents and startups may underrepresent the broader contributions of engineering faculties, including industry collaboration, technology diffusion, infrastructure development, and talent formation.

Overall, the study highlights the need for broader performance measures and more context-sensitive approaches to understanding university entrepreneurship. While Chinese engineering universities demonstrate clear entrepreneurial characteristics, their impact on innovation outcomes is complex and not fully captured by traditional metrics.

REFERENCES

Brislin, R. W. (1970). Back-Translation For Cross-Cultural Research. *Journal of Cross-Cultural Psychology, 1*(3), 185-216. doi:10.1177/135910457000100301

Clark, B. (1989). *Creating Entrepreneurial Universities: Organizational Pathways Of Transformation*: Oxford: IAU Press/Pergamon.

Covin, J. G., & Slevin, D. P. (1989). Strategic Management Of Small Firms In Hostile And Benign Environments. *Strategic Management Journal (Wiley-Blackwell) - 1980 to 2009, 10*(1), 75-87. doi:10.1002/smj.4250100107

Covin, J. G., & Wales, W. J. (2019). Crafting High-Impact Entrepreneurial Orientation Research: Some Suggested Guidelines. *Entrepreneurship: Theory & Practice, 43*(1), 3-18. doi:10.1177/1042258718773181

Etzkowitz, H., & Leydesdorff, L. (2000). The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University-Industry-Government Relations. *Research Policy, 29*(2), 109-123. Retrieved from https://research.ebsco.com/linkprocessor/plink?id=7fcf0a78-a18e-3f39-9955-b01996a4e509

Lumpkin, G. T., & Dess, G. G. (1996). Clarifying The Entrepreneurial Orientation Construct And Linking It To Performance. *The Academy of Management Review, 21*(1), 135-172. doi:10.2307/258632

Miller, D. (1983). The Correlates Of Entrepreneurship In Three Types Of Firms. *Management Science (INFORMS), 29*(7), 770-791. doi:10.1287/mnsc.29.7.770

Rauch, A., Wiklund, J., Lumpkin, G. T., & Frese, M. (2009). Entrepreneurial Orientation and Business Performance: An Assessment of Past Research and Suggestions for the Future. *Entrepreneurship: Theory & Practice, 33*(3), 761-787. doi:10.1111/j.1540-6520.2009.00308.x

Todorovic, Z., McNaughton, R. B., & Guild, P. (2011). ENTRE-U: An entrepreneurial orientation scale for universities. *Technovation, 31*(2/3), 128-137. doi:10.1016/j.technovation.2010.10.009

Wiklund, J., & Shepherd, D. (2005). Entrepreneurial orientation and small business performance: a configurational approach. *Journal of Business Venturing, 20*(1), 71-91. doi:10.1016/j.jbusvent.2004.01.001

Session A: MANAGEMENT AND OPERATION MANAGEMENT

Papers (pp. 49-110):

Muhammed Ernur Akiner
WATER SCARCITY CHALLENGE FOR TURKEY: RECOGNITION OF REGIONAL DISCREPANCIES AND URGENT SOLUTION FOR SUSTAINABILITY ...49

İlknur Akiner, Büşra Selin Kepenek
A SYSTEMATIC REVIEW OF CRITICAL FACTORS AFFECTING COMPANY SUCCESS IN INTERNATIONAL CONTRACTING SERVICES ...56

Dušan Jovanić, Valentina Mladenović
RISK ANALYSIS OF INFRARED THERMOGRAPHIC EQUIPMENT ...65

Dušan Jovanić, Valentina Mladenović
RISK ASSESSMENT AND RISK REDUCTION MEASURES FOR ELECTROPNEUMATIC EQUIPMENT ...71

Natalija Nikolić, Milka Bubalo Živković, Tamara Lukić, Bojan Đerčan, Dajana Bjelajac
INTERNET COVERAGE AND SMART RURAL DEVELOPMENT: THE CASE STUDY OF VOJVODINA, SERBIA ...77

Ivan Palinkaš, Eleonora Desnica, Jasmina Pekez, Bogdana Vujić, Ljiljana Radovanović, Borko Bulajić ANALYSIS OF THE CONDITION OF HISTORICAL BUILDINGS IN SERBIA – LITERATURE REVIEW ...83

Adriana Radosavac, Oliver Momčilović
STRATEGIC SELECTION OF A LOGISTICS CENTER LOCATION USING A HYBRID MCDM MODEL BASED ON PIPRECIA AND SAW METHODS: AN EMPIRICAL STUDY ...87

László Szabó
INNOVATION AND TECHNOLOGICAL CHANGES IN SUPPLY CHAINS ...94

Vesna Spasojević Brkić, Branislav Tomić, Iva Savić, Martina Perišić Jokić, Abdulghder Alsharif
LINKING ORGANIZATIONAL CULTURE, QUALITY AND AGILITY TO BUSINESS PERFORMANCE: A CROSS-COUNTRY CLUSTER ANALYSIS OF A TRANSPORTATION SUPPLY CHAIN ...99

Stefan Ugrinov, Edit Terek Stojanović, Sanja Stanisavljev, Mila Kavalić, Verica Gluvakov, Mića Đurđev
MANAGING THE STRATEGIC LOGISTICS POSITION OF THE REPUBLIC OF SERBIA IN REGIONAL AND EUROPEAN SUPPLY CHAINS ...106

WATER SCARCITY CHALLENGE FOR TURKEY: RECOGNITION OF REGIONAL DISCREPANCIES AND URGENT SOLUTION FOR SUSTAINABILITY

DOI: 10.5937/EMC26049A

Muhammed Ernur Akiner
Akdeniz University, Vocational School of Technical Sciences, Department of Environmental Protection Technologies, Antalya, Turkey
E-mail: ernurakiner@gmail.com

ABSTRACT

This study examines dam fill rates across Turkey between 2010 and 2020 using statistical trend analysis methods, including the Mann-Kendall test and Sen's slope estimation. The results reveal slightly negative national average annual trends reaching -0.47% (p=0.349), while also identifying significant social and economic impacts stemming from regional differences. The study observed statistically significant growth trends only in Northeastern Anatolia, with an annual growth rate of +1.76% (p=0.005). Central Anatolia and the Aegean region, however, experienced significant declines, with annual decreases of -1.11% (p=0.087) in Central Anatolia and -2.46% (p=0.062) in the Aegean region. The provincial-level study confirms strong, statistically significant declines, reaching the 0.05% significance level in 26% of the provinces. While large metropolitan areas like Istanbul maintain high occupancy rates reaching 51.7%, drought-affected regions such as Central Anatolia (26.1%) and the Mediterranean (35.2%) are facing maximum storage capacity. Water scarcity emerges as an environmental problem that engineers must address. The study reveals that Turkey needs to implement urgent policy measures, such as drought-resilient agriculture and reducing urban water loss.

Key words: Climate Adaptation, Dam Occupancy, Regional Inequalities, Water Governance, Water Stress

INTRODUCTION

Dams which function as water storage facilities and flood control systems represent an exceptional engineering achievement that provides optimal water resource management through their construction. The structures create substantial effects on aquatic systems and the organisms inhabiting the region (Chalise et al., 2023; Cho and Qi, 2023; He et al., 2024). The entire system of infrastructure and water resources faces severe danger from climate change. The capacity of reservoirs to receive direct water inputs is restricted by changing rainfall patterns and snowmelt and hot weather conditions (Gruss et al., 2023; Sambou et al., 2023). The dams face two opposing forces which create a situation that will become increasingly difficult for them to manage (Ariffin et al., 2025; Abu-Afifeh et al., 2023; Genç et al., 2026). The Three Gorges Dam operation has increased low-flow events according to research conducted by Wang et al. (2023) which shows that this phenomenon mainly affects vegetation patterns. In Iraq, climate change poses a serious threat to the Al Abila Dam, according to research by Abed et al. (2023). The complex relationship between climate change and dam operations requires the development of flexible water management regulations according to the presented cases. The African continent meets the Mediterranean Basin in Turkey, which will experience the most severe climate change impacts. The occupancy rates of dams serve as the most precise and extensive indicators which show the complete water condition of the basin. The present water stress situation needs evaluation through assessment of rate patterns which demonstrate its progress throughout different time periods and various geographical areas (Disasa et al., 2026; Ji and Senay, 2023; Kong et al., 2023). Erosion risk assessments provide valuable information about how long-term sedimentation affects the occupancy of dam basins (Karaoğlu, 2023; Kholmurodova et al., 2025). The research will establish the national trend while examining regional and provincial variations which stem from different

geographical and climatological characteristics to create scientifically based water management solutions for specific regions. This study would be of significant importance for providing Turkey with the development of a resilient and sustainable water management strategy that can endure the increasing water stress.

METHODOLOGY

This study investigates how reservoir occupancy ratios in Turkey changed over time from 2010 to 2020 and how they differ across different regions. The study used official provincial scale reservoir occupancy data which was supplied by DSI and TÜİK. The dataset went through a preprocessing step which removed all data points that contained errors or missing data or extreme values. The researchers divided provinces into 13 different regions according to their climate and geographic characteristics. The dataset required nonparametric methods because it contained non-Gaussian data along with suspected outlier cases. The researchers used the Mann–Kendall test to study temporal trends while they used Sen's slope estimator to measure the strength of those trends. The researchers determined statistical significance at the α=0.10 level. The analysis was conducted at national, regional, and provincial levels using specific hypotheses; H_0: No trend; H_a: Monotonic trend. Test statistic T is shown in Eq. 1, where N stands for the total number of observations, y_l and y_k are the data at time k and l; the sign() function is defined in Eq. 2; the variance of T in Eq. 3, where g is the number of tied groups and r_m is the size of the m-th tied group; the standardized test statistic Z^* is defined in Eq. 4; and the trend slope θ is estimated using Sen's method as presented in Eq. 5, where θ denotes the slope and $t_q - t_p$ represents the time difference.

$$T = \sum_{k=1}^{N-1} \sum_{l=k+1}^{N} \text{sign}(y_l - y_k) \tag{1}$$

$$\text{sign}(z) = \begin{cases} +1, & z > 0 \\ 0, & z = 0 \\ -1, & z < 0 \end{cases} \tag{2}$$

$$Var(T) = \frac{N(N-1)(2N+5) - \sum_{m=1}^{g} r_m(r_m-1)(2r_m+5)}{18} \tag{3}$$

$$Z^* = \begin{cases} \dfrac{T-1}{\sqrt{Var(T)}}, & T > 0 \\ 0, & T = 0 \\ \dfrac{T+1}{\sqrt{Var(T)}}, & T < 0 \end{cases} \tag{4}$$

$$\theta = median\left(\frac{y_q - y_p}{t_q - t_p}\right), \forall\, q > p \tag{5}$$

RESULTS

Decision-making about water management planning needs information about Turkey's dam occupancy ratios. Figure 1 demonstrates that dam occupancy rates in Turkey show extreme variation which results from both climate conditions and distinct water management methods. Malatya, Kayseri, Kırşehir, Isparta, and Van show the lowest average values among all provinces in Turkey. The Central Anatolia and Mediterranean regions approach critical occupancy thresholds, which creates severe hazards to agricultural activities and drinking water supplies. The Aegean region experienced low occupancy rates which showed a clear downward pattern that demonstrated rising water stress levels and drought conditions. Some areas have enhanced their water storage capabilities, but essential agricultural zones and urban water supply regions continue to suffer from reduced water levels. The Black Sea and the Marmara areas experienced more stable occupancy rates, which remained at moderate-to-high levels throughout the study period. The Southeastern Anatolia Region demonstrated substantial yearly variations, which created fluctuations from its average values. A violin plot in Figure

2 displays how occupancy rates change over time. 2015 exhibited both a wide range of values and a substantial increase in its median measurement. The extended lower violin reaches from 2019 to 2020 showed that additional provinces would experience low occupancy rates, which would create severe water shortages. The violin plots show that some years exhibit bimodal or multimodal patterns, which include the years 2012 and 2017. The period from 2010 to 2013 showed a stable distribution which reached a high point but 2014 brought about expanded values which resulted in greater concentration during lower intervals. The Violin plot shows how water stress distribution occurs during dry years and differs between different regions during wet years.

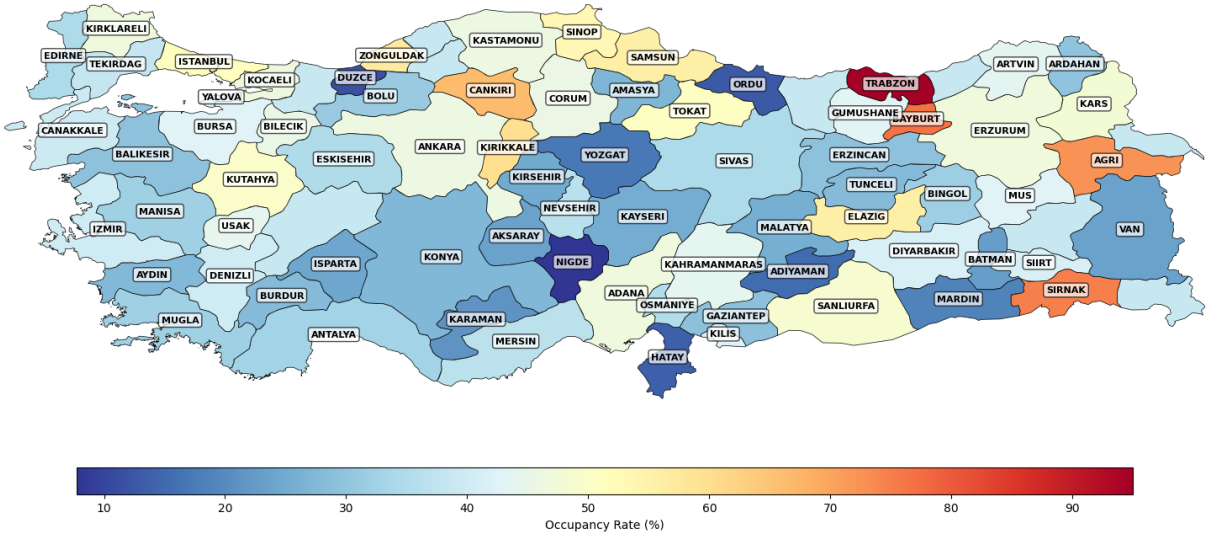


Figure 1: 2010-2020 average dam occupancy rates by provinces of Turkey

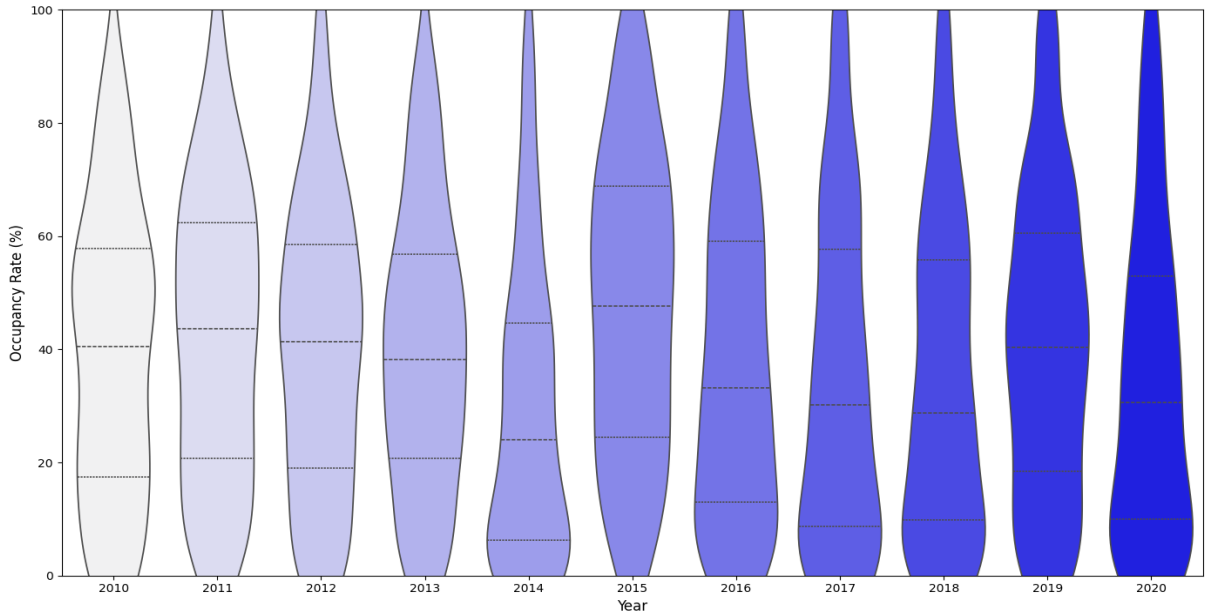


Figure 2: Violin plots depict yearly distribution of dam occupancy rates

The upper panel in Figure 3 displays three data sets, which include original data and three-year moving average data and linear regression model results. The moving average curve shows annual variations in data while it demonstrates the overall long-term trend of the data. The analysis of linear regression shows that the country experiences an annual declining trend of 0.47, which achieves statistical significance at the 90 percent confidence level. The lower panel displays percentage changes, which show green columns for increases and red columns for decreases. The moving average shows that water stress has become a new regular pattern because it has not reached its pre-2014 level.

The regional trends in Turkey are assessed through four graphs which are displayed in Figure 4. The top-left graph shows the strength of trends that exist in each region's Sen slopes. The graph displays the annual rate of change that exists in Turkey's regions while presenting the statistically significant development patterns. The study identifies Northeastern Anatolia as the region that displays the strongest positive trend since it experiences 1.76% annual growth. The Aegean region experiences its most severe negative trend, which results in an annual decline of -2.46%.

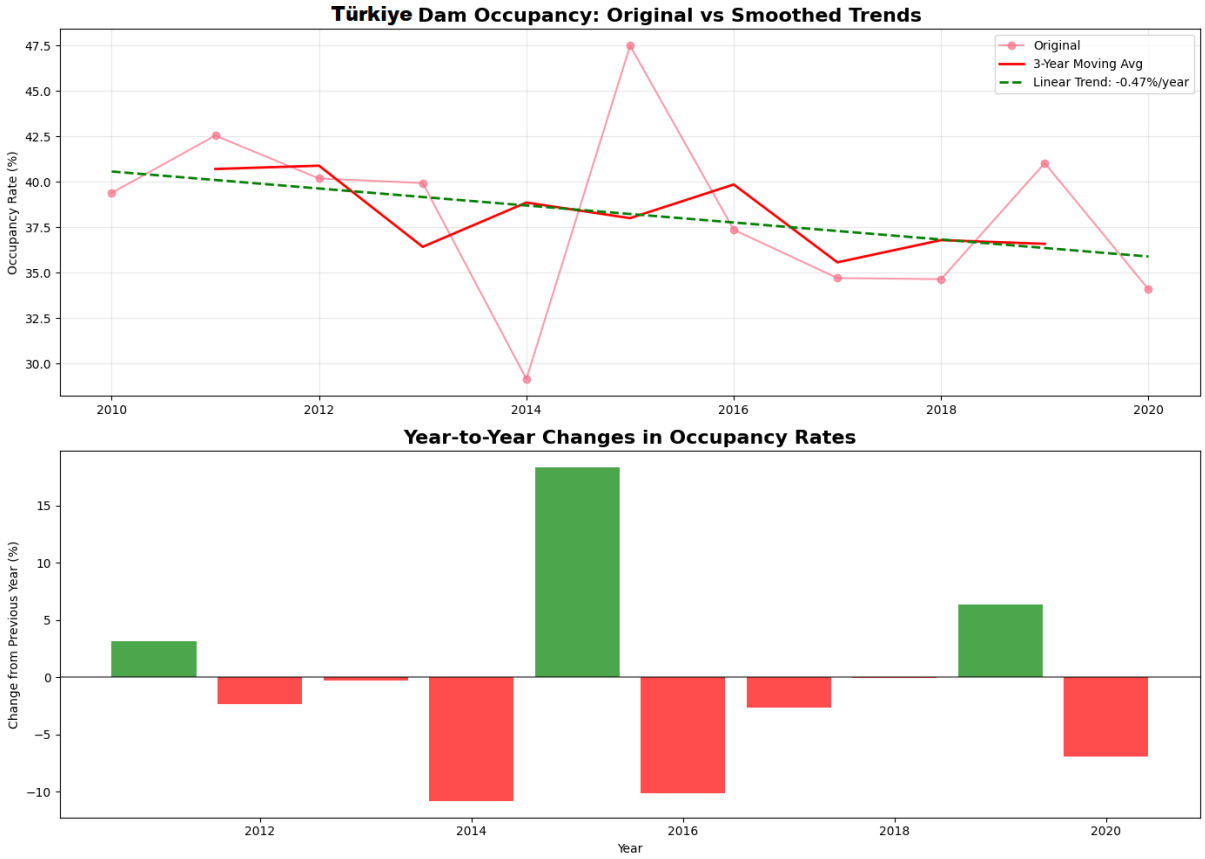


Figure 3: a) Original over smoothed dam occupancy trends for Turkey, b) Yearly changes in occupancy

DISCUSSION

The Turkish dam occupancy rates experienced their most considerable changes between 2010 and 2020. Turkish water resource management operates through multiple layers and various methods according to the research results. Al-Ansari et al. (2023) attribute water scarcity in Iraq to various factors that include climate change, poor management of water, and increased water demand, leading to water stress. Turkey demonstrates a negative trend through its data which shows results at -0.47% every year though the results lack statistical significance. The water trends in Northeastern Anatolia and Eastern Black Sea Region show increasing patterns because of the area's geographical and climatological characteristics. Central Anatolia and Aegean Regions show downward trends because their water patterns have started to decline. The Kilombero River Basin of Tanzania demonstrates similar hydroclimatic patterns according to Sigalla et al. (2023) who found that the same patterns exist throughout Turkey and other parts of the world. The interrelations among precipitation, runoff, and land use operate as the primary elements that control basin-scale water dynamics according to Carvalho et al. (2023) who established a fundamental system to examine regional water system differences.

Dams lose their ability to store water because of sedimentation which leads to a major decrease in their storage capacity. Ferreira et al. (2023) conducted research on reservoir erosion in a Brazilian

semiarid region using the 210Pb geochronological method to determine sedimentation rates which demonstrated how sediment accumulation decreased both dam operational life and storage capacity. Mostafazadeh et al. (2024) conducted research through an index-based approach which assessed how land-use changes and dam regulations affected river flow patterns. Bai et al. (2024) developed a model which uses hidden information to reduce the harmful effects that hydroelectric dams and climate change create for fish habitats. Sun (2023) demonstrated how hydroelectric dam construction in China affects the environment while he emphasized the requirement for conducting environmental impact assessments to support sustainable water management practices.

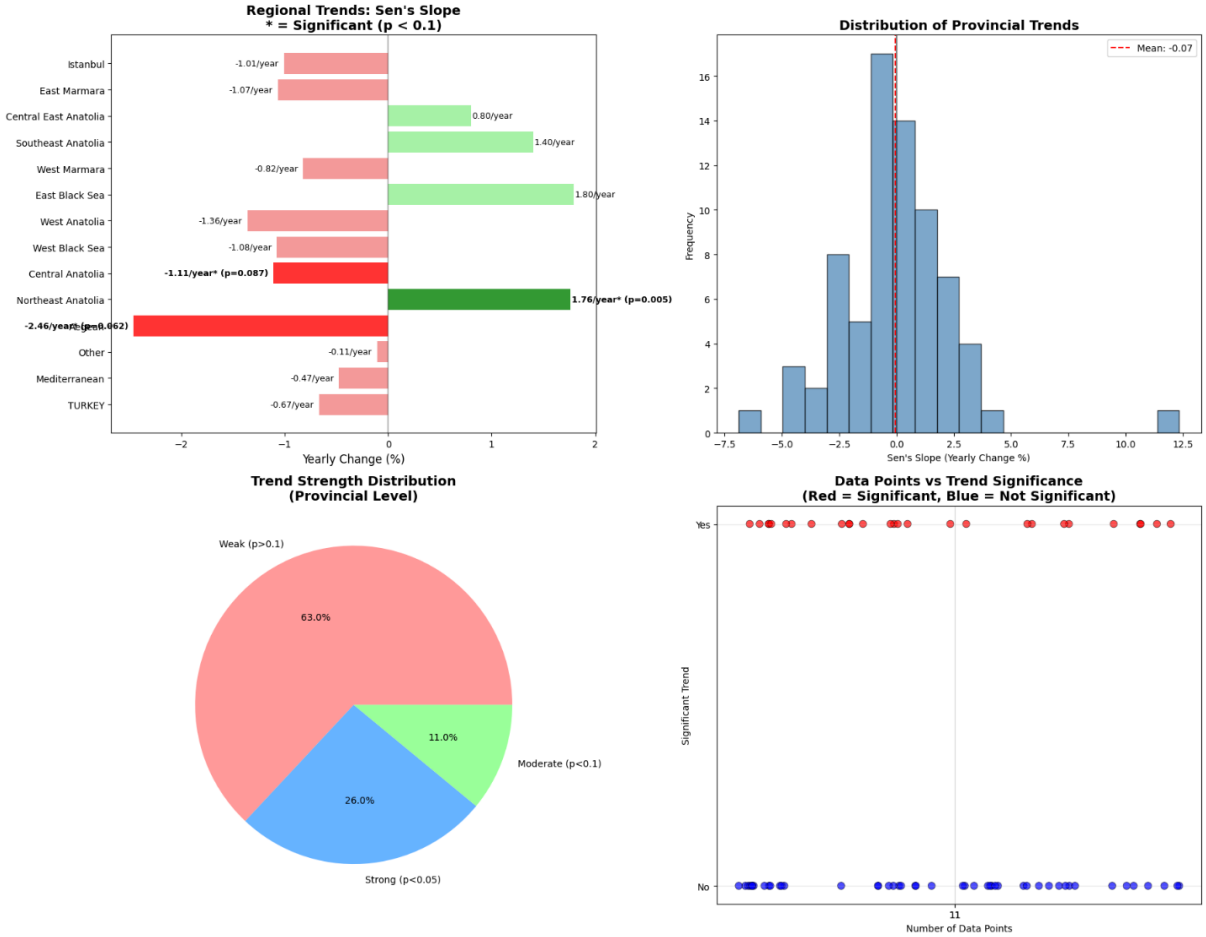


Figure 4: Statistical significance and yearly change trends of dam occupancy

Provincial authorities need to establish water management policies which require consideration of specific characteristics present in each individual region. Water resources management includes multiple components which connect together through their functions in dam construction, safety operations, and flood control activities (Yameogo et al., 2023). Samsudin et al. (2023) used GIS methods to study dam-break flood events which proved valuable for developing emergency management response plans. Lee et al. (2023) developed an ensemble model which uses multiple data sources to forecast water flow at the Soyang River Dam. The study establishes hydrological forecasting as an essential component necessary for effective water management. The research conducted by Yakar et al. (2023) studied the fatty acid composition of fish from Atatürk Dam Lake which demonstrated that ecological health assessment requires monitoring of aquatic ecosystems. Muddasir and Dondaş (2023) examined the connection between housing prices and economic indicators in Turkey which helped them show how water resource management interacts with economic growth. The research results show that Turkey needs to create new water management approaches which should include flexible policies to develop climate change resilience.

The study suffers from its major constraint which restricts research to a particular time period. The period from 2010 to 2020 which lasts ten years is insufficient to study extended climate changes. According to Mostafazadeh et al. (2024) researchers require extended time periods to study changes in river flow patterns. The research conducted by Ferreira et al. (2023) in Brazil demonstrates that sedimentation rates impose a critical impact on the capacity of dams to store water. The study presents another limitation because it failed to combine climate change predictions with forecasts of water requirements. The assessment method developed by Bai et al. (2024) which evaluates how hydroelectric dams and climate change together affect ecosystems can be used to study ecological impacts in Turkey. The study excluded both groundwater level measurements and measurements of surface water quality attributes.

CONCLUSION

The study's findings about water management showed important results which water management policy makers used to make their decisions. The study identified important trends which affected 27 out of 73 provinces because they developed at an average rate of-0.066% every year. Central Anatolia and Mediterranean regions which provide essential water supply for agriculture and urban areas have reached critical occupancy levels because they already have 26.1% and 35.2% occupancy rates respectively. The results require the country to establish water resources management policies which should be designed to address climate change effects through regional-specific solutions. The study findings show that ongoing conditions will lead to serious issues which will impact farming activities, drinking water distribution in cities, and the well-being of ecosystems. The main solutions for this situation require farmers to switch to drought-resistant farming methods and water supply systems to minimize their water distribution losses and all stakeholders to work together for effective water management throughout the entire basin while they establish new water sources and enhance their water collection techniques and increase public knowledge. The study uses scientific evidence to support its recommendation that Turkey needs to revise its water management strategies and create flexible solutions which will help the country handle climate change. The next studies need to use long-term data and create integrated modeling methods while they build partnerships with other disciplines at their most effective level. Turkey requires effective water resource management to accomplish its development objectives and create a future that can withstand climate change impacts.

REFERENCES

Abed, R., Adham, A., Allawi, M., & Ritsema, C. (2023). Potential impacts of climate change on the Al Abila Dam in the Western Desert of Iraq. *Hydrology, 10*(9), Article 183. https://doi.org/10.3390/hydrology10090183

Abu-Afifeh, Q., Rahbeh, M., Al-Afeshat, A., Al-Omari, S., Qutishat, T., Brezat, A., ... & Alkayed, A. (2023). Dam sustainability's interdependency with climate change and dam failure drivers. *Sustainability, 15*(23), Article 16239. https://doi.org/10.3390/su152316239

Al-Ansari, N., Adamo, N., Hachem, A., Sissakian, V., Laue, J., & Abed, S. (2023). Causes of water resources scarcity in Iraq and possible solutions. *Engineering, 15*(9), 467–496. https://doi.org/10.4236/eng.2023.159036

Ariffin, W., Sidek, L., Basri, H., Idros, N., Adrian, M., Ghani, N., ... & Ahmed, A. (2025). Overtopping risk of high-hazard embankment dam under climate change condition. *PLOS ONE, 20*(2), e0311181. https://doi.org/10.1371/journal.pone.0311181

Bai, X., Zhang, P., Cao, X., Zhang, D., Yang, Z., Dong, X., ... & Xiong, L. (2024). Incorporating implicit information to disentangle the impacts of hydropower dams and climate change on basin-scale fish habitat distribution. *Ecology and Evolution, 14*(10), e70412. https://doi.org/10.1002/ece3.70412

Carvalho, A., Silva, M., Batista, F., Araújo, J., Montenegro, A., Silva, T., ... & Silva, J. (2023). Spatio-temporal dynamics and physico-hydrological trends in rainfall, runoff and land use in Paraíba watershed. *Geographies, 3*(4), 714–727. https://doi.org/10.3390/geographies3040038

Chalise, D., Sankarasubramanian, A., Olden, J., & Ruhí, A. (2023). Spectral signatures of flow regime alteration by dams across the United States. *Earth's Future, 11*(2), e2022EF003078. https://doi.org/10.1029/2022EF003078

Cho, M., & Qi, J. (2023). Determination of spatial pattern of environmental consequences of dams in watersheds. *Land, 12*(12), Article 2154. https://doi.org/10.3390/land12122154

Disasa, K. N., Yan, H., Wang, G., Zhang, J., Zhang, C., Wang, B., & Bao, R. (2026). Modelling the impact of climate and land cover changes on hydrological cycle components: A case of the middle Huai River Basin. *Theoretical and Applied Climatology, 157*(1), Article 40. https://doi.org/10.1007/s00704-025-05964-4

Ferreira, C., Araújo, M., Júnior, J., & Souza, V. (2023). Method of 210Pb geochronological to estimate sedimentation rate in water reservoir in the Brazilian semiarid region. *Journal of Environmental Analysis and Progress, 8*(2), 99–109. https://doi.org/10.24221/jeap.8.2.2023.5552.099-109

Genç, Ö., Uğur, L. O., Akbıyıklı, R., Bozali, B., & Ateş, V. (2026). Revitalizing water storage capacity: Remote sensing and optimization-based design for a new dam. *Sustainability, 18*(7), Article 3312. https://doi.org/10.3390/su18073312

Gruss, Ł., Wiatkowski, M., Połomski, M., Szewczyk, Ł., & Tomczyk, P. (2023). Analysis of changes in water flow after passing through the planned dam reservoir using a mixture distribution in the face of climate change: A case study of the Nysa Kłodzka River, Poland. *Hydrology, 10*(12), Article 226. https://doi.org/10.3390/hydrology10120226

He, F., Zarfl, C., Tockner, K., Olden, J. D., Campos, Z., Muniz, F., ... & Jähnig, S. C. (2024). Hydropower impacts on riverine biodiversity. *Nature Reviews Earth & Environment, 5*(11), 755–772. https://doi.org/10.1038/s43017-024-00596-0

Ji, L., & Senay, G. (2023). Temporal trends in agricultural water use and the relationships to hydroclimatic factors in the High Plains Aquifer region. *JAWRA Journal of the American Water Resources Association, 59*(5), 950–969. https://doi.org/10.1111/1752-1688.13133

Karaoğlu, M. (2023). Erosion risk analysis in Unlendi Dam basin. *Polish Journal of Environmental Studies, 32*(6), 5631–5640. https://doi.org/10.15244/pjoes/170033

Kholmurodova, M., Juliev, M., Abdikairov, B., Djanpulatova, Z., Turdalieva, S., Khadjieva, Z., ... & Shamsiev, M. (2025). A systematic review of soil erosion susceptibility: Trends and insights from 2010 to 2023. *Applied Ecology and Environmental Research, 23*(5), 9991–10013. http://dx.doi.org/10.15666/aeer/2305_999110013

Kong, M., Zhao, J., Zang, C., Li, Y., & Deng, J. (2023). Characteristics and driving mechanism of water resources trend change in Hanjiang River Basin. *International Journal of Environmental Research and Public Health, 20*(4), Article 3764. https://doi.org/10.3390/ijerph20043764

Lee, S., Kim, J., Bae, J., Lee, G., Yang, D., Hong, J., ... & Lim, K. (2023). Development of multi-inflow prediction ensemble model based on auto-sklearn using combined approach: Case study of Soyang River Dam. *Hydrology, 10*(4), Article 90. https://doi.org/10.3390/hydrology10040090

Mostafazadeh, R., Silabi, M., Mobaser, J., & Moezzipour, B. (2024). Index-based alteration of long-term river flow regimes influenced by land use change and dam regulation. *Earth, 5*(3), 404–419. https://doi.org/10.3390/earth5030023

Muddasir, M., & Dondaş, U. (2023). A 10-year analysis of housing prices and the influence of economic factors in Turkey. *Financial Internet Quarterly, 19*(3), 100–112. https://doi.org/10.2478/fiqf-2023-0022

Sambou, M., Liersch, S., Koch, H., Vissin, E., Albergel, J., & Sane, M. (2023). Synergies and trade-offs in water resources management in the Bafing watershed under climate change. *Water, 15*(11), Article 2067. https://doi.org/10.3390/w15112067

Samsudin, S., Zuhaily, N., Setu, A., Muda, R., & Amin, M. (2023). Dam break flood mapping and analysis using open source GIS tool and data. *IOP Conference Series: Earth and Environmental Science, 1167*(1), Article 012022. https://doi.org/10.1088/1755-1315/1167/1/012022

Sigalla, O., Valimba, P., Selemani, J., Kashaigili, J., & Tumbo, M. (2023). Analysis of spatial and temporal trend of hydro-climatic parameters in the Kilombero River Catchment, Tanzania. *Scientific Reports, 13*(1), Article 7353. https://doi.org/10.1038/s41598-023-35105-8

Sun, S. (2023). Development of hydropower and the environmental impacts of hydroelectric dam construction in China. *E3S Web of Conferences, 393*, Article 01032. https://doi.org/10.1051/e3sconf/202339301032

Wang, D., Liu, Y., Zheng, L., & Li, D. (2023). Growing impacts of low-flow events on vegetation dynamics in hydrologically connected wetlands downstream Yangtze River Basin after the operation of the Three Gorges Dam. *Journal of Geographical Sciences, 33*(4), 885–904. https://doi.org/10.1007/s11442-023-2111-0

Yakar, Y., Parmaksız, A., Dörtbudak, M., & Doğan, N. (2023). Investigation of fatty acid profiles in some economically important fish species living in Atatürk Dam Lake, Adıyaman, Türkiye. *Aquatic Research, 6*(1), 11–18. https://doi.org/10.3153/ar23002

Yameogo, W., Akpa, Y., Danumah, J., Traoré, F., Tankoano, B., Sanon, Z., ... & Hien, M. (2023). Spatio-temporal evolution of rainfall over the period 1981–2020 and management of surface water resources in the Nakanbe–Wayen watershed in Burkina Faso. *Earth, 4*(3), 606–626. https://doi.org/10.3390/earth4030032

A SYSTEMATIC REVIEW OF CRITICAL FACTORS AFFECTING COMPANY SUCCESS IN INTERNATIONAL CONTRACTING SERVICES

DOI: 10.5937/EMC26056A

İlknur Akiner
Akdeniz University, Faculty of Architecture, Department of Architecture, Antalya, Türkiye
E-mail: ilknurakiner@gmail.com
Büşra Selin Kepenek
Akdeniz University, Institute of Natural and Applied Sciences, Department of Architecture, Antalya, Türkiye

ABSTRACT

The construction industry, where numerous contractors operate, is under constant pressure due to the global competition which is prevailing in the world economy and the industry itself. In such a situation, the sustainable success of contracting firms relies on various internal and external factors. The present research intends to expose the key factors that influence the success and competitiveness of construction companies and at the same time to provide a strategic framework for industry professionals and researchers by thoroughly compiling those factors. The study's primary data source consists of peer-reviewed academic articles and papers that have been indexed in the Web of Science (WOS) database. A qualitative analysis has been conducted after filtering out those studies that matched the criteria. The study asserts that success in the construction sector is not the result of a single factor, but rather a mixture of different aspects influencing it all over. The results may provide directions to companies for their strategic planning by directing the little resources they have towards the vital areas. It was concluded that firms should be accepting new and constructive management practices along with having a proficient and talented labor force to maintain their growth.

Key words: Construction Business, International Contracting, Critical Factors, Company Success, Systematic Analyses.

INTRODUCTION

The competitive advantage of a company rests mainly on its efforts to penetrate foreign markets and differentiate itself through trade activities. Welch and Luostarinen (1988) have posited that globalization is synonymous with a firm's engagement in global activities. On the other hand, Elango and Pattnaik (2007) differentiate that this very process is measured by how much the firms are shifting their activities or sales income towards the international market. Behyan (2016) has pointed out internal factors, strategic factors, and external factors as the three significant aspects responsible for the speedup of the globalization process. The internal factors comprise the attitude of the management team of the firm regarding the internationalization process. A proactive, committed, and entrepreneurial management team is an important factor in the company's international growth. An entrepreneurial orientation highlights a proactive, risk-taking, and innovative approach and is the basis of the company's growth. In contrast, a reactive export orientation indicates an unplanned international strategy and has a smaller effect on the company's international strength. Strategic factors comprise how firms' competitive advantages. A company having a competitive edge over domestic competitors can manage international risks. The outer world factors are the ones that a company gets its involvement with the stakeholders, such as suppliers, consumers, competitors, the government, universities, or financial institutions, through the various networks. Many companies that belong to the contracting services sector are increasingly inclined to opt for internationalization. Contracting projects not only involve technical specifications but also entail cultural, legal, and economic aspects, which in turn make the whole process even more complicated. Crossing international boundaries has several benefits. These include expanding project variety, taking advantage of opportunities in international markets, and reaching a large consumer base. However, new challenges present themselves to contracting organizations due to globalization. To enjoy long-term success, a company must deal with cultural differences, follow local laws, and maintain international standards (Koçak, 2019). The Engineering News-Record (ENR) Top 250 list ranks companies engaged in construction projects, compiled annually (ENR, 2023). A variety of factors, such as construction projects, revenues, market shares, and other significant metrics, form

the basis of the list. By this compilation, one can find a standard reference point for recognizing the top companies in the global construction industry. A comprehensive overview of the relevant literature on the subject will be provided within the scope of the study, and the interrelation between research on international contracting services and company success, as well as the ENR list, was also discussed. The study analyzes the key success factors of international contracting service companies in a broader framework while emphasizing the need not to overlook the interactions of these complementary factors if sustainable success is to be gained. Most of the studies available in the literature, focusing on different geographical areas or on firms, found that factors such as adaptation to local regulations, cultural awareness, financial management, and risk management are critical in completing international construction projects.

THEORETICAL BACKGROUND

The success of firms in the international contracting services industry is a multifaceted and complicated topic (Apfelthaler and Vaiman 2012). Some factors that would contribute to the success of firms in this domain include how well they can adjust to cultural differences, legal requirements, and all aspects of global supply chain dynamics (Trent and Monczka 2003). Excellent communication skills must be developed between companies and foreign buyers, as the companies must understand and accommodate each market's needs and preferences (Kotabe and Murray 2004). This is equally important for companies that can adapt their service offerings and operational models to suit the specific requirements of the various regions (Abecassis-Moedas et al. 2012). Another critical one comprises the company's commitment to quality management. Offering high-quality services always, observing all existing professional and industry standards, and possessing the best quality assurance processes maintains the reputation to establish long-term relations with clients (Doulatabadi et al., 2014; Claver and Tarí, 2003).

Furthermore, financial stability and capital access weigh heavily on the company's pursuit of foreign contracts and executing them successfully (Samaddar and Bhogal, 2024; Holschbach and Hofmann, 2011). Even prudent financial management and investment in resources such as equipment, personnel, etc., are necessary to ensure the successful delivery of projects and the competitive edge (Ismail et al., 2018). In addition, the company must have an appropriate internal organizational structure and management set-up, because without these, it will have difficulty succeeding in the international contracting services market (Zhan et al., 2019). Mission, vision, and values statement; types of key suppliers and partnerships; reporting on the interactions of various parts of the organization; and use of technology to support strategies are critical success factors to increase the competitiveness of Egyptian construction firms (Mohamed and Eltohamy, 2022). According to Trtílek and Hanák (2021), the quality and balance of the contract, the characteristics of the contract, communication between project stakeholders, project documentation, and the choice of supplier or subcontractor are essential factors for the optimal conclusion of construction contracts.

Tetteh et al. (2022) state that the growth in construction globalization, overcoming the lack of domestic or foreign knowledge of international firms, the opportunity to work on large and complex projects, advancement in management skills, and the competitive nature of national development are the five most important drivers for the implementation of international joint ventures worldwide. According to Lühr et al. (2022), stakeholder views on the current and ideal partnership project culture have many similarities and differences. In particular, general contractors expect more cooperation from (sub)contractors, and investors expect more flexibility from general contractors. Fernandes and Joseph (2020) reveal the organizational strategies implemented by Chinese multinational contractors operating in the Southern African region that have reinforced their success. According to Ma et al. (2020), which aims to determine the competitiveness of contractors operating in international construction projects, knowledge, learning, talent, technical support, effective communication, organization, cultural awareness, competitiveness, and leadership are the most important factors affecting success. According to Muthusamy and Adnan (2020), who investigated the causal relationship between national culture and organizational culture, organizations that effectively recognize and manage cultural differences can gain advantages in the countries they operate. Faraji et al. (2020) identify the critical criteria for the success of enormous construction firms operating in the construction sector in Iran. A conceptual model for Chinese construction firms' international project partnerships and project performance is presented by Yang et al. (2019).

AboAbdo et al. (2019) indicate that the Enterprise Resource Planning (ERP) system is essential for construction firms to improve themselves and their success. Adnan et al. (2019) identify the success factors of joint venture projects of contracting firms operating in Malaysia. Aznar et al. (2017) argue that the ability to analyze and have a local partner in Australian infrastructure projects is the most critical factor for competitive advantage. Polat and Bingol (2017) recommend the Data Envelopment Analysis (DEA) approach as a vital and strategic decision for the survival and sustainable success of Turkish construction firms in the sector. Kao et al. (2016) reveal that

improving the ability of contractors operating in Taiwan to adapt to new market conditions plays an influential role in their success in international construction projects. Son et al. (2015) analyze Korean firms operating in the global construction market. Wibowo et al. (2015) identify key factors that improve contractors' project performance and positively influence the procurement strategy. Park et al. (2010) analyze the global construction market and the success factors of construction firms within the framework of Korean construction firms. The success of companies operating in the international arena has been the subject of many studies. The factors influencing companies' entry into and sustained success in the global market and the impact of individual characteristics have been central to these research efforts. These studies have been conducted in various countries, across different periods, and in significant numbers.

RESEARCH METHOD AND DATA

Using the Web of Science (WOS) database, this study systematically reviewed the pertinent literature addressing multinational corporate success in contracting services. To expand the scope of the analysis and obtain relevant information, "company success" OR "firm success" AND "contractor," "company success" OR "firm success" AND "contracting services", "company success" OR "firm success" in "all areas" The keywords "AND "contracting professionals" are used. After a total of 601 results were obtained, non-related subjects (toxicology, nursing, nuclear science, ergonomics, etc.) were removed by preliminary screening. Furthermore, "open access" publications are highlighted to facilitate more thorough analysis of the content. After these actions, the remaining 56 potential studies were carefully examined, and 22 articles suitable for the content were selected. The selected articles were transferred to an Excel table organized according to specific criteria.

DISCUSSION OF FINDINGS

Host countries where China, which provides contracting services in studies for which data can be obtained, operates are Venezuela, Taiwan and South Africa. The conditions that vary between countries are the limitations of studies (1, 4, 8, 12, 21) that generally address company success in international contracting services without associating it with any country. A critical success factor for one country may not be valid for another. In this context, most of the studies (77.7%) were conducted by considering a specific country, and "cultural awareness" was included as a factor. When the government examines the studies on international contracting services, it is seen that most studies are concentrated in China, Turkey, Korea, and Malaysia, which are at the top of the ENR List. Other countries researched for International Contracting Services are China (4), Turkey (2), Korea (2), Malaysia (2), Egypt (1), Czechia (1), Germany (1), Spain (1), Tunisia (1), and Australia (1). Considering the years of study, it has been determined that the subject has gained importance in the last ten years. There is no parabolic increase or decrease between years. However, looking at the graph, it can be said that it gained popularity between 2019 and 2020 (Figure 1).

As a result of the searches made with keywords, it was seen that the studies on the role of company success can be divided into specific categories in terms of subject. Table 1 contains essential information such as author names, year of publication, focused topics, research purpose, and method. Studies (22) show that, considering the role of the company, competition factors (6), risk and performance management factors (3), establishing partnerships, determining subcontractors, etc. They were evaluated under organizational factors (9), factors affecting financing, and bid success (4). Most (81.8%) studies examining firm success are based on surveys and semi-structured interviews with contractors.

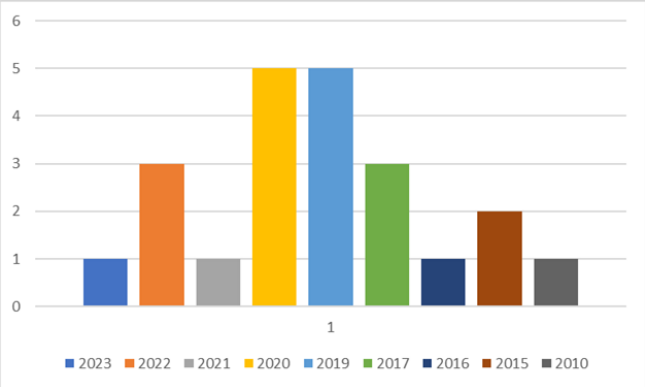


Figure 1: Graph of international contracting services activities by year

In addition, success factors were identified through case studies (9.1%) and bibliometric analysis of the literature (9.1%). In some studies, factor rankings were determined by topics, fuzzy Delphi, relative importance index,

logistic regression, and chi-square. Some studies included the factors textually or identified them through case studies and expressed them without a ranking.

Table 1: Studies on company success based on Web of Science

No	Source	Topic	Research Purpose	Country Researched	Method
1	Gao et al. (2023)	Subcontractor Selection	To establish the big construction companies' selection criteria for qualified subcontractors	General	Topsis, Delphi
2	Mohamed and Eltohamy (2022)	Competitiveness	Finding the Critical Success Factors (CSFs) that Egyptian construction businesses need to be competitive	Egypt	Fuzzy Delphi (FDM), survey, and relative importance index (RII)
3	Trtílek and Hanák (2021)	Performance Management Subcontractor Performance	Analyze and assess the performance management strategies of Czech contractors	Czechia	Survey
4	Tetteh et al. (2022)	Partnership Formation	Searching for the key motivators for the creation of international joint ventures (ICJVs) by conducting a worldwide survey	General	Survey, factor analysis
5	Lühr et al. (2022)	Partnership Formation	To investigate the present condition of project cultures within the German turnkey construction sector and identify the optimal project cultures concerning cooperation, as seen from the viewpoints of key stakeholders.	Germany	Survey
6	Fernandes and Joseph (2020)	Competitiveness	To identify the organizational tactics used by Chinese multinational contractors in Southern Africa that have contributed to their sustained success.	Chinese contractors in South Africa	Survey
7	Ma et al. (2020)	Competitiveness	Identify ways in which the ability to implement ICS (international construction standard) can improve contractors' competitiveness.	China	Survey
8	Lozano-Torró et al. 2020).	Competitiveness	Determining which competitive advantages and obstacles have the most significant impact on contractors' performance abroad.	General	Bibliometric, chi-squared
9	Muthusamy and Adnan (2020)	Project Success Cultural Differences	To research how national culture and organizational culture are causally related.	Malaysia	Survey
10	Faraji et al. (2020)	Determining Organization	To determine the primary selection criteria for significant service/goods providers serving Iranian clients.	Iran	Expert opinion, Delphi-AHP
11	Yang et al. (2019)	Partnership Formation	Building a conceptual model that illustrates the causal links between partnership, risk management, interface management, and project performance from the standpoint of an evolutionary game.	China, Venezuela	Survey, case study
12	Gundes et al. (2019)	Financing	Categorizing the primary concerns and supporting themes in the study of construction finance.	General	Bibliometric analysis
13	Lozano-Torró et al. (2019)	Risk Management	It looks at how crucial risk management is to Spanish engineering consultancy companies' performance in the global building industry.	Spain	Semi-structured interviews
14	AboAbdo et al. (2019)	Information Technology as a Competitive Factor	The objective is to identify the most significant number of CSFs that impact the implementation of an ERP system.	Tunisia	Structured interview
15	Adnan et al. (2019)	Partnership Formation	Determining the elements contributing to joint venture projects between Malaysian IBS contractors and their success.	Malaysia	Survey
16	Aznar et al. (2017)	Bid Success	Looks for the elements affect that bids for Australian infrastructure projects success.	Australia	Logistic regression
17	Polat and Bingol (2017)	Bid Success	It suggests using Data Envelopment Analysis (DEA) to determine whether to submit a bid.	Turkey	Case study, data envelopment analysis
18	Akgul et al. (2017)	Partnership Formation	To examine how contractors behave in partnerships on international projects.	Turkey	Social network analysis (SNA)
19	Kao et al. (2016)	Partnership Formation	Identifying the impact factors capabilities and partnership relationship (PR) with companies in Taiwan.	China, Taiwan	Survey
20	Son et al. (2015)	Partnership Formation	To analyze the collaboration process between Korean construction companies operating overseas.	Korea	Semi-structured interviews
21	Wibowo et al. (2015)	Bid Success	To determine each variable's most important influencing factor by analyzing the effect of bidding strategy on project and company performance.	General	Survey, Structural Equation Modeling Partial Least Squares (SEM PLS)
22	Park et al. (2010)	Competitiveness	To understand the global construction markets and identify the elements of success that lead to a firm's growth.	Korea	Case study

If the identified key factors were named differently in different studies, a common expression was determined and categorized according to the topics (Table 2). The content from studies investigating competition, partnering, risk management, finance, and bid success is interconnected and must be brought under one umbrella. For example, selecting key suppliers and partnerships, an essential component of competitive success, also affects risk management and financial success. In this context, these contents were evaluated within the framework of the factors affecting globalization momentum proposed by Behyan (2016) using the categorical data analysis method. Accordingly, the themes were identified as internal, external, and strategic factors and grouped (Figure 2).

The internal factors identified in this context are experience, reputation, human resources, firm infrastructure, capital, and adaptability. The factors in this group are about the firm's capabilities and competence. The age of the firm, experience from previous jobs, previous experience in the same type of contracts, established business contacts, ability to adapt to rules and regulations overseas, and human resources provided by the awareness that a different country has different practices or different cultures have been identified as critical factors. Finance, the most frequently repeated factor in the studies, is considered an intrinsic factor under the title of capital only, without including support or incentives such as funding credit facilities or government borrowing. Securing large loans at low interest rates from financial institutions to finance international projects plays a crucial role in international construction (Gunhan and Arditi, 2005). However, this item was deemed appropriate under market conditions as an extrinsic factor.

Table 2: Key factors identified by topic

Competitive Success	**Partnership Formation Success**	**Risk and Performance Management Success**	**Finance and Bid Success**
Determine mission and vision (2)	Experience in similar projects (1,15)	Contract specifications (3)	Cash management (12, 17, 21)
Key suppliers and partnerships (2,6,7,8,22)	Trust and past relationships (1,15,18,20)	Subcontractor/supplier/partnership selection (3, 13)	Local partnership (16)
Relationship management (2,7, 8)	Technical qualification (1,4, 10, 11, 15, 19)	Human Resources (3,13)	Relevant expertise (16)
Use of technology (2, 7, 8, 14)	Managerial skill (1, 4, 10, 11, 15, 18)	Communication among stakeholders (3, 13)	Past relationships (16)
Financial performance (6, 7, 8, 22)	Finance (1, 4, 10, 19, 20)	Finance (3, 13)	Experience (16)
Human Resources (6, 7, 8)	Use of technology (4, 18, 19, 20)	Cultural awareness (9, 13)	Contract complexity (17)
Access to local resources (6)	Use of local expertise, resources, and knowledge (4, 18)	Ability to adapt to sector demand (13)	Borrowing/loan (12)
Technical skills (6, 7, 8)	Flexibility (5)	Organizational capacity (13)	Time Management (12, 16)
Good relationship with the customer, trust offered convenience (6, 8)	Reputation (10)	The Experience (13)	Cost reduction (12)
Variety in contracts (6, 22)	Health and safety (10)	A subsidiary in the host country (13)	
Establishing private and specialized subsidiaries (6)	Cultural awareness (11)		
Experience (7, 8)	Coordination and communication (15)		
Cultural awareness and adaptability (7,8)			
Project management (8)			
Avoiding corruption and bribery (8)			
Supporting the domestic market (7, 8, 22)			

Other extrinsic factors refer to legal and environmental factors, and economic factors in the market to be entered. For example, a country with high local currency volatility against the exchange rate has a higher risk factor, and the steps to be taken are critical (Lozano-Torró et al. 2020). On the other hand, strategic factors include the steps that will lead the company to success and provide an advantage over its competitors. Accordingly, risk management must be made by considering the internal and external factors that are determined accordingly, which makes the company advantageous. For example, choosing

partnerships with local firms is a criterion that will affect the risk factor. Whether or not it reduces the risk should be evaluated together with other criteria for the success of establishing a partnership. Continuous learning, innovative company approaches, and quality/specialized service delivery affect customer satisfaction. At the same time, price and quality are among the most critical competitive parameters regulating construction companies' success and long-term prospects (Marinič and Záthurecký, 2014).

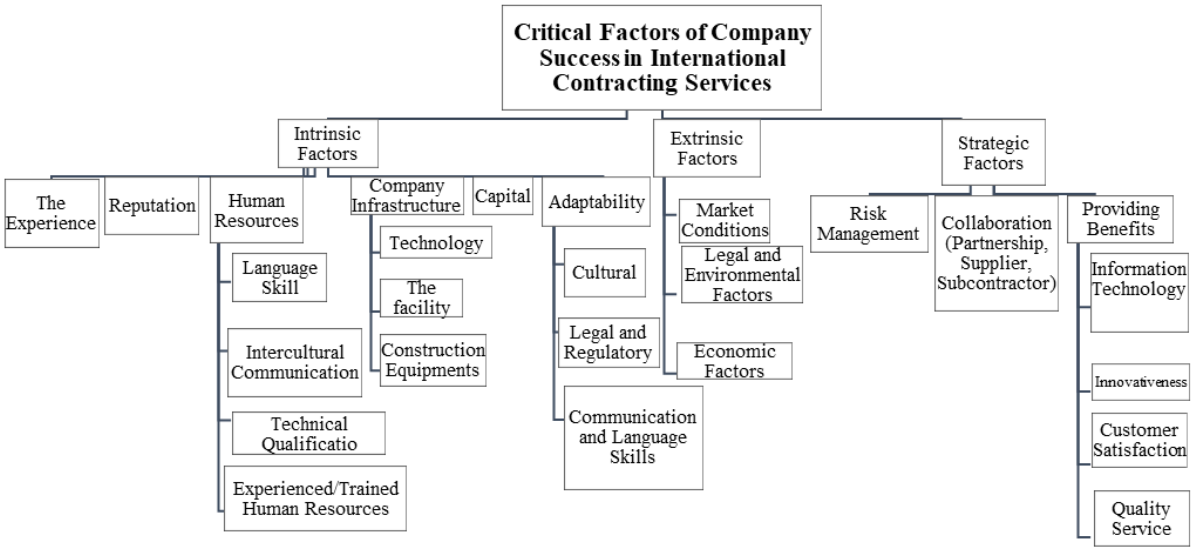


Figure 2. Critical factors of company success in international contracting services

The critical factors affecting success in international contracting services in current field practices also stand out in the analyses made on the ENR Top 250 International Contractors List. Contracting companies, which have successfully operated in China, Turkey, and the USA, where these factors matter, have been topping this list for the last few years (ENR, 2023). Case studies for successful international contracting projects act as instruments to illustrate how the critical success factors laid out in the literature are put into practice. For instance, a large-scale infrastructure project by a Turkish contracting firm in the Middle East demonstrates the effectiveness of the local partnership strategy in achieving success. In this project, the firm adapted more quickly to local regulations and cultural differences by partnering with a local company and ensuring the project was completed on time and within budget. Such examples show that collaborating with local partners contributes to completing projects and creating long-term business opportunities.

Regarding this subject, contracting companies, especially those from China, can succeed in all international works, given their ability to adapt to the target local legal framework and culture. Likewise, it is viewed that Turkish contracting companies find success in strengthening their connections with local partners and rendering business more flexible. The importance of risk-handling and financial strategies on construction practices is also pinpointed. For example, the study by Lozano-Torró et al. (2019) shows how risk management and financial management bear heavily on the success of Spanish construction companies in international markets. Similarly, financial management is critical for the success of Turkish contracting firms (Gundes et al., 2019). On the other hand, the synthesis of current field studies elaborates the "collaboration with local partners" strategy, which is a significant success factor in international projects. For instance, Akgul et al.'s (2017) study shows that strong ties developed by Turkish contracting firms with their local partners in international projects are important for ensuring the success in the completion of projects. To see how effective these factors are in great field applications, it becomes important to compare project success factors in different countries and to determine which strategies are employed to, in fact, overcome those differences. In this context, joint support from sectoral reports and current field applications will give a solid backdrop for success in international contracting services. A careful study of the reciprocal interactions among the tables of critical success factors reveals that these factors cannot be assessed independently. For instance, risk management and financial strategies are interwoven with the internal and external forces needed to boost the firm's competitiveness in international markets. While risk management may influence the firm's financial decisions, it could also influence decisions related to cooperation with local partners.

Similarly, awareness of cultural differences and adaptation to local laws impact human resource or project management activities while maintaining a competitive edge and remaining in local markets for the long haul. These factors further influence decision-making at the strategic level of the firm's management and marketing strategies. As such interactions occur, it is obvious that there cannot be a single success factor for international contracting services, but rather a focus upon a balance of factors. For instance, the firm may be financially strong but may lack cultural know-how or locally partnering knowledge, thus increasing the firm's chances of failure. Similarly, if risk management and financial know-how are not considered, even with strong human resources and technical expertise, it may not lead to sustainable success. Hence, approaches that integrate different factors, such as the hybrid subcontractor selection model proposed by Gao et al. (2023), may enhance the success of firms in international projects. These integrated models help firms understand and implement how success factors operate together rather than concentrating their efforts solely on one factor. Achieving success in the domain of international contracting services necessitates a holistic approach, encompassing the multifaceted interactions between various internal factors, including human resources and financial resources, external factors such as cultural awareness and local regulations, and strategic factors comprising risk management and diverse partnerships. Consequently, companies must consider these factors not as discrete elements, but as components that complement and support each other.

CONCLUSIONS

This study was prepared by compiling all articles, papers, and conference studies on corporate success in international contracting services, obtained solely from the Web of Science database with no time constraints. Factors influencing international success differ depending on country conditions, hence, research findings from other countries are required. Critical internal, external, and strategic factors have been identified through an extensive review of studies conducted across various countries and periods. Common themes and factors have been categorized, thus providing a more precise framework for what drives success in international markets. Establish strong collaborations with local partners and transform these partnerships into long-term strategic partnerships; Adopting flexible and adaptive approaches in project management processes, quickly adapting to cultural differences and local regulations; Minimizing financial and operational risks by proactively implementing risk management strategies; and Ensuring efficient use of financial resources and effectively managing cash flow are the strategies obtained from case studies. These practical strategies suggested by case studies on successful international contracting projects increase the firm's chances of success in international projects and contribute to their competitive advantage, in terms of showing how the critical success factors presented in the literature are applied in practice. Within the scope of future research recommendations, supporting the literature review results with sectoral reports and current field studies to determine how effective the critical success factors are in field applications will provide a more comprehensive guide for success in international contracting services.

REFERENCES

Abecassis-Moedas, C., Ben Mahmoud-Jouini, S., Dell'Era, C., Manceau, D., & Verganti, R. (2012). Key resources and internationalization modes of creative knowledge-intensive business services: The case of design consultancies. *Creativity and Innovation Management, 21*(3), 315–331. https://doi.org/10.1111/j.1467-8691.2012.00646.x

AboAbdo, S., Aldhoiena, A., & Al-Amrib, H. (2019). Implementing enterprise resource planning (ERP) system in a large construction company in KSA. In A. Rocha, H. Adeli, L. P. Reis, & S. Costanzo (Eds.), *Proceedings of the International Conference on Enterprise Information Systems/Projman2019–International Conference on Project Management/HCIST2019* (Vol. 164, pp. 463–470). Elsevier. https://doi.org/10.1016/j.procs.2019.12.207

Adnan, H., Baharuddin, H. E. A., Hassan, A. A., Mahat, N. A. A., & Kaharuddin, S. K. (2019). Success factors among Industrialised Building System (IBS) contractors in Malaysia. *IOP Conference Series: Earth and Environmental Science, 233*(1), Article 022033. https://doi.org/10.1088/1755-1315/233/2/022033

Akgul, B. K., Ozorhon, B., Dikmen, I., & Birgonul, M. T. (2017). Social network analysis of construction companies operating in international markets: Case of Turkish contractors. *Journal of Civil Engineering and Management, 23*(3), 327–337. https://doi.org/10.3846/13923730.2015.1073617

Apfelthaler, G., & Vaiman, V. (2012). Challenges and opportunities of internationalization in professional service industries. *The Service Industries Journal, 32*(10), 1589–1592. https://doi.org/10.1080/02642069.2012.665898

Aznar, B., Pellicer, E., Davis, S., & Ballesteros-Pérez, P. (2017). Factors affecting contractor's bidding success for international infrastructure projects in Australia. *Journal of Civil Engineering and Management, 23*(7), 880–889. https://doi.org/10.3846/13923730.2017.1341955

Behyan, M. (2016, April). Investigating the influence of external networks on internationalization success of firms. In *2016 10th International Conference on e-Commerce in Developing Countries with Focus on e-Tourism (ECDC)* (pp. 1–18). IEEE.

Claver, E., & Tarí, J. J. (2003). Levels of quality management in certified firms. *Total Quality Management & Business Excellence, 14*(9), 981–998. https://doi.org/10.1080/1478336032000151439

Doulatabadi, M., Khalifah, Z., & Yusof, S. M. (2014). An analysis of key factors for quality practices in the UAE's industry. In *Applied Mechanics and Materials* (Vol. 606, pp. 253–257). Trans Tech Publications. https://doi.org/10.4028/www.scientific.net/AMM.606.253

Elango, B., & Pattnaik, C. (2007). Building capabilities for international operations through networks: A study of Indian firms. *Journal of International Business Studies, 38*, 541–555. https://doi.org/10.1057/palgrave.jibs.8400280

ENR. (2023). *The top 250 global contractors 1–100*. ENR. Retrieved December 24, 2023, from https://www.enr.com/toplists/2023-Top-250-Global-Contractors-Preview

Faraji, A., Rashidi, M., & Sorooshnia, E. (2020). An integrated organizational system for project source selection in the major Iranian construction companies. *Buildings, 10*(12), 251. https://doi.org/10.3390/buildings10120251

Fernandes, D. S., & Joseph, G. (2020). Organisational strategies for competitive advantage in the construction industry: Chinese dominance in Southern Africa. *Journal of Construction in Developing Countries, 25*(2), 1–38.

Gao, C., Elzarka, H., Yan, H., Chakraborty, D., & Zhou, C. (2023). A hybrid TOPSIS–structure entropy weight group subcontractor selection model for large construction companies. *Buildings, 13*(6), 1535. https://doi.org/10.3390/buildings13061535

Gundes, S., Atakul, N., & Buyukyoran, F. (2019). Financial issues in construction companies: Bibliometric analysis and trends. *Canadian Journal of Civil Engineering, 46*(4), 329–337. https://doi.org/10.1139/cjce-2018-0249

Gunhan, S., & Arditi, D. (2005). Factors affecting international construction. *Journal of Construction Engineering and Management, 131*(3), 273–282. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:3(273)

Holschbach, E., & Hofmann, E. (2011). Exploring quality management for business services from a buyer's perspective using multiple case study evidence. *International Journal of Operations & Production Management, 31*(6), 648–685. https://doi.org/10.1108/01443571111131980

Ismail, K., Talib, Y. A., Salleh, N., & Japri, A. (2018). Critical success factors in operation phase of private finance initiative (PFI) projects. *International Journal of Academic Research in Business and Social Sciences, 8*(1), 878–888.

Kao, C. H., Huang, C. H., Hsu, M. S. C., & Tsai, I. H. (2016). Success factors for Taiwanese contractors collaborating with local Chinese contractors in construction projects. *Journal of Business Economics and Management, 17*(6), 1007–1021. https://doi.org/10.3846/16111699.2015.1137486

Koçak, M. (2019). İşletmelerin uluslararasılaşmasına yönelik kavramsal bir çerçeve. *Sinop Üniversitesi Sosyal Bilimler Dergisi, 3*(1), 169–190. https://doi.org/10.30561/sinopusd.558168

Kotabe, M., & Murray, J. Y. (2004). Global sourcing strategy and sustainable competitive advantage. *Industrial Marketing Management, 33*(1), 7–14. https://doi.org/10.1016/j.indmarman.2003.08.004

Lozano-Torró, A., García-Segura, T., Montalbán-Domingo, L., & Pellicer, E. (2020). Competitive advantages and barriers in international construction: An origin-host market approach. *Journal of Civil Engineering and Management, 26*(5), 475–489. https://doi.org/10.3846/jcem.2020.12180

Lozano-Torró, A., García-Segura, T., Montalbán-Domingo, L., & Pellicer, E. (2019). Risk management as a success factor in the international activity of Spanish engineering. *Administrative Sciences, 9*(1), Article 15. https://doi.org/10.3390/admsci9010015

Lühr, G. J., Bosch-Rekveldt, M. G. C., & Radujkovic, M. (2022). Key stakeholders' perspectives on the ideal partnering culture in construction projects. *Frontiers of Engineering Management, 9*, 312–325. https://doi.org/10.1007/s42524-020-0135-z

Ma, D., Li, X., & Cheng, C. (2020). The impact of the international construction standard application capability on contractors' competitiveness: Chinese contractors' experience. *Journal of Civil Engineering and Management, 26*(8), 757–774. https://doi.org/10.3846/jcem.2020.13749

Marinič, P., & Záthurecký, V. (2014). Evaluation of the construction industry's economic situation and expected development according to managers of SMBs. *Central European Journal of Management, 1*(1), 49–64. https://doi.org/10.5817/CEJM2014-1-5

Mohamed, H. A. E., & Eltohamy, A. I. (2022). Critical success factors for competitiveness of Egyptian construction companies. *Sustainability, 14*(17), Article 10460. https://doi.org/10.3390/su141710460

Muthusamy, K., & Adnan, R. C. (2020, May). The relationship between national culture and organizational culture in determining the project success factors in the perception of project professionals in Malaysia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 498, No. 1, Article 012093). IOP Publishing. https://doi.org/10.1088/1755-1315/498/1/012093

Park, C. S., Jang, H. S., Choi, S. I., & Cho, H. C. (2010). Comparative analysis of strategic planning in construction firms. *Journal of Asian Architecture and Building Engineering, 9*(1), 25–30. https://doi.org/10.3130/jaabe.9.25

Polat, G., & Bingol, B. (2017). Data envelopment analysis (DEA) approach for making the bid/no bid decision: A case study in a Turkish construction contracting company. *Scientia Iranica, 24*(2), 497–511. https://doi.org/10.24200/sci.2017.2413

Samaddar, G., & Bhogal, S. K. (2024). Strategic partnership between medical technology companies and health care service providers toward global competitiveness. In R. Bhattacharyya & D. Mazumdar (Eds.), *Contemporary issues in international trade: Challenges and opportunities* (pp. 291–307). Emerald Publishing Limited. https://doi.org/10.1108/978-1-83797-320-020241019

Son, J., Han, S. H., & Rojas, E. M. (2015). Embeddedness and collaborative venture networks among Korean construction firms for overseas construction projects. *Journal of Civil Engineering and Management, 21*(4), 478–491. https://doi.org/10.3846/13923730.2014.890658

Tetteh, M. O., Chan, A. P. C., Darko, A., Yevu, S. K., Boateng, E. B., & Nwaogu, J. M. (2022). Key drivers for implementing international construction joint ventures (ICJVs): Global insights for sustainable growth. *Engineering, Construction and Architectural Management, 29*(9), 3363–3393. https://doi.org/10.1108/ECAM-07-2020-0512

Trent, R. J., & Monczka, R. M. (2003). Understanding integrated global sourcing. *International Journal of Physical Distribution & Logistics Management, 33*(7), 607–629. https://doi.org/10.1108/09600030310499286

Trtílek, P., & Hanák, T. (2021). Contracts' performance measurement in Czech construction companies. *Civil and Environmental Engineering Reports, 31*(4), 214–236.

Welch, L. S., & Luostarinen, R. (1988). Internationalization: Evolution of a concept. *Journal of General Management, 14*(2), 34–55. https://doi.org/10.1177/030630708801400203

Wibowo, M. A., & Astana, I. N. Y. (2015). An analysis of bidding strategy, project performance, and company performance relationship in construction. *Procedia Engineering, 125*, 95–102. https://doi.org/10.1016/j.proeng.2015.11.015

Yang, Y., Tang, W., Shen, W., & Wang, T. (2019). Enhancing risk management by partnering in international EPC projects: Perspective from evolutionary game in Chinese construction companies. *Sustainability, 11*(19), Article 5332. https://doi.org/10.3390/su11195332

Zhan, W., Yang, C., & Meng, Q. (2019, March). Characteristics of regional international engineering contracting market of the Belt and Road. In *IOP Conference Series: Earth and Environmental Science* (Vol. 242, No. 6, Article 062045). IOP Publishing. https://doi.org/10.1088/1755-1315/242/6/062045

RISK ANALYSIS OF INFRARED THERMOGRAPHIC EQUIPMENT

DOI: 10.5937/EMC26065J

Dušan Jovanić
Technical College of Applied Sciences, Zrenjanin, Republic of Serbia
E-mail: dusan.jovanic@vts-zr.edu.rs
Valentina Mladenović
Technical College of Applied Sciences, Zrenjanin, Republic of Serbia

ABSTRACT

This paper presents a risk analysis of the use of a thermal imaging camera in a production environment. Infrared thermography is a method used for condition monitoring of machines, quality control, and non-destructive testing. Thermal imaging enables non-contact temperature measurement and visualization of thermal phenomena in real time, making it highly suitable for industrial diagnostics. The risk analysis was conducted by determination of the limits of the machine, hazards identification and risks estimation, in accordance with the ISO 14121-1 standard. Mechanical, electrical, thermal, laser, ergonomic, and other hazards that may arise during operation in the cutting zone and while handling the thermal imaging camera were identified. Hazard identification using standardized forms was applied as the risk assessment method.

Key words: Risk analysis, Hazard identification, Thermografic.

INTODUCTION

Modern industrial systems require reliable monitoring and diagnostic methods in order to ensure the safe, efficient, and continuous operation of machines and equipment. One of the key parameters for monitoring machine condition is temperature, since its variations often directly indicate operational irregularities, component wear, or the occurrence of failures. Infrared thermography, also known as thermal imaging, represents a modern, non-invasive method for measuring and visualizing temperature distributions on object surfaces, thereby enabling the early detection of potential problems and the improvement of maintenance systems.

In addition to the technical advantages that thermography offers in diagnostics and quality control, it is also necessary to consider the safety aspects of its application. The operation of a thermal imaging camera in an industrial environment, particularly near machine tools and cutting zones, exposes operators to various types of hazards. Therefore, conducting risk analysis and assessment in accordance with relevant international standards is of great importance.

The aim of this paper is to present the application of infrared thermography in monitoring machine conditions during the manufacturing process, as well as to perform a systematic risk analysis related to the use of a thermal imaging camera in accordance with ISO 12100 and ISO 14121-1 standards.

Standard ISO 12100 is the overarching international standard for machinery safety, defining the principles of design, risk assessment, and risk reduction throughout the entire life cycle of a machine. It provides a systematic framework for hazard identification, risk analysis and evaluation, as well as methods for reducing risks to an acceptable level.

Standard ISO 14121 is the predecessor of ISO 12100 and is specifically dedicated to risk assessment. Standard EN 292 was the first standard to clearly define that safety must be integrated into the design process rather than addressed afterward through protective measures, forming the foundation of the modern principle of inherent safety.

In the available scientific and professional literature, infrared thermography is widely used as a method for machine condition monitoring, predictive maintenance, quality control, and non-destructive testing. Numerous authors emphasize its advantages in terms of non-contact measurements, rapid response, and the possibility of early detection of irregularities in the operation of electrical and mechanical systems. However, an analysis of the available studies shows that most research focuses on the technical aspects of thermography applications, while the assessment of safety risks associated with the use of thermal imaging cameras in industrial environments is considerably less represented.

Certain studies examine risk assessment in combination with thermography, mainly in the field of occupational health and safety, where thermographic data are used to identify ergonomic and physiological workloads of workers [Soares et al., 2020].

Furthermore, the literature includes studies pointing to limitations and potential sources of error in thermographic measurements, such as the influence of emissivity, reflections, and thermogram interpretation, which may indirectly be considered risk factors in the application of this method [Livada et al., 2023].

Nevertheless, systematic analysis and risk assessment of thermal imaging cameras as technical equipment, conducted in accordance with ISO 14121-1 and ISO 12100 standards, are rarely the subject of dedicated scientific studies, thereby confirming the justification and significance of the research presented in this paper.

THERMOGRAPHY

Infrared thermography (IRT), also known as thermal imaging, can be used for the identification and documentation of irregularities for the purposes of machine condition monitoring, quality control, and non-destructive testing, as well as for monitoring temperatures during various manufacturing processes, such as temperature in the cutting zone, extrusion temperature in forming processes, casting and cooling temperatures of castings, and thermal phenomena occurring during welding.

In machine condition monitoring, irregularities are caused by mechanisms such as the operating process, lubrication issues, misalignment, component wear, or mechanical loading. Thermography is based on the detection and measurement of the distribution of thermal radiation emitted from the observed surface and its conversion into a representation of radiation intensity differences, i.e., a surface temperature map known as a thermogram. Therefore, the proper application of infrared thermography requires the operator–thermographer to possess fundamental knowledge of heat and temperature concepts, as well as heat transfer mechanisms.

Thermal energy is generated during the operation of all machines and may arise due to friction, energy losses, fluid characteristics, the technological process itself, or a combination of these factors. For this reason, temperature represents one of the key parameters for machine operation monitoring, condition assessment, and the identification of potential failures.

IRT has proven to be a highly suitable method for temperature monitoring because it enables comprehensive thermal imaging of machines or their components through non-contact (non-invasive) measurements, with minimal setup requirements and very rapid acquisition of results. A significant advantage of infrared thermometers compared to contact temperature measurement methods lies in their extremely fast response time, since the radiated energy is transferred from the object to the sensor at the speed of light, enabling an almost instantaneous response. An additional advantage of these instruments is their high sensitivity, as they are capable of detecting and displaying thermal images composed of very small temperature differences. Nevertheless, despite its numerous advantages, infrared thermography has certain limitations, since radiometric measurements may be affected by significant errors when applied to surfaces with low emissivity.

RISK ANALYSIS

Risk analysis of the thermal imaging camera, as shown in the decomposition diagram in Figure 1, consists of the following phases: determination of machine limits, hazard identification, and risk estimation. After the completion of the risk analysis and the implementation of risk evaluation, the overall risk assessment process was carried out.

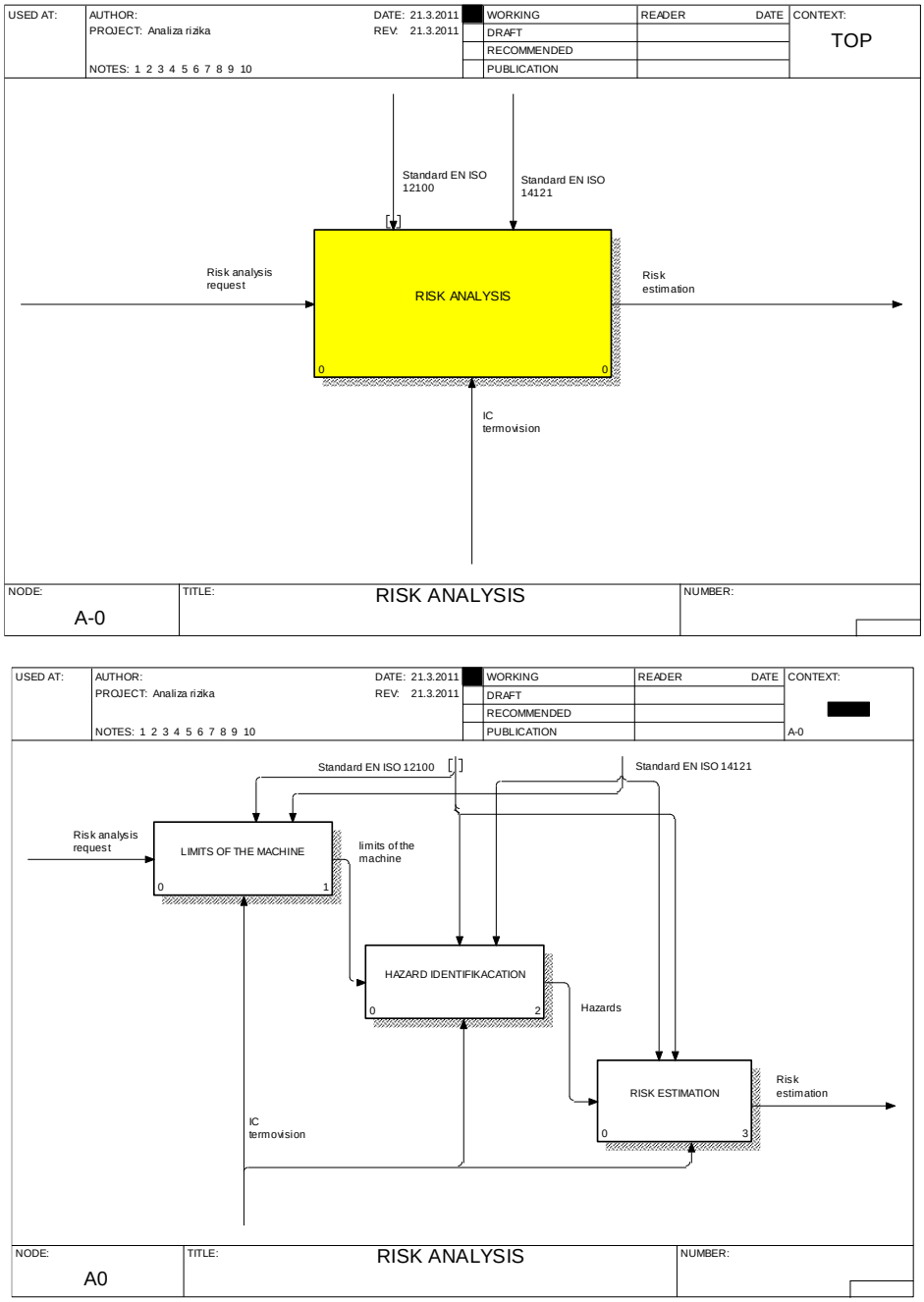


Figure 1: Decomposition diagram of activity risk analysis

The activity tree of the risk analysis is shown in Figure 2.

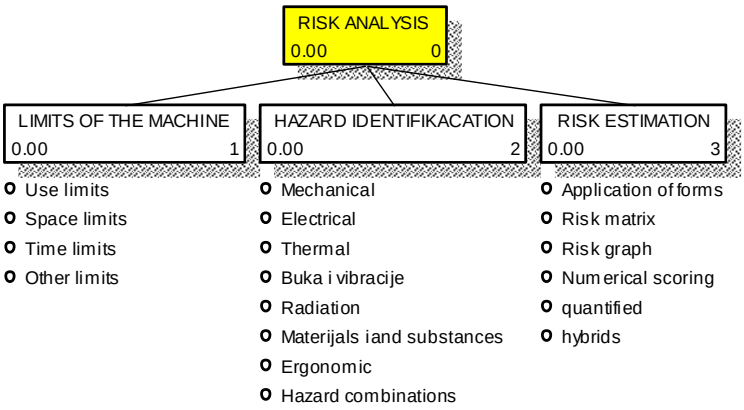


Figure 2: The activity tree of the risk analysis

Determining the machine limits

Risk analysis begins with determining the machine limits, taking into account all phases of the machine life cycle, and consists of: use limits, space limits, time limits, and other limits. Use limits define the different operating modes of the thermal imaging camera and the various intervention procedures for users. The thermal imaging camera has no restrictions regarding use based on gender, age, dominant hand usage, or physical abilities. The required training level for operator–thermographers is defined by EN ISO 9712 and ISO 18436-7. Space limits related to the use of the thermal imaging camera are defined by restricted access to the equipment whose temperature is being measured during operation, as well as by the spatial requirements for the operator.

Time limits define the service life of the thermal imaging camera and some of its components, as well as the maintenance intervals recommended by the manufacturer. Other limits define the measurement range, as well as the properties of the measured material, including emissivity, reflection, transmissivity, calibration, camera location, distance, range, focus, as well as machine condition and ambient conditions.

Hazard identification

Hazard, hazardous situations, and events are identified for all phases of the machine life cycle: design, transport, assembly and installation, commissioning, operation, and decommissioning, after which measures must be taken to eliminate or reduce the associated risks and shown in Table 1. For the purpose of hazard identification for the thermal imaging camera, it is necessary to define the operations it performs, the tasks of the operator, and the environment in which it operates. The thermal imaging camera is primarily intended for the diagnostics and temperature measurement of electrical and mechanical machine components, as well as for quality control through non-destructive testing (NDT) and the creation of thermograms.

The tasks performed by operator–thermographers include setting the measurement range, material emissivity, reflectivity, transmissivity, and focus, laser marking, monitoring and diagnostics (thermogram generation and analysis), as well as charging and maintenance.

Regarding the environment in which the thermal imaging camera operates, given that its primary purpose is the monitoring and diagnostics of electrical and mechanical equipment and NDT, the associated hazards are mainly electrical and thermal, as well as other hazards and harmful effects resulting from the operation of the machines and components being inspected.

During temperature monitoring in the cutting zone using a thermal imaging camera, the following hazards were identified, in accordance with the Regulation on the manner and procedure of risk assessment at the workplace and in the working environment: mechanical hazards arising from the use

of work equipment, hazards related to workplace characteristics, hazards arising from the use of electrical energy, harmful effects arising or appearing in the work process, and harmful effects resulting from psychological and psychophysiological strain associated with the workplace and job tasks performed by the employee.

Table 1: Hazard identification using application of forms

Machine		**IC Thermal Camera FRIK**	**Method / Standard**	Application of forms/ ISO 14121	
Phase		Work Process – Production	**Analyst**	Dr D. Jovanić	
Hazard Zone		Cutting Zone	**Date**	20.12.2025.	
no	**Task**	**Hazard**	**Origin**	**Consequences**	**Hazardous Situation / Event**
1	Monitoring – temperature measurement	**Mechanical hazards** related to the machine, machine parts or surfaces, tools, workpieces, loads, or projected solid or liquid materials	Approach of a moving element (tool) to a fixed part (workpiece); Rotating elements (tool); Moving elements (tool, machine parts); Sharp edges (tool, workpiece, chips)	- crushing - severing - cutting - entanglement - trapping - impact - puncture	Working near moving parts; Exposure to ejected parts; Unexpected machine movement
2		**Mechanical hazards** caused by the machine, machine parts (including material holding mechanisms), workpiece, or loads			
3		**Electrical hazards** – direct contact	Machine tool electrical installations; Live parts due to malfunction; Short circuit; Camera power supply	Electric shock; Shock	Contact with power cable; Poor insulation of the power cable; Restoration of power supply
4		**Electrical hazards** – indirect contact			
5		**Thermal hazards** – burns from contact with objects or materials at extreme temperatures, flame or explosion, and radiation from heat sources	High-temperature materials (tool, workpiece, and chips); Radiation from heat sources (machine tools)	Burns; Injuries caused by heat radiation; Fire	Contact with the workpiece, chips, or drill; Working near high-temperature objects
6		**Radiation**	Laser radiation	Eye and skin damage	laser pointer directed toward the eyes
7		**Noise**	Production process (cutting)	Discomfort; Tinnitus	Tool wear; Lack of lubricant (MWF)
8		**Material / Substance**	Dust; Liquid (coolant/lubricant); Smoke	Breathing difficulties	Splashing of MWF, smoke, and dust from the cutting zone
9		**Ergonomics**	Strain; Posture; Visibility	Fatigue; Stress; Any other	Holding the camera in an awkward position; Physical strain

Risk estimation

Risk estimation together with the determination of machine limits and hazard identification the risk analysis, which, when combined with risk evaluation (i.e. determining whether the risk has been adequately reduced), represents the overall risk assessment process. Risk assessment methods, according to ISO/TR 14121-2:2012– Part 2: Practical guidance and examples, include: application of forms, risk matrices, risk graphs, numerical scoring, quantified risk evaluation, and hybrid methods.

Hazard identification using application of forms, as a risk estimation method, is an approach for identifying hazards that primarily uses checklists defined in ISO 14121-1:2007. These checklists cannot be considered exhaustive; therefore, other risk assessment methods should be used as a supplement. This method can be applied for risk assessment at any stage of the machine life cycle.Risk

estimation using application of forms is presented in a table and performed in accordance with ISO 14121-1.

CONCLUSION

Temperature measurement using an infrared thermal imaging camera is a safe and non-contact method, but it requires careful planning, training, and compliance with prescribed safety measures, particularly due to the presence of mechanical and thermal hazards associated with the machines being monitored and diagnosed.

Infrared thermography represents a powerful tool for machine condition monitoring and optimization of industrial processes, thanks to its speed, high sensitivity, and ability to perform non-contact temperature measurements. Its application enables the timely identification of irregularities in machine operation, thereby reducing downtime, increasing system reliability, and improving work safety.

However, the use of thermal imaging cameras in industrial environments involves certain risks, especially in proximity to machines and high-temperature zones. The conducted risk analysis has shown that it is necessary to systematically identify all potential hazards throughout the entire life cycle of the equipment and to implement appropriate technical and organizational protective measures. During temperature monitoring in the cutting zone using a thermal imaging camera, mechanical hazards were identified related to machines, machine parts or surfaces, tools, workpieces, loads, or projected solid or liquid materials, as well as mechanical hazards caused by machine components (including workpiece holding mechanisms), the workpiece, or loads. Electrical hazards arising from direct and indirect contact were also identified, as well as thermal hazards causing burns due to contact with objects or materials at extreme temperatures, flames, explosions, and radiation from heat sources. Among harmful effects, the most significant were laser radiation during marking of the measurement target, ergonomics, noise, and material/substance-related hazards.

Based on the conducted risk assessment, it can be concluded that the proper application of standards, adequate operator training, and adherence to safety procedures enable the safe and efficient use of thermal imaging cameras in industrial practice. This ensures full utilization of infrared thermography while minimizing risks to human health and workplace safety.

REFERENCES

Soares, A. L., de Paula Xavier, A. A., & Michaloski, A. O. (2020). Occupational risk evaluation through infrared thermography: Development and proposal of a rapid screening tool for risk assessment arising from repetitive actions of the upper limbs. *International Journal of Environmental Research and Public Health, 17*(10), Article 3390. https://doi.org/10.3390/ijerph17103390

Livada, Č., Glavaš, H., Baumgartner, A., & Jukić, D. (2023). The dangers of analyzing thermographic radiometric data as images. *Journal of Imaging, 9*(7), Article 143. doi.org

International Organization for Standardization. (2010). *Safety of machinery — General principles for design — Risk assessment and risk reduction* (ISO Standard No. 12100).

International Organization for Standardization. (2007). *Safety of machinery — Risk assessment — Part 1: Principles* (ISO Standard No. 14121-1).

Institut za standardizaciju Srbije. (1992). *Bezbednost mašina — Osnovni pojmovi, opšti principi za konstruisanje — Deo 1: Osnovna terminologija i metodologija* (SRPS EN 292-1).

International Organization for Standardization. (2008). *Condition monitoring and diagnostics of machines — Thermography — Part 1: General procedures* (ISO Standard No. 18434-1).

Pravilnik o načinu i postupku procene rizika na radnom mestu i u radnoj okolini, Službeni glasnik RS, br. 72/2006, 84/2006, 30/2010 i 102/2015.

Pravilnik o bezbednosti mašina, Službeni glasnik RS, br. 58/2016.

Pravilnik o preventivnim merama za bezbedan i zdrav rad pri korišćenju opreme za rad, Službeni glasnik RS, br. 23/2009, 123/2012 i 102/2015.

Pravilnik o evidencijama u oblasti bezbednosti i zdravlja na radu, Službeni glasnik RS, br. 62/2007 i 102/2015.

RISK ASSESSMENT AND RISK REDUCTION MEASURES FOR ELECTROPNEUMATIC EQUIPMENT

DOI: 10.5937/EMC26071J

Dušan Jovanić
Technical College of Applied Sciences Zrenjanin, Serbia
E-mail: dusan.jovanic@vts-zr.edu.rs
Valentina Mladenović
Technical College of Applied Sciences Zrenjanin, Serbia

ABSTRACT

This paper presents a risk assessment related to the use of an electropneumatic educational set intended for laboratory teaching. The risk assessment was conducted in accordance with the ISO 12100 and ISO 14121-1 standards, based on risk analysis through defining machine limits, hazard identification, and risk evaluation. Mechanical, electrical, thermal, ergonomic, and other hazards that may arise during the use of the electropneumatic educational set were identified. A risk matrix was used as the risk assessment method to quantify risk levels before and after the implementation of risk reduction measures, and to perform risk evaluation. Based on the assessment results, technical, organizational, and personal protective measures were proposed, with particular emphasis on user-implemented measures, including the development of safe work procedures, operator training, the use of personal protective equipment, and organizational safety measures. The results show that, after applying the proposed measures, all risks are reduced to an acceptable level, confirming that the use of the electropneumatic educational set in a laboratory environment is safe when the prescribed safety measures are consistently applied.

Key words: Risk assessment, risk reduction, electropneumatic equipment.

INTODUCTION

The development of modern industrial and educational systems increasingly involves the integration of pneumatic, electrical, and control components, which significantly enhances functionality but at the same time introduces new potential sources of risk to user safety. Electropneumatic systems are now widely used in industry, as well as in educational institutions, where they serve as a fundamental tool for acquiring practical knowledge in the fields of automation and mechatronics.

The safety of machines and work equipment represents one of the key requirements in both industrial and educational environments. The European Machinery Directive 2006/42/EC, along with corresponding national regulations and international standards, clearly defines the obligation to conduct risk assessment as a fundamental step in ensuring the safe use of machines and technical systems.According to ISO 12100 and ISO 14121-1 standards, risk analysis includes a systematic identification of all hazards that may arise throughout the machine life cycle, as well as an assessment of the probability and severity of possible consequences.The definition of general rules and safety requirements for pneumatic systems and their components, in accordance with ISO 4414, contributes to reducing the risk of failures and injuries.Previous research indicates that ANSI guidelines emphasize the identification of tasks and hazards that had not previously been considered, particularly those related to maintenance [Etherton, 2007].

The critical need to improve machine safety represents a strategic framework for risk mitigation through effective hazard identification, risk assessment, and implementation of control measures [Li et al., 2025].Therefore, considering that the electropneumatic educational set is used under laboratory

conditions while working with students, it is necessary to conduct a detailed risk analysis that includes the examination of all mechanical, electrical, and thermal hazards, as well as harmful effects caused by noise and vibrations, in addition to ergonomic and organizational aspects of work.The aim of this paper is to carry out a risk assessment related to the use of an electropneumatic educational set through risk analysis and evaluation. After identifying hazards in all relevant phases of the life cycle, it is necessary to perform risk assessment using a risk matrix and, after implementing measures for risk reduction, determine the magnitude and acceptability of the residual risks.

ELECTROPNEUMATIC EQUIPMENT

The electropneumatic educational set is laboratory equipment that enables practical learning of electropneumatics, a field that integrates pneumatics—through pneumatic components (control of single-acting and double-acting cylinders and valves (2/2, 3/2, 5/2, etc.) using compressed air, pressure regulators, filters, and connectors with electrical engineering and automation through electrical components (control of components by means of electric current, sensors, switches, relays, PLC controllers, indicators, and actuators).Pneumatics is used in performing manufacturing operations such as drilling, turning, milling, sawing, forming, and others, as well as for general material handling methods including clamping, moving, positioning, orientation, and material flow distribution. Figure 1 shows the electropneumatic educational set and the diagram of pneumatic components. The diagram schematically presents: Power components (cylinders, motors, visual indicators), Control elements (directional control valves), Process elements (control and non-return valves, pressure control valves, timers, sequencers), Input elements (valves, switches), and Supply elements (compressor, reservoir, service unit, and pressure regulation valves). Pneumatic tools and operational components can be loaded up to the stall point and are therefore protected against overload.



Figure 1: Electropneumatic educational set and diagram of pneumatic components

RISK ASSESSMENT

Risk assessment consists of risk analysis and risk evaluation. Risk analysis is carried out through determining the machine limits, hazard identification, and risk estimation, while risk evaluation determines whether the risk has been adequately reduced. According to ISO/TR 14121-2:2012- Part 2: Practical Guidance and Examples, risk assessment methods include: hazard identification using checklists, risk matrices, risk graphs, numerical scoring, quantified risk evaluation, and hybrid methods.Hazards identified on the electropneumatic set during the testing phase and operational process, according to the Rulebook on the Method and Procedure of Risk Assessment in the Workplace and Work Environment, are: Mechanical hazards arising from the use of work equipment, hazards associated with workplace characteristics, hazards arising from the use of electrical energy, harmful effects occurring during the work process (noise, vibrations, radiation, materials/substances) and harmful effects resulting from psychological and psychophysiological strain causally related to the workplace and tasks performed by employees (ergonomics).

Risk matrix

The risk matrix is one of the methods used for risk assessment and is applied after risk analysis has been carried out, that is, after hazards have been identified. The risk matrix represents one of the most commonly applied risk assessment methods and is used after the completion of risk analysis, namely after the identification of all relevant hazards. This method enables the assessment of risks associated with machines and equipment in various industrial fields.The primary purpose of the risk matrix is to enable the ranking of identified risks according to their magnitude, in order to clearly distinguish those that are unacceptably high and for which risk reduction measures must be implemented. In this way, the risk matrix serves as a tool for decision-making regarding risk acceptability and for determining priorities in the implementation of preventive and protective measures. Its advantages are reflected in its simplicity, speed, and efficiency of application, making it suitable for practical use in industrial environments.The following Table 1 presents the risk assessment performed using the risk matrix method, as well as the measures for risk reduction. Risk evaluation was also carried out in order to determine whether the risk was adequately reduced after the implementation of the proposed measures.

Table 1: Risk assessment using the risk matrix method

Operator / Task	**Hazard**	**Initial Risk Assessment**			**Risk Reduction Measures**	**Risk Assessment After Measures**			**Status (Acceptable)**
		Severity	Probability	Risk Level		Severity	Probability	Risk Level	
Testing and operation	Mechanical (kinetic energy): moving cylinders, crushing	3	4	12 High	Restricted work zone, training	3	2	6 Moderate	Y
	Mechanical: uncontrolled cylinder start	4	3	12 High	Lockout procedure, signaling, supervision	4	2	8 Moderate	Y
	Mechanical – hose rupture (pressurized fluid impact)	3	3	9 Moderate	Regular hose inspection, pressure limitation	3	1	3 Low	Y
	Electrical – direct contact	4	2	8 Moderate	24 V DC voltage, proper cables, prohibit. of live work	4	1	4 Low	Y
	Electrical – indirect contact	3	2	6 Moderate	Grounding, installation testing	3	1	3 Low	Y
	Thermal – hot compressor surfaces	2	3	6 Moderate	Warning signs, safe distance	2	1	2 Low	Y
	Compressor and exhaust noise	2	3	6 Moderate	Maintenance, PPE if required	2	2	4 Low	Y
	Vibrations	2	2	4 Low	Stable installation, maintenance	2	1	2 Low	Y
	Substances – compressed air, dust	2	3	6 Moderate	Ventilation, proper connections	2	2	4 Low	Y
	Ergonomics	2	2	6 Moderate	Adjustable table height, breaks	2	2	4 Low	Y
	Slipping, tripping, and falling	3	2	6 Moderate	Organize cables, mark walkways	3	1	3 Low	Y

Risk matrices have been in use for many years and have been developed in various forms, such as 5×5 matrices, as well as matrices defined by standards and guidelines, including ANSI B11 TR3:2000 and IEC 61508. The differences among them are reflected in the number of levels and the method of defining risk factors, with four-level and five-level matrices being the most commonly used in practice. For each identified hazard or hazardous situation, it is necessary to assess the severity of the possible consequences. In addition to the severity of consequences, the probability of occurrence of a

hazardous event is also evaluated for each hazard.Based on the conducted risk assessment using the risk matrix method, it can be concluded that the initially identified risks associated with the operation of the electropneumatic educational set were predominantly classified within the categories of moderate and increased risk, particularly in relation to mechanical and electrical hazards.After the implementation of the prescribed technical, organizational, and personal protective measures, all assessed risks were reduced to an acceptable level. No risk remained within the high-risk category, confirming that the electropneumatic educational set is safe for use under laboratory conditions, provided that the defined protective measures are consistently applied.

REDUSTION OF RISK

Measures for the prevention, elimination, or reduction of risks are determined based on the assessed risk, in accordance with occupational safety and health regulations, technical regulations, and standards, and are aimed at achieving risk reduction. The Figure 2. shows the decomposition diagram of measures for risk reduction.

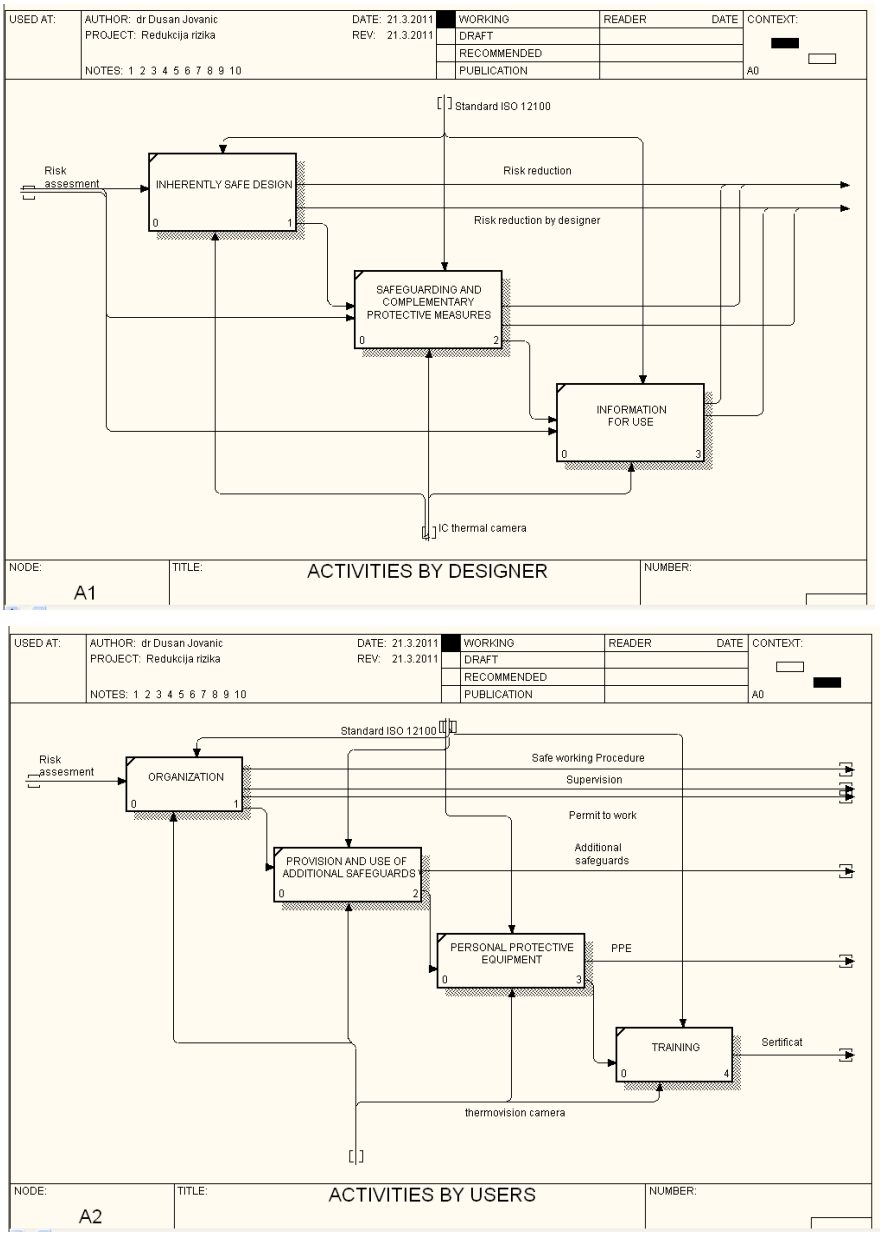


Figure 2: Decomposition diagram of activities by designers and users

The activity tree of the risk reduction is shown in Figure 3.

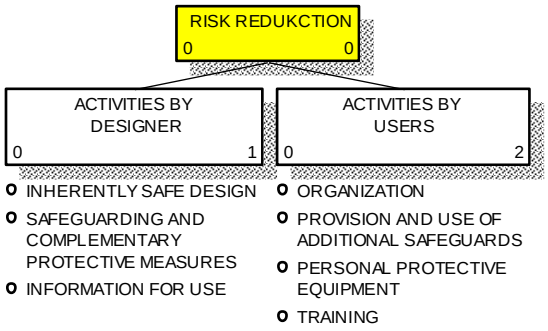


Figure 3: The activity tree of the risk reduction

Instruction No.	02/2026	**Device**	Electropneumatic Set	**Manufacturer**	Festo	**Type**	TP101

General Rules: Use of the equipment by untrained (unqualified) personnel is prohibited

Disconnect the power supply before changing connections. Do not touch moving parts or electrical contacts during operation. Air pressure must be shut off and released from the system before maintenance. Never increase the pressure above 6 bar. Do not operate the system if there are loose or damaged connections. In case of an electrical fault, immediately disconnect the power supply.

Measures to Be Taken Before Starting Work

Check that the compressor is functioning properly and that the filters are operational. Gradually increase the pressure to the operating level and check for leaks. Check pressure gauges, valves, and regulators for correct readings. Verify that all mechanical components are properly installed (cylinders, valves, sensors). Visually inspect pneumatic hoses to ensure they are: in good condition (without cracks, bends, or damage), firmly connected and secured, positioned so they do not interfere with moving parts. Check electrical connections: cables must be insulated and undamaged, connectors must be properly connected and labeled. Check that sensors and solenoid valves respond correctly. Connect the 24V DC power supply and verify grounding. Ensure there are no visible traces of oil, water, dirt around connections, or fumes from components (in electropneumatic systems). Verify the presence of signs, labels, and diagrams (they must be legible and in place).

Measures to Be Taken During Operation

Safe Start-Up: Before starting, ensure that no one is standing within the operating area of the cylinder or moving parts. Use an audible/light signal before starting the system, if possible. Start the system slowly, gradually increasing the load.

Operating Guidelines: Do not exceed the maximum pressure and voltage values. Do not use unsuitable media (air with excessive moisture or impurities). Do not manually stop or obstruct cylinder movement — use the designated blocking valves. Adjust cylinder movement speed using regulating valves, not by sudden changes. Avoid vibrations and hammering effects that may cause material fatigue.

Safe Shutdown / Stopping: Use designated valves for safe shutdown (air flow blocking). Release pressure from the system before accessing components. Disconnect the electrical power supply (for the electropneumatic section).

Measures to Be Taken After Completing Work

Disconnect the power supply. Shut off the air supply. Release pressure from the system. Properly store and arrange the equipment.

Warning Signs



Mandatory Signs



Prohibition Signs





Phone:

Procedure in Case of Accident, Failure, or Damage:

Date	20.12.2025.	**Prepared by:**	Dr Dušan Jovanić

Figure 4: Safe work procedure

The measures undertaken by the manufacturer for risk reduction include: Inherently safe design, Guards and complementary protective measures, and Information for use (information, operating instructions, warnings). Risk reduction measures implemented by the user include: Organization

(procedures for safe work, supervision, work permits), Provision and use of additional protective measures and guards, Use of personal protective equipment (PPE), Training, Inspection and testing of work equipment, Maintenance etc.

The risk reduction measure applied by the user in terms of organization is the preparation of a procedure (instruction) for safe operation, presented in Figure 4. In addition to general information and technical characteristics of the electropneumatic educational set, the instruction also describes the measures that should be undertaken before, during, and after operation, as well as hazard, prohibition, obligation (PPE), and first aid signs.

CONCLUSION

The risk assessment of the electropneumatic educational set was carried out through risk analysis and evaluation. The risk estimation was performed using the risk matrix method. It was determined that the highest risks originate from mechanical hazards related to the kinetic energy of cylinder movement, in particular uncontrolled movement of cylinders and the accumulated potential energy associated with hose rupture and the resulting impact of pressurized fluid, as well as electrical hazards due to direct contact.After the implemented risk reduction measures, including the definition of a safe work procedure, as well as the risk evaluation, no risks remain in the increased-risk category. The highest remaining risk is related to mechanical hazards caused by uncontrolled cylinder movement, with a moderate risk level. Most risks have been reduced to a low level.It can be concluded that the operator's activities when working with the electropneumatic educational set are not considered high-risk work, provided that the prescribed safety measures are followed, appropriate training is ensured, and regular supervision and maintenance of the equipment are carried out.

REFERENCES

Etherton, J. R. (2007). Industrial machine systems risk assessment: A critical review of concepts and methods. *Risk Analysis*, *27*(1), 171–182. doi.org

Li, H., Sun, Y., Adumene, S., Goleiji, E., & Yazdi, M. (2025). Machinery safety improvement in manufacturing-oriented facilities: A strategic framework. *The International Journal of Advanced Manufacturing Technology*, *138*, 4531–4560. doi.org

Croser, P., & Ebel, F. (2000). *Pneumatics basic level: Festo textbook TP101* (Equipment set ID: PROD_DID_540710). Festo Didactic GmbH & Co. https://www.festo.com/us/en/p/pneumatics-basic-level-equipment-set-id_PROD_DID_540710/?page=0

European Committee for Standardization. (1991). *Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology and methodology* (EN Standard No. 292-1).

Institut za standardizaciju Srbije. (2016). *Bezbednost mašina - Delovi sistema za upravljanje koji se odnose na bezbednost - Deo 1: Opšti principi za projektovanje* (SRPS EN ISO 13849-1).

International Organization for Standardization. (2003). *Safety of machinery - General principles for design - Risk assessment and risk reduction* (ISO Standard No. 12100-1).

International Organization for Standardization. (2007). *Safety of machinery - Risk assessment - Part 1: Principles* (ISO Standard No. 14121-1).

International Organization for Standardization. (2010). *Compressed air — Part 1: Contaminants and purity classes* (ISO Standard No. 8573-1).

International Organization for Standardization. (2010). *Pneumatic fluid power — General rules and safety requirements for systems and their components* (ISO Standard No. 4414).

International Organization for Standardization. (2012). *Safety of machinery — Risk assessment — Part 2: Practical guidance and examples of methods* (ISO/TR Standard No. 14121-2).

Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast). (2006). *Official Journal of the European Union*, L 157, 24–86. https://eur-lex.europa.eu/eli/dir/2006/42/oj/eng

Pravilnik o bezbednosti mašina, Službeni glasnik RS, br. 58/2016.

Pravilnik o načinu i postupku procene rizika na radnom mestu i u radnoj okolini, Službeni glasnik RS, br. 72/2006, 84/2006, 30/2010 i 102/2015.

Pravilnik o preventivnim merama za bezbedan i zdrav rad pri korišćenju opreme za rad, Službeni glasnik RS, br. 23/2009, 123/2012 i 102/2015.

INTERNET COVERAGE AND SMART RURAL DEVELOPMENT: THE CASE STUDY OF VOJVODINA, SERBIA

DOI: 10.5937/EMC26077N

Natalija Nikolić
Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia
E-mail: natalija.nikolic@dgt.uns.ac.rs
Milka Bubalo Živković
Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia
Tamara Lukić
Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia
Bojan Đerčan
Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia
Dajana Bjelajac
Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia

ABSTRACT

Rural areas in Serbia have been facing a continuous decline over the last few decades. Population decline and emigration of the youth has been followed by reduced labor market opportunities, limited access to the services and emptying of the rural areas. Smart village concept emphasizes the use of information and communication technologies in rural development. This paper focuses on 4G internet coverage in Vojvodina, Northern Serbia, and its relationship with the level of rurality of the municipalities in order to assess whether a higher share of rural population is associated with lower levels of internet coverage. The results indicate that 4G coverage is widely available across settlements, regardless of their classification as urban or 'other', suggesting no significant relationship between rural population share and internet coverage. Future research on smart rural development should investigate demographic characteristics of rural population, education levels and access to the digital technologies. The development of effective smart village strategies requires consideration of the specific characteristics and challenges of rural settlements.

Keywords: Smart villages, Rural settlements, Digital development, Serbia

INTRODUCTION

Although the world population is projected to grow by the end of the century, this growth is not evenly distributed among the countries or settlements. The countries projected to grow through 2054 are located in Africa, North and South America, Asia, and Australia. Most countries in Europe, including Serbia, have reached the peak of population before 2024 (United Nations [UN], 2024). Additionally, rural areas are more likely to face population decline, emigration of younger population and rapid population ageing (Newsham & Rowe, 2025). As a result, local labour market is not as attractive to either investors nor remaining population, causing further emigration and decline (Komorowski, 2024). This process leads to creating "almost self-perpetuating circle effect" (Komorowski, 2024, 1), where the lack of human capital results in the lack of services and job opportunities (Komorowski, 2024; Loewen & Streifeneder, 2025), marginalization of the communities and hollowing the rural areas (Li et al., 2019). As focusing solely on economic development of rural areas does not result in satisfactory results, the innovative and community-based approaches are needed to address the challenges of rural decline (Dax & Fischer, 2017). In order to face these challenges, the European Union [EU] issued the document *EU Action for Smart Villages* in 2017.

A term "smart village" covers the rural settlements where local communities use information and communication technologies (ICT) to improve their life quality (European Commission, 2017). Smart

villages are built on the principles of smart (technological) infrastructure, sustainable energy, consideration of local traditions and economy, communities and institutional support (Smart Rural 27, n.d.) (Figure 1). The research on smart villages starts with the analysis of availability of digital services and internet coverage, as these are necessary conditions for further smart development (Komarowski & Stanny, 2020). Integrating ICT infrastructure in rural development can improve communal services, decrease rural marginality (Ofori et al., 2025), and strengthen social relationships through local projects and platforms (Piekut & Rybaltowicz, 2024).

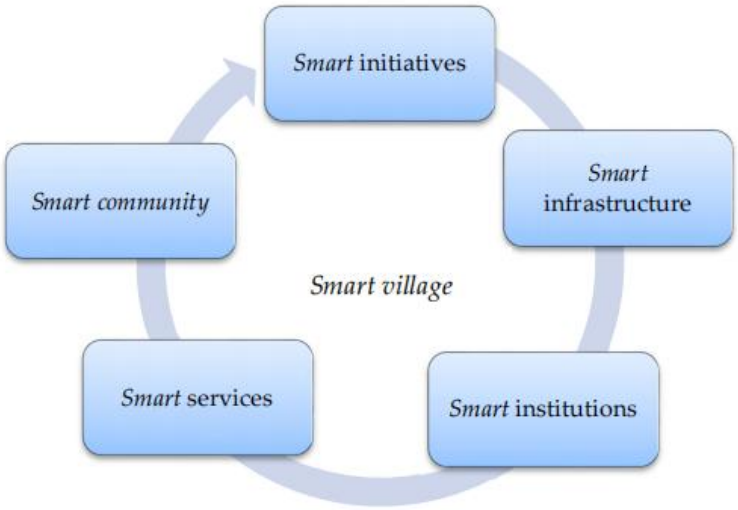


Figure 1: Main elements of smart villages (Komorowski & Stanny, 2020)

In Serbia, rural decline has been a long-term process. Rapid industrialization and urbanization processes in the previous century lead to rural abandonment, and subsequently population ageing and decline in services availability (Živanović et al., 2021; Živanović et al., 2022; Bubalo Živković et al., 2024). Nowadays, rural population accounts for 38% of the Serbian population. Demographic data reveal that the average age, ageing index and share of the elderly have been steadily increasing between the 2011 and 2022 population censuses. Although Vojvodina and the Belgrade region have a little more favorable demographic conditions than the other regions in Serbia, rural decline is evident and remains one of the crucial challenges in contemporary society (Institute of Economic Sciences, 2025). Utilizing quantitative research on smart villages in Serbia can improve theoretical knowledge on the condition of Serbian villages, further allowing for the creating smart development strategies through legal and institutional frameworks (Tošić & Živanović, 2022; Gajić et al., 2025).

This paper examines 4G internet coverage in Vojvodina, Northern Serbia, and its correlation with the share of rural population, with the aim of assessing whether adequate internet access is available in rural areas as a fundamental prerequisite for the development of smart villages.

DATA SOURCES AND METHODS

Study Area

With an area of 21,614 km^2, the Autonomous Province of Vojvodina is located in northern Serbia (Figure 2). Vojvodina is composed of 7 Areas and 45 local self-government units (LAU 1), of which 8 are Cities and 37 are municipalities. According to the 2022 Population Census, Vojvodina had the population of 1,740,230 inhabitants. The largest urban settlement and the administrative center of the province is Novi Sad, with 260,438 inhabitants. Rural population accounted for 38.18% of the total population (Statistical Office of the Republic of Serbia [SORS], 2023).

Data

For the research of internet coverage, the data from Regulatory Agency for Electronic Communications and Postal Services (RATEL) was utilized (RATEL, n.d.). The analysis is based on 4G signal coverage data obtained from three internet service providers in Serbia for the third quarter of 2025. Signal strength is expressed in dBm, where lower (more negative) values indicate weaker signal levels.

The 2022 Census of population (SORS, 2023) data were used for the analysis of rural population. All settlements in Serbia are administratively divided into urban and "other" settlements. Both municipalities and Cities comprise settlements belonging to each of these categories within their administrative boundaries. In this paper, "other" settlements will be considered rural, as they belong to non-urban type of settlements (Bubalo Živković et al., 2024).

Methodology

The analysis of internet coverage was conducted using QGIS 3.40.4 software. Following data acquisition from RATEL (n.d.), the original datasets were processed into raster (.tif) format to enable spatial analysis. The weakest internet coverage was assigned a value of 0, while the strongest was assigned a value of 3. Data from each provider were initially processed separately and subsequently merged into a single layer by calculating the arithmetic mean of their values. This resulting layer was then reclassified into integer values ranging from 0 to 3, using equal interval classification.

The area of each coverage class at the municipal level was calculated using the zonal histogram tool. After completing the GIS analysis, the data were exported in .xlsx format. Data on the rural population were then incorporated into the same dataset, and a correlation analysis was performed between the share of areas with the highest level of internet coverage and the share of the rural population.

RESULTS AND DISCUSSION

After the geospatial analysis, a map of internet coverage in Vojvodina was obtained (Figure 2). The pattern of excellent Internet coverage mostly corresponds to the settlement pattern in Vojvodina, and it covers about a third of the territory (33.30%). Good internet coverage accounts for 60.43% of the territory. On the other hand, acceptable and unacceptable internet coverage are observed across a significantly smaller portion of the territory, representing only 2.35% and 3.92% of the territory, respectively. The municipalities with the highest share of unacceptable coverage are Šid (southwest), as it is a bordering municipality, and Kovin (southeast), due to the remoteness of the Special Nature Reserve [SNR] "Deliblatska peščara".

The correlation between the share of excellent internet coverage in the municipality and rural population indicates a negligible relationship ($r = 0.02$) (Table 1). This finding reveals that the level of excellent internet coverage is not directly associated with rurality across municipalities in Vojvodina. The results suggest that high-quality internet coverage has primarily been developed to ensure coverage of settlements. This indicates that the spatial distribution of coverage is more closely aligned with the location of settlements than with their administrative classification. Furthermore, the predominantly flat terrain of Vojvodina does not significantly influence signal strength, with only minor variations observed in areas with more pronounced relief and protected areas, such as Fruška Gora, the Vršac Mountains, and SNR "Deliblatska peščara". Other European countries, such as the Czech Republic, exhibit a similar situation (Vaishar & Šťastná, 2019). The authors suggest that it is not the lack of digital infrastructure in the rural areas that hinder the smart rural development. Rather, it is the lack of human capital, depopulation and smaller share of digitally literate population living in the villages (Vaishar & Šťastná, 2019).

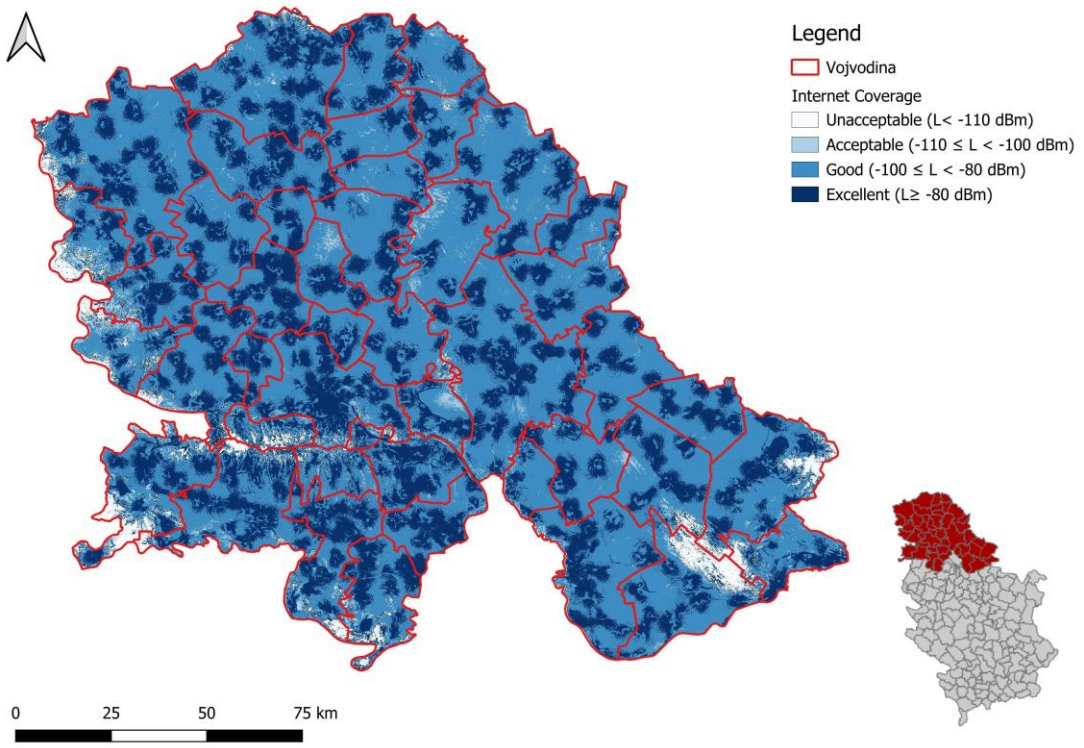


Figure 2: 4G Internet coverage in Vojvodina

Table 1: Internet coverage and the share of rural population in Vojvodina

LAU 1	Excellent Internet coverage	Share of rural population	LAU 1	Excellent Internet coverage	Share of rural population
Novi Sad	48.75	16.88	Sremska Mitrovica	43.24	44.69
Bač	23.01	61.46	Inđija	52.67	43.72
Bačka Palanka	38.75	47.22	Irig	31.43	58.00
Bački Petrovac	47.20	54.60	Pećinci	45.23	100
Beočin	36.83	47.57	Ruma	47.55	42.93
Bečej	28.91	36.47	Stara Pazova	50.92	70.28
Vrbas	53.22	42.92	Šid	37.83	54.76
Žabalj	24.81	64.58	*Pančevo*	36.49	25.16
Srbobran	28.17	26.89	Alibunar	31.56	58.44
Sremski Karlovci	48.28	0.00	Bela Crkva	33.67	48.40
Temerin	38.08	10.49	*Vršac*	32.26	29.73
Titel	36.58	67.66	Kovačica	33.81	74.51
Sombor	32.70	40.96	Kovin	28.64	58.70
Apatin	31.17	36.89	Opovo	22.25	56.17
Kula	29.49	37.89	Plandište	35.52	100
Odžaci	40.75	69.69	Subotica	40.89	23.98
Kikinda	24.81	34.96	Bačka Topola	38.03	54.51
Ada	15.51	7.61	Mali Iđoš	40.66	100
Kanjiža	38.22	59.95	*Zrenjanin*	32.96	36.50
Novi Kneževac	22.73	34.07	Žitiste	26.80	80.99
Senta	23.41	19.50	Nova Crnja	27.89	100
Čoka	31.38	63.55	Novi Bečej	17.02	44.85
			Sečanj	26.41	82.08

CONCLUSION

This paper studies the relationship between internet coverage and rurality in Vojvodina. Although internet coverage is one of the most important foundations of the smart rural development, it represents only its initial step. As the rural settlements in Vojvodina are generally well-covered, the next step should be designing the strategies for smart rural development. Future research should consider demographic characteristics of rural settlements (average age, ageing index, etc.), education levels of rural population, computer/digital literacy, and the access to the digital technologies. With the knowledge of the unique characteristics of the settlements, the specific strategies may be developed in order to address the main challenges and highlight the positive characteristics of each settlement.

ACKNOWLEDGEMENTS

This paper was financed by the Provincial Secretariat for Higher Education and Scientific Research of the Province of Vojvodina, Serbia, as part of the project "Rural immigration - a factor in regional revitalization and survival of villages in Vojvodina", number: 003786630 2025 09418 003 000 000 001 04 002.

REFERENCES

Bubalo Živković, M., Lukić, T., Bjelajac, D., Pogrmić, Z., & Jovanović, G. (2024). Deruralization as a global process and its trends in Serbia. *Journal of the Department of Geography, Tourism and Hotel Management, 53*(1), 67–79. https://doi.org/10.5937/ZbDght2401069Z

Dax, T., & Fischer, M. (2018). An alternative policy approach to rural development in regions facing population decline. *European Planning Studies, 26*(2), 297–315. https://doi.org/10.1080/09654313.2017.1361596

European Commission. (2017). *EU action for smart villages*. European Commission. Retrieved January 2026, from https://agriculture.ec.europa.eu/document/download/197ce76e-050b-45b4-986c-c57a7905edb2_en?filename=rur-dev-small-villages_en.pdf

Gajić, T., Blešić, I., Vukolić, D., Ivkov, M., Radovanović, M. M., Malinović-Milićević, S., & Miljković, O. (2025). Adapting the Smart Village Index as a technological tool for rural digitalization and tourism development in emerging economies. *Technologies, 13*(11), 513. https://doi.org/10.3390/technologies13110513

Komorowski, Ł. (2024). Digitalisation as a challenge for smart villages: The case of Poland. *Agriculture, 14*(12), 2270. https://doi.org/10.3390/agriculture14122270

Komorowski, Ł., & Stanny, M. (2020). Smart villages: Where can they happen? *Land, 9*(5), 151. https://doi.org/10.3390/land9050151

Li, Y., Westlund, H., & Liu, Y. (2019). Why some rural areas decline while some others not: An overview of rural evolution in the world. *Journal of Rural Studies, 68*, 135–143. https://doi.org/10.1016/j.jrurstud.2019.03.003

Loewen, B., & Streifeneder, T. (2025). Smart(er) rural areas: Framing "smart villages" for conceptual development and EU policy. *European Urban and Regional Studies, 0*(0). https://doi.org/10.1177/09697764251398439

Newsham, N., & Rowe, F. (2025). The demographic causes of European sub-national population declines. *European Journal of Population, 41*, 10. https://doi.org/10.1007/s10680-025-09730-0

Ofori, A. S., Keaveney, K., Campo, A. G. d., & Robinson, D. (2025). Rural transformation through digitalisation? Understanding the digital in the context of rural change. *European Countryside, 17*(1), 91–110. https://doi.org/10.2478/euco-2025-0005

Piekut, M., & Rybaltowicz, J. (2024). The role of information and communication technologies in rural development / Rola technologii informacyjno-komunikacyjnych w rozwoju obszarów wiejskich. *Zagadnienia Ekonomiki Rolnej / Problems of Agricultural Economics, 378*(1), 69–92. https://doi.org/10.30858/zer/181136

Regulatory Agency for Electronic Communications and Postal Services (RATEL). (n.d.). *Coverage maps*. Retrieved February 2026, from https://mapepokrivenosti.ratel.rs/eng

Smart Rural 27. (n.d.). *Smart villages guidebook*. Smart Rural 27. Retrieved January 2026, from https://www.smartrural27.eu/wp-content/uploads/2024/05/Guidebook_EN.pdf

Statistical Office of the Republic of Serbia. (2023). *2022 census of population, households and dwellings: Age and sex. Data by settlements*. Statistical Office of the Republic of Serbia. Retrieved March 2026, from https://publikacije.stat.gov.rs/G2023/Pdf/G20234003.pdf

Tošić, B., & Živanović, Z. (2022, June 16–18). *Rural planning at the local level in the contemporary European context – Is the "smart villages" concept a real possibility in Serbia?* Lokalna samouprava u planiranju i uređenju prostora i naselja, Veliko Gradište.

United Nations. (2024). *World population prospects 2024: Summary of results* (UN DESA/POP/2024/TR/NO. 9). United Nations.

Vaishar, A., & Šťastná, M. (2019). Smart village and sustainability: Southern Moravia case study. *European Countryside, 11*(4), 651–660. https://doi.org/10.2478/euco-2019-0036

Živanović, V., Joksimović, M., Golić, R., Malinić, V., Krstić, F., Sedlar, M., & Kovjanić, A. (2022). Depopulated and abandoned areas in Serbia in the 21st century – From a local to a national problem. *Sustainability, 14*, 10765. https://doi.org/10.3390/su141710765

Živanović, Z., Tošić, B., & Vesić, M. (2021). Rural abandonment in the Balkans: Case study of a Serbian village. *Journal of Family History, 46*(3), 344–362. https://doi.org/10.1177/03631990211000817

ANALYSIS OF THE CONDITION OF HISTORICAL BUILDINGS IN SERBIA – LITERATURE REVIEW

DOI: 10.5937/EMC26083P

Ivan Palinkaš
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
E-mail: ivan.palinkas@tfzr.rs
Eleonora Desnica
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Jasmina Pekez
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Bogdana Vujić
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Ljiljana Radovanović
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Borko Bulajić
University of Novi Sad, Faculty of technical sciences, Novi Sad, Republic of Serbia

ABSTRACT

Historical buildings represent an essential part of cultural identity and architectural heritage, particularly in countries with rich historical and urban traditions such as Serbia. However, these structures are increasingly exposed to environmental, structural, and seismic risks while simultaneously facing demands for improved energy performance and sustainable use. This paper presents an overview of the current state of research related to risk management, energy efficiency, and seismic vulnerability of historical buildings in Serbia, based on recent literature and case studies. The paper analyzes traditional construction systems, seismic assessment methodologies, energy retrofitting strategies, and sustainable regeneration approaches applied to protected historical buildings. Historical buildings in Serbia possesses significant cultural and environmental value, but there are often problems with poor thermal performance, old and aging materials and structural vulnerabilities. Through literature review is shown that integrated and context-sensitive interventions can significantly improve both the seismic resilience and energy efficiency of historical buildings while preserving their architectural authenticity and cultural significance.

Key words: historical buildings, risk management, energy efficiency, seismic vulnerability

INTRODUCTION

The preservation and sustainable modernization of historical buildings have become major challenges in contemporary architectural and engineering practice. Across Europe, increasing attention is being directed toward reducing energy consumption, improving resilience to natural hazards, and preserving cultural heritage. This literature overview focuses on analysis of the condition of historical buildings in Serbia. The aim is to understand existing building typologies, assess their vulnerabilities, and evaluate possibilities for energy and seismic retrofitting while respecting their cultural and architectural identity.

In Serbia, historical buildings include a wide range of traditional rural houses, urban masonry structures, religious complexes, and public buildings. Many of these structures were constructed using traditional materials and techniques that reflect local climatic conditions and cultural practices. However, due to aging materials, insufficient maintenance, and changing environmental conditions, many buildings face deterioration and increased vulnerability to earthquakes and climate-related risks.

Recent scientific studies emphasize the need for integrated risk management strategies that combine seismic assessment, energy retrofitting, sustainable regeneration, and urban planning. This paper presents the key findings from the reviewed literature and discusses approaches to sustainable heritage preservation.

HISTORICAL BUILDINGS AND TRADITIONAL CONSTRUCTION IN SERBIA

Traditional architecture in Serbia was defined by the natural environment. The influence of natural factors can be found in the all the segments of the house: usage of natural materials found in the surrounding environment, dimensional adjustment and adjustment to the terrain done to fit available natural materials and climatic conditions which led to forming a functional space (Radivojević et al., 2017). These buildings often demonstrated efficient passive climate control through thick walls and natural ventilation.

The principles of sustainable architecture and the reduction of the negative environmental impacts in all phases of the building lifecycle are recognized in many ways (biodegradability, recycling, and reuse potentials of materials and structures) (Radivojević et al., 2017).

Radivojević et al., (2017) wrote that inevitable changes that happened over time first influenced urban architecture. Modernization has contributed to the improvement of certain aspects of living comfort, and increased the longevity of buildings. During the nineteenth and early twentieth centuries, Serbia experienced rapid urbanization and modernization, resulting in significant transformations in construction techniques and development of building regulations. That results in the use of new building materials which were more durable, but which carried a larger environmental burden in comparison to natural ones. Radivojević et al. (2016) describe the transition from timber-framed and mixed structural systems, that for that period had good resistance to seismic activity as well as good maintainability, toward massive masonry structures and the introduction of reinforced concrete.

Historical urban centers such as Belgrade and Novi Pazar (Muminovic et al., 2020.) contain numerous examples of protected buildings that require preservation and functional revitalization. These structures often possess significant cultural and historical value but face technical challenges related to structural stability, thermal performance, and adaptive reuse.

SEISMIC VULNERABILITY AND RISK MANAGEMENT

The formulation of seismic vulnerability in Serbia is not only of interest for predicting the economic impact of future earthquakes, but can also be of importance for risk mitigation (Radovanović and Petronijević, 2009). Seismic vulnerability represents one of the most significant risks affecting historical buildings in Serbia and the Balkan region. Earthquakes such as the 2010 Kraljevo earthquake and the 2020 Petrinja earthquake demonstrated the fragility of unreinforced masonry buildings and highlighted the necessity for improved seismic risk assessment (Blagojević et al., 2021).

Blagojević et al. (2021) focused on simplified seismic assessment methodologies for unreinforced masonry residential buildings in Serbia. Their study introduced the Wall Index concept which is based on the minimum requirements for the total wall area relative to the floor plan area derived from Eurocode 8. Main purpose of Eurocode 8 is to use Wall Index for design and build new buildings but for Blagojević et al (2021) research authors use it for seismic assessment of existing masonry buildings in pre- and post-earthquake situations.

Additional advances in seismic assessment were achieved through the Adriseismic methodology developed within the Interreg ADRION program. Predari et al. (2023) proposed an expeditious seismic assessment method that was developed to mitigate seismic risk associated with urban heritage buildings that was build with unreinforced masonry commonly found in the Adriatic and Balkan regions. These countries are characterised by the high seismic exposure and significant stock of vulnerable unreinforced masonry (URM) buildings, which were designed to withstand only gravity

loads and were unable to sustain the effects of moderate to strong earthquakes without substantial damage. The methodology evaluates masonry quality, structural response, and potential collapse mechanisms.

Furthermore, the classification of Serbia's residential building stock developed by Blagojević et al. (2023) established a foundation for regional seismic risk assessment studies consists of three components: hazard, vulnerability, and exposure modelling. Effective risk management in historical buildings therefore requires a combination of preventive conservation, structural monitoring, seismic strengthening, and strategic planning. These interventions must minimize damage while preserving the authenticity and cultural significance of heritage structures.

ENERGY EFFICIENCY AND SUSTAINABLE RETROFITTING

Improving the energy efficiency of historical buildings represents another major challenge in heritage conservation. Many historical buildings in Serbia exhibit poor thermal performance due to inadequate insulation, inefficient heating systems, and deteriorated building envelopes. However, aggressive energy retrofitting measures may compromise historical appearance and material authenticity.

Stanojević et al. (2021) proposed a multi-criteria decision-making model based on the fuzzy Analytic Hierarchy Process (AHP) for selecting optimal energy retrofitting strategies for heritage buildings with maximal preservation of building itself. Their research demonstrated that interventions should depend on the level of heritage protection and should prioritize minimally invasive solutions such as technical system upgrades and internal insulation. The National Typology of Residential Buildings in Serbia (Krstić-Furundžić et al. 2013) also demonstrated significant energy-saving potential across different building categories. Standard and advanced renovation scenarios showed that heating demand could be reduced by more than 70% through improvements in insulation, heating systems, and energy management.

A practical example of sustainable energy refurbishment was presented through the restoration of historical structures in the Hilandar Monastery complex. Šekularac et al. (2018) applied Building Performance Simulation methods to evaluate energy refurbishment end energy efficiency while respecting conservation requirements. Their study confirmed that renewable energy integration and energy-efficient retrofitting can be successfully implemented without compromising visual authenticity of historic structures.

Sustainable regeneration approaches are also visible in rural heritage preservation. Research on the traditional houses of Sirinićka Župa demonstrated that traditional construction techniques possess valuable environmental characteristics and climate resilience. Functional reactivation and adaptive reuse of rural heritage can therefore contribute to sustainable regional development while preserving cultural identity. (Kosanović et al., 2019)

CONCLUSION

The analysis of scientific literature and case studies related to historical buildings in Serbia reveals that the country's architectural heritage possesses significant cultural, structural, and environmental value, but also faces notable challenges. Historical buildings, whether vernacular rural houses, early modern urban masonry structures, or protected heritage complexes, often suffer from energy inefficiency, material degradation, and varying levels of seismic vulnerability. At the same time, their preservation requires strict adherence to conservation principles, which limits the range of permissible interventions.

Research studies in this paper emphasize several important themes. First, sustainable materials and traditional construction methods used in Serbian architecture demonstrate inherent environmental advantages and provide a foundation for culturally appropriate retrofitting strategies. Second, the shift from timber framing to unreinforced masonry and early reinforced concrete necessitates varied seismic

assessment approaches, while new tools such as the Adriseismic method contribute to more efficient vulnerability screening and strengthen regional seismic risk mitigation efforts. Energy efficiency represents another critical dimension. Studies on retrofitting scenarios and building performance simulations confirm that substantial reductions in energy demand are possible, even within strict conservation limits, particularly when focusing on internal insulation, system upgrades, and renewable energy integration that preserve the building's visual identity.

At the same time, strategic planning and sustainable regeneration models can transform historical buildings into resilient and functional components of modern urban and rural environments. By integrating seismic strengthening, energy efficiency improvements, and conservation ethics, future interventions can ensure both the preservation of cultural heritage and the achievement of broader sustainability goals.

ACKNOWLEDGEMENTS

The scientific paper was prepared within the framework of the project 2025-1-RO01-KA220-HED-000364478 "Strengthening green and digital capacities in higher education through collaboration in integrating historical buildings into a sustainable and digital future - HEIstorical" (HEIstorical) co-funded by the European Union under the Erasmus+ KA220-HED — Cooperation partnerships in higher education program.

REFERENCES

Blagojević, N., Brzev, S., Petrović, M., Borozan, J., Bulajić, B., Marinković, M., Hadzima-Nyarko, M. Koković, V., Stojadinović, B. (2023). Residential building stock in Serbia: Classification and vulnerability for seismic risk studies. *Bulletin of Earthquake Engineering*, 21, 4315-4383

Blagojević, P., Brzev, S., Cvetković, R. (2021). Simplified seismic assessment of unreinforced masonry residential buildings in the Balkans: The case of Serbia. *Buildings*, 11, 392. https://doi.org/10.3390/buildings11090392

Kosanović, S., Folić, B., Kovacević, S., Nikolić, I., Folić, Lj. (2019). A study on the sustainability of the traditional Sirinić houses in the Šar Mountain region, the South-Western Balkans. *Sustainability*, 11, 4711. https://doi.org/10.3390/su11174711

Krstić-Furundžić, A., Kosorić, V., Gajić, R., Ignjatović, D. (2013). National typology of residential buildings in Serbia. Faculty of Architecture, University of Belgrade

Muminović, E., Radosavljević, U., & Beganović, D. (2020). Strategic planning and management model for the regeneration of historic urban landscapes: The case of historic center of Novi Pazar in Serbia. *Sustainability*, 12, 1323. https://doi.org/10.3390/su12041323

Predari, G., Stefanini, L., Marinković, M., Stepinac, M., Brzev, S. (2023). Adri-seismic methodology for expeditious seismic assessment of unreinforced masonry buildings. Buildings, 13, 344. https://doi.org/10.3390/buildings13020344

Radivojević, A., Roter-Blagojević, M., Đukanović, Lj. (2017). Sustainability and the material aspect of traditional residential buildings in Serbia. In *Materials for a Healthy, Ecological and Sustainable Built Environment: Principles for Evaluation* (pp. 1–10). https://doi.org/10.1016/B978-0-08-100707-5.00010-1

Radivojević, Lj., Đukanović, M., Roter-Blagojević, M. (2016). From tradition to modernization – Building techniques in Serbia during 19th and early 20th century. In K. Van Balen & E. Verstrynge (Eds.), *Structural analysis of historical constructions – Anamnesis, diagnosis, therapy, controls* (pp. 922-929). Taylor & Francis. ISBN 978-1-138-02951-4

Radovanović, S., & Petronijević, M. (2009). Building types and vulnerability to ground shaking in Serbia. Paper presented at the International Conference on Earthquake Engineering, Banja Luka, Bosnia and Herzegovina, October 26–28. 2009 (pp. 181-192)

Stanojević, A. D., Milošević, M. R., Milošević, D. M., Turnšek, B. A. J., Jevremović, L. Lj. (2021). Developing multi-criteria model for the protection of built heritage from the aspect of energy retrofitting. *Energy and Buildings*, 250, 111285. https://doi.org/10.1016/j.enbuild.2021.111285

Šekularac, N., Šumarac, D., Ćikić-Tovarović, J., Čokić, M., Ivanović-Šekularac, J. (2018). Re-use of historic buildings and energy refurbishment analysis via building performance simulation (BPS): A case study. *Thermal Science*, 22(Suppl. 5), 89–89. https://doi.org/10.2298/TSCI171124089S

STRATEGIC SELECTION OF A LOGISTICS CENTER LOCATION USING A HYBRID MCDM MODEL BASED ON PIPRECIA AND SAW METHODS: AN EMPIRICAL STUDY

DOI: 10.5937/EMC26087R

Adriana Radosavac
University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Republic of Serbia
E-mail: adriana.radosavac@mef.edu.rs
Oliver Momčilović
University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Republic of Serbia

ABSTRACT

The strategic selection of a logistics center location represents a complex multi-criteria problem involving economic, infrastructural, and socio-geographical factors. This paper applies a hybrid MCDM model based on the PIPRECIA and SAW methods to evaluate and rank potential locations in the Republic of Serbia. A set of ten criteria was defined, and weight coefficients were determined using the PIPRECIA method via direct and inverse procedures. The stability of the obtained weights was confirmed using Spearman's rank correlation coefficient (ρ=0.723724). The final ranking was performed using the SAW method for three alternative locations: Belgrade, Smederevo and Požarevac. The results indicate that utility infrastructure C_4, proximity to the highway C_2, and labor availability C_3 are the most important criteria. Belgrade was identified as the optimal location (score 4.26), ahead of Smederevo (3.86) and Požarevac (3.69). The research confirms that the hybrid PIPRECIA-SAW model represents an efficient and transparent decision-support tool for logistics center site selection at the regional level in Serbia.

Keywords: PIPRECIA, SAW, MCDM, Logistics Center, Strategic Planning

INTRODUCTION

Global digitalization and the widespread expectation of same-day delivery have pushed logistics beyond its traditional role as a support function, elevating it into a core source of competitive advantage. As Farahani & Hekmatfar (2009), Kayikci (2010), and the City of Požarevac (2021) have observed, choosing a location for a new logistics center is no longer simply about finding available land; it is a complex investment decision with long-term strategic consequences. An incorrect choice can lock a company into permanently high operational costs, restrict access to skilled labor, and degrade service levels, all of which directly weaken its market position.The problem of selecting an optimal location is marked by considerable uncertainty and the presence of many conflicting factors. As (Garić et al., 2024) point out, sites with excellent transport links often come with high rental and tax costs, while fiscally attractive areas may suffer from poor infrastructure or a shortage of specific labor profiles. For this reason, the academic literature classifies this type of problem as a typical multi-criteria decision-making (MCDM) problem (Hwang & Yoon, 1981; Triantaphyllou, 2000; Zavadskas et al., 2014).The aim of this paper is to implement a hybrid mathematical model that combines the subjective expertise of decision-makers with objective ranking methods. The research focuses on ten key criteria covering economic, infrastructural, and socio-geographical aspects for the strategic selection of a logistics center location in the Republic of Serbia (Mihajlović et al., 2019). Through the application of the PIPRECIA and SAW methods, the paper seeks to establish a transparent and replicable decision-making process that minimizes cognitive biases and provides an objective foundation for the final selection among three considered alternatives - the cities of Belgrade (henceforth abbreviated as A), Smederevo (B), and Požarevac (C). Similar hybrid approaches

integrating criteria weighting and ranking have also been used in other studies of logistics facilities in Serbia (Pajić et al., 2024).

THEORETICAL FRAMEWORK

The PIPRECIA Method (Determining Criterion Weights)

Developed by (Stanujkić et al., 2025), the PIPRECIA method responds to the need for simpler yet equally reliable alternatives compared to traditional approaches such as the Analytic Hierarchy Process (AHP). One of its main advantages is that it does not require decision-makers to carry out an excessive number of pairwise comparisons. With ten criteria, as in the present study, such a large number of comparisons often leads to logical inconsistencies and fatigue (Saaty, 1990; Rezaei, 2015; Govindan, et al., 2016; Stanujkić et al., 2025).

The methodological procedure is carried out in two key phases, illustrated in Figure 1 (Algorithm of the hybrid PIPRECIA-SAW model):

- Direct procedure: The decision-maker ranks the criteria and assigns to each a value sj, which represents the importance of a given criterion relative to the previously ranked one. If the criterion is more important $s_j>1$; if it is less important, $s_j<1$. Based on these values, coefficients k_j are calculated, followed by recursive values q_j, which form the basis for the normalization of weights w_j.
- Inverse (reverse) procedure: This step is essential for validating the model. The process is repeated starting from the last ranked criterion and moving backward to the first. Weights w'_j. are calculated from this reverse run. The final weight coefficients are obtained as the arithmetic mean of the values from both directions. This approach allows for the detection of so-called "resistance" in decision-making - if the differences between direct and inverse weights are too large, this indicates that the decision-maker lacks a clear hierarchy of priorities, requiring a revision of the model. Stability is further confirmed by Spearman's rank correlation coefficient (ρ), with values close to one indicating a high level of consistency (Conover, 1999; Well & Myers, 2003).

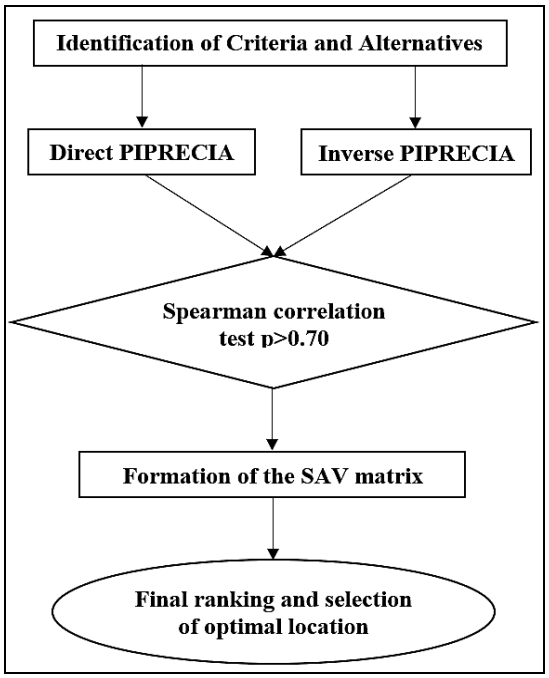


Figure 1: Algorithm of the hybrid PIPRECIA-SAW model

The SAW Method (Ranking Alternatives)

Once the criterion weights have been precisely determined, the evaluation of alternatives proceeds using the Simple Additive Weighting (SAW) method. Although it is among the oldest MCDM methods (Fishburn, 1967; MacCrimmon, 1968), SAW remains widely used in engineering practice due to its intuitive nature and mathematical transparency (Afshari et al., 2010; Özcan et al., 2011). The SAW implementation consists of three steps:

- Forming the decision matrix: The performance of each location (alternative) with respect to each criterion is entered.
- Normalization: Since criteria may have different units of measurement or different natures (e.g., costs to be minimized versus profits to be maximized), all values are scaled to the interval [0, 1]. In this study, because all evaluations were assigned on a unified scale (1-5), the focus is on linear transformation.

– Aggregation: The total score for each alternative is obtained by summing the products of the normalized score and the criterion weight coefficient.

The final score represents a weighted sum that allows us to clearly identify which location best satisfies the stated strategic goals. The SAW method was chosen for this research because it enables the decision-maker to see clearly the contribution of each individual criterion to the overall score of an alternative, thereby facilitating discussion and final acceptance of the solution.

ANALYSIS AND CALCULATIONS

The first step in applying the PIPRECIA method was to define a set of ten criteria C_1-C_{10} covering all aspects of logistics operations and three alternatives, and as shown in Tables 1 and 2.

Table 1: Defined criteria for logistics center site selection with descriptions

Criterion	Description
C_1 Land costs	Total purchase or lease costs of the plot, including associated fees
C_2 Proximity to highway	Distance from the site to key transport corridors (e.g., E-75)
C_3 Labor availability	Presence of qualified personnel and proximity to populated areas
C_4 Utilities (electricity, water, gas)	Level of site equipment (connections for electricity, gas, water)
C_5 Local taxes and incentives	Administrative costs and available investment incentives
C_6 Proximity to major customers	Geographic distance from key distribution points
C_7 Environmental regulations	Stringency of environmental norms and construction restrictions
C_8 Site security	Risk level from theft, natural disasters, or vandalism
C_9 Future expansion potential	Availability of adjacent plots for future expansion
C_{10} Telecommunication quality	Quality and availability of fiber optic and 4G/5G networks at the site

Table 2: Defined alternatives for logistics center site selection with descriptions

Alternatives	Description
Belgrade (A)	Regional center of the Republic of Serbia
Smederevo (B)	Municipality and town on the Danube, eastern part of the Republic of Serbia
Požarevac (C)	Municipality and town in the eastern part of the Republic of Serbia

The decision-maker first ranked the criteria in order of importance and then determined the relative significance s_j of each criterion relative to the previous one. In the direct procedure (Table 3), the sum of recursive values was 9.973, while in the inverse procedure (Table 4) carried out to verify precision the sum reached 11.241. In the direct procedure the first criterion C_1 is taken as the base with a value of $k_1=1$. For each subsequent criterion, the coefficient k_j was calculated according to Formula (1):

$$k_j = 2 - s_j \tag{1}$$

Based on this, the weights w_j were calculated by normalization: $w_j=q_j/\sum q_j$. In this direction, criterion C_4 (Utilities) emerged as the most important with a weight of 0.123, while C_{10} (Telecommunication quality) was the least important with a weight of 0.070.

Inverse procedure (Table 4) to verify stability, the procedure was repeated in the opposite direction, starting from C_{10} and moving to C_1. In this step, the sum of recursive values q'_j was 11.241. The weights obtained in this step (w'_j) showed slight variation. Criterion C_4 (Utilities) again ranked highest with a weight of 0.117, while C_9 (Future expansion potential) was the least important with a weight of 0.077. were determined using Formula (2):

$$q_j = \frac{q_{j+1}}{k_j} \tag{2}$$

Table 3: Weight coefficient calculation for the direct procedure of the PIPRECIA method

Criterion	s_j	$k_j=2-s_j$	$q_j=q_{j-1}/k_j$	w_j	rank
C_1 Land costs		1.00	1.000	0.100	**6**
C_2 Proximity to highway	1.05	0.95	1.053	0.106	**4**
C_3 Labor availability	1.05	0.95	1.108	0.111	**3**
C_4 Utilities (electricity, water, gas)	1.10	0.90	1.231	0.123	**1**
C_5 Local taxes and incentives	0.80	1.20	1.026	0.103	**5**
C_6 Proximity to major customers	1.15	0.85	1.207	0.121	**2**
C_7 Environmental regulations	0.75	1.25	0.966	0.097	**7**
C_8 Site security	0.95	1.05	0.920	0.092	**8**
C_9 Future expansion potential	0.80	1.20	0.766	0.077	**9**
C_{10} Telecommunication quality	0.90	1.10	0.697	0.070	**10**
			9.973	1.000	

Table 4: Weight coefficient calculation for the inverse procedure of the PIPRECIA method

Criterion	$s`_j$	$k`_j=2-s`_j$	$q`_j=q`_{j+1}/k`_j$	$w`_j$	rank*
C_{10} Telecommunication quality		1	1.000	0.089	**9**
C_9 Future expansion potential	0.85	1.15	0.870	0.077	**10**
C_8 Site security	1.15	0.85	1.023	0.091	**8**
C_7 Environmental regulations	1.20	0.80	1.279	0.114	**2**
C_6 Proximity to major customers	0.80	1.20	1.066	0.095	**6**
C_5 Local taxes and incentives	1.10	0.90	1.184	0.105	**5**
C_4 Utilities	1.10	0.90	1.316	0.117	**1**
C_3 Labor availability	0.90	1.10	1.196	0.106	**4**
C_2 Proximity to highway	1.05	0.95	1.259	0.112	**3**
C_1 Land costs	0.80	1.20	1.049	0.093	**7**
			11.241	1.000	

Final weights (Table 5) were obtained as the arithmetic mean of both procedures, thereby neutralizing potential extremely subjective assessments. The key weights favor C_4 (Utilities) with 0.115, C_2 (Proximity to highway) with 0.109, C_3 (Labor availability) with 0.109, and C_6 (Proximity to major customers) with 0.108. The least important criterion is C_9 (Future expansion potential) with a weight of 0.077. Final weights are calculated using Formula (3):

$$\bar{\omega}_j = \frac{\omega_j + \omega'_j}{2} \tag{3}$$

Table 5: Comparative presentation of weights and calculation of final weights

Criterion	$(w_j+w`_j)/2$	rank(fin)
C_1 Land costs	0.097	**7**
C_2 Proximity to highway	0.109	**2**
C_3 Labor availability	0.109	**3**
C_4 Utilities (electricity, water, gas)	0.115	**1**
C_5 Local taxes and incentives	0.104	**6**
C_6 Proximity to major customers	0.108	**4**
C_7 Environmental regulations	0.105	**5**
C_8 Site security	0.092	**8**
C_9 Future expansion potential	0.077	**10**
C_{10} Telecommunication quality	0.079	**9**
	0.995	

To confirm that the subjective assessments were not contradictory, Spearman's rank correlation coefficient (ρ). was applied (Table 6). Rankings were performed for both sets of weights (w_{ji} i w'_j). Some deviations were observed, particularly for C_7 (Environmental regulations) with a squared difference of 25 and C_6 (Proximity to major customers) with a squared difference of 16. The resulting

Spearman coefficient (ρ=0.723724), confirms that the model is ready for the ranking phase of alternatives. The calculation was carried out according to Formula (4):

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \quad (4)$$

Table 6: Rank difference matrix and calculation of Spearman's correlation coefficient (ρ)

Criterion	rank	rank*	rank - rank*	(rank - rank*)^2
C_1 Land costs	6	7	-1	1
C_2 Proximity to highway	4	3	1	1
C_3 Labor availability	3	4	-1	1
C_4 Utilities (electricity, water, gas)	1	1	0	0
C_5 Local taxes and incentives	5	5	0	0
C_6 Proximity to major customers	2	6	-4	16
C_7 Environmental regulations	7	2	5	25
C_8 Site security	8	8	0	0
C_9 Future expansion potential	9	10	-1	1
C_{10} Telecommunication quality	10	9	1	1
			Sum:	**46**

In the second part of the analysis the SAW method (Table 7) was applied to the three potential locations Belgrade (A), Smederevo (B), and Požarevac (C), using scores on a scale from 1 to 5. Figure 2 presents a comparative overview of the importance of the alternatives (radar chart of final weights) for all alternatives. Based on the results, we can conclude that alternative A (Belgrade) performs best, followed by alternative B (Smederevo), with alternative C (Požarevac) ranking third.

Table 7: Decision matrix with alternative scores (A, B, C) by criterion and SAW ranking results

Criterion	$(w_j+w`_j)/2$	A (Belgrade)	B (Smederevo)	C (Požarevac)
C_1 Land costs	0.097	5	4	2
C_2 Proximity to highway	0.109	4	4	4
C_3 Labor availability	0.109	5	3	4
C_4 Utilities (electricity, water, gas)	0.115	5	5	5
C_5 Local taxes and incentives	0.104	3	4	3
C_6 Proximity to major customers	0.108	4	3	4
C_7 Environmental regulations	0.105	3	3	3
C_8 Site security	0.092	5	5	4
C_9 Future expansion potential	0.077	4	4	5
C_{10} Telecommunication quality	0.079	5	4	3
Sum:		**4.26**	**3.86**	**3.69**
rank		**1**	**2**	**3**

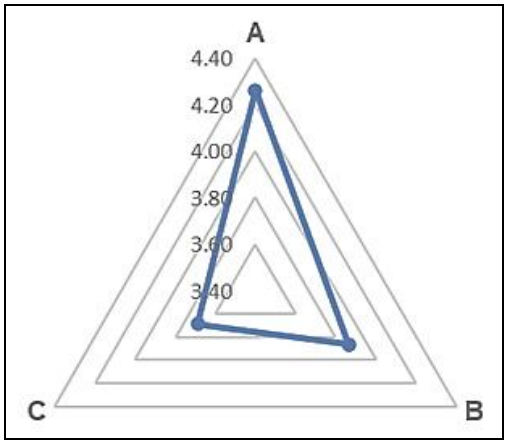


Figure 2: Comparative overview of alternative importance (Radar chart of final weights)

FINDINGS & DISCUSSION

Model stability - Spearman's rank correlation coefficient between the rankings obtained from the direct and inverse procedures is ρ=0.724. Although this value is not extremely high (close to 1), it falls within the range of acceptable consistency for subjective assessments in MCDM procedures (Conover, 1999; Well & Myers, 2003). The deviations are most pronounced for criteria C_7 (Environmental regulations) and C_6 (Proximity to major customers), as can be seen in Table 6.

These two criteria evidently introduce greater uncertainty for the decision-maker environmental regulations can be either a constraint or an incentive, while proximity to customers may be valued differently depending on whether the center's function is distributive or transit. Despite these deviations, the overall correlation is sufficiently high to justify using the average weights.Ranking of alternatives - based on the final weights and the scores in Table 6, the SAW method produced the following order: first place belongs to alternative A (Belgrade) with a total score of 4.26, followed by alternative B (Smederevo) with 3.86, and finally alternative C (Požarevac) with 3.69. The difference between the first- and second-ranked locations is 0.40 points, which is quite substantial on a 1-5 scale. Belgrade leads due to excellent scores for land costs (5), labor availability (5), infrastructure (5), security (5), and telecommunication quality (5). Smederevo has somewhat lower scores for labor (3) and proximity to customers (3), while Požarevac lags primarily because of higher land costs (2) and lower telecommunication quality (3). Interestingly, all three alternatives received the maximum score of 5 for criterion C_4 (Utilities), because basic utility connections are not a differentiating factor in this district. In contrast, land costs C_1 and telecommunication quality C_{10} proved to be key differentiators.Compared to similar studies in Serbia (Pajić et al., 2024), the obtained results confirm that regional centers (Belgrade) have an advantage over smaller municipalities when the SAW method is applied with a larger number of criteria. However, unlike some earlier works that favored locations solely based on transport accessibility, here human resources and security also played a significant role. Strategic planning of logistics centers in Serbia has become a full-fledged multi-criteria problem.

CONCLUSIONS AND IMPLICATIONS

This study aimed to apply a hybrid MCDM model based on the PIPRECIA and SAW methods for the strategic selection of a logistics center location in the Republic of Serbia. Based on the conducted analysis, the following conclusions can be drawn:

- The hybrid PIPRECIA-SAW model proved to be operationally feasible and transparent as a decision-support tool. The decision-maker successfully ranked ten criteria and assigned them weights without the need for a large number of pairwise comparisons. The Spearman coefficient of 0.724 confirms acceptable stability of the assessments, despite individual deviations for environmental and market criteria.
- The obtained weights show that under the conditions of the Republic of Serbia, the most important criteria are utility infrastructure (C_4), proximity to the highway (C_2), and labor availability (C_3). Together, these factors form the foundation for successfully positioning a logistics center. On the other hand, future expansion potential C_9 and telecommunication quality C_{10} received the lowest weights, which can be interpreted either as an assessment that these conditions are already satisfied at all locations, or as a short-term orientation on the part of the decision-maker.
- The SAW method determined that Belgrade (alternative A) is the highest-ranked location, ahead of Smederevo (B) and Požarevac (C). Belgrade achieves its advantage through balanced high scores for land costs, labor, infrastructure, and security. Smederevo and Požarevac lag primarily in the areas of human resources and telecommunications.

The research has certain limitations. First and foremost, this is a case study referring to only three alternatives. Generalizing the conclusions to other regions would require repeating the procedure with locally adapted criteria and a larger number of decision-makers. Additionally, the scores in the SAW matrix were given on an ordinal 1-5 scale, which is practical but does not constitute interval measurement. Future research could extend the model in several directions:

- Including a larger number of decision-makers and applying aggregation techniques (e.g., copula methods);
- Using fuzzy extensions of the PIPRECIA and SAW methods to handle uncertainty;
- Comparing the results with other MCDM methods (e.g., TOPSIS, PROMETHEE, ELECTRE); and
- Conducting a sensitivity analysis by varying the weights of the most important criteria.

In practical terms, the results provide a useful framework for local governments and investors in the Republic of Serbia. The recommendation is that when negotiating logistics center locations, special attention should be paid to improving conditions at locations Smederevo (B) and Požarevac (C), particularly regarding labor availability and telecommunications infrastructure, so that they can become more competitive relative to Belgrade (A).

REFERENCES

Afshari, A., Mojahed, M., & Yusuff, R. M. (2010). Simple additive weighting approach to personnel selection problem. *International Journal of Innovation, Management and Technology, 1*(5), 511–515.

Conover, W. J. (1999). *Practical nonparametric statistics* (3rd ed.). Wiley.

Farahani, R. Z., & Hekmatfar, M. (2009). *Facility location: Concepts, models, algorithms and case studies*. Springer. https://doi.org/10.1007/978-3-7908-2151-2

Fishburn, P. C. (1967). Additive utilities with incomplete product sets. *Operations Research, 15*(3), 537–542. https://doi.org/10.1287/opre.15.3.537

Garić, N., Pajić, V., & Andrejić, M. (2024). A comprehensive model for calculating the LPI index of key transport corridors in Serbia. *Journal of Operational and Strategic Analytics, 2*(3), 177–192. https://doi.org/10.56578/josa020304

Govindan, K., Khodaverdi, R., & Vafadarnikjoo, A. (2016). Intuitionistic fuzzy based DEMATEL method. *Expert Systems with Applications, 42*(20), 7207–7220. https://doi.org/10.1016/j.eswa.2015.04.030

Hwang, C. L., & Yoon, K. (1981). *Multiple attribute decision making: Methods and applications*. Springer. https://doi.org/10.1007/978-3-642-48318-9

Kayikci, Y. (2010). Intermodal freight logistics centre location decisions. *Procedia Social and Behavioral Sciences, 2*(3), 6297–6311. https://doi.org/10.1016/j.sbspro.2010.04.039

MacCrimmon, K. R. (1968). *Decisionmaking among multiple-attribute alternatives*. RAND Memorandum.

Mihajlović, J., Rajković, P., Petrović, G., & Ćirić, D. (2019). The selection of the logistics distribution center location based on MCDM methodology in southern and eastern region in Serbia. *Operational Research in Engineering Sciences: Theory and Applications, 2*(2), 72–85. https://doi.org/10.31181/oresta190247m

Özcan, T., Çelebi, N., & Esnaf, Ş. (2011). Comparative analysis of MCDM methodologies and warehouse location selection. *Expert Systems with Applications, 38*(8), 9773–9779. https://doi.org/10.1016/j.eswa.2011.02.022

Pajić, V., Andrejić, M., Jolović, M., & Kilibarda, M. (2024). Strategic warehouse location selection in business logistics: A novel approach using IMF SWARA–MARCOS. *Mathematics, 12*(5), 776. https://doi.org/10.3390/math12050776

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega, 53*, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research, 48*, 9–26.

Stanujkić, M., Mirčetić, V., Stanujkić, D., Karabašević, D., Popović, G., Saračević, M., & Brzaković, P. (2025). A new hybrid MCDM model for personnel selection in the mining industry based on the PIPRECIA-S, CRITIC, and WISP methods. *Acta Montanistica Slovaca*. https://doi.org/10.46544/AMS.v30i3.18

Triantaphyllou, E. (2000). *Multi-criteria decision making methods: A comparative study*. Springer. https://doi.org/10.1007/978-1-4757-3157-6

Well, A. D., & Myers, J. L. (2003). *Research design & statistical analysis* (2nd ed.). Psychology Press. https://doi.org/10.4324/9781410607034

Zavadskas, E. K., Turskis, Z., & Kildienė, S. (2014). State of art surveys of overviews on MCDM/MADM methods. *Technological and Economic Development of Economy, 20*(1), 165–179. https://doi.org/10.3846/20294913.2014.892037

City of Požarevac. (2021). *Invest in Požarevac*. Retrieved March 5, 2026, from https://pozarevac.rs/wp-content/uploads/2021/06/Invest-in-Pozarevac.pdf

INNOVATION AND TECHNOLOGICAL CHANGES IN SUPPLY CHAINS

DOI: 10.5937/EMC26094S

László Szabó
Budapest University of Economics and Business, Faculty of Marketing and Business Communication, Budapest, Hungary
E-mail: szabo.laszlo4@uni-bge.hu

ABSTRACT

The supply chains have undergone significant transformation in recent decades due to rapid technological development, digitalization, globalization, and changing customer expectations. Innovation has become a critical factor in maintaining supply chain competitiveness, resilience, and sustainability. The most important technological changes and innovations influencing modern supply chains, including automation, artificial intelligence, blockchain technology, Internet of Things (IoT), big data analytics, and sustainable logistics solutions. Technological innovation substantially improves supply chain visibility, operational efficiency, flexibility, and decision-making processes. However, implementation challenges such as high investment costs, cybersecurity risks, and workforce adaptation remain significant barriers.

Key words: Supply chain, Innovation, Digitalization, Artificial intelligence, Logistics

INTRODUCTION

The traditional supply chains focused primarily on cost reduction and operational efficiency. However, modern supply chains increasingly emphasize flexibility, resilience, digital connectivity, and sustainability. Technological innovations enable organizations to optimize transportation, inventory management, warehousing, forecasting, and customer service processes more effectively than ever before (Ivanov & Dolgui, 2020).

The COVID-19 pandemic further highlighted the importance of technological adaptation in supply chains. Companies with advanced digital capabilities were better able to manage disruptions, monitor inventory, and respond rapidly to unexpected market changes (Queiroz et al., 2020). The purpose of this paper is to identify the most significant innovations and technological changes affecting supply chains and to illustrate their impact on logistics and supply chain performance.

DIGITAL TRANSFORMATION IN SUPPLY CHAINS

Digital transformation refers to the integration of digital technologies into supply chain operations and organizational processes. It fundamentally changes how companies collect, analyze, and utilize information.

One of the most important aspects of digital transformation is real-time data availability. Modern supply chains increasingly rely on digital platforms, cloud computing, and integrated information systems to improve coordination between suppliers, manufacturers, distributors, and customers (Winkelhaus & Grosse, 2020).

The main benefits of digital transformation are generally as follows:
– greater operational transparency,
– faster decision-making,

- more effective communication,
- lower operating costs,
- greater flexibility,
- better customer service.

However, digital transformation also creates challenges. Companies often face high implementation costs, integration difficulties, and cybersecurity risks. Small and medium-sized enterprises may encounter additional barriers due to limited financial and technological resources (Kache & Seuring, 2017).

AUTOMATION AND ROBOTICS

Automation has become one of the most important technological trends in supply chain management. Warehouses, production systems, and transportation operations increasingly utilize automated technologies and robotics solutions.

Automated Guided Vehicles (AGVs), autonomous mobile robots (AMRs), and robotic picking systems significantly improve warehouse efficiency and reduce labor dependency. These technologies increase speed, accuracy, and productivity while minimizing human error (Boysen et al., 2019). Example: intelligent AGV in warehouse (see also Figure 1).

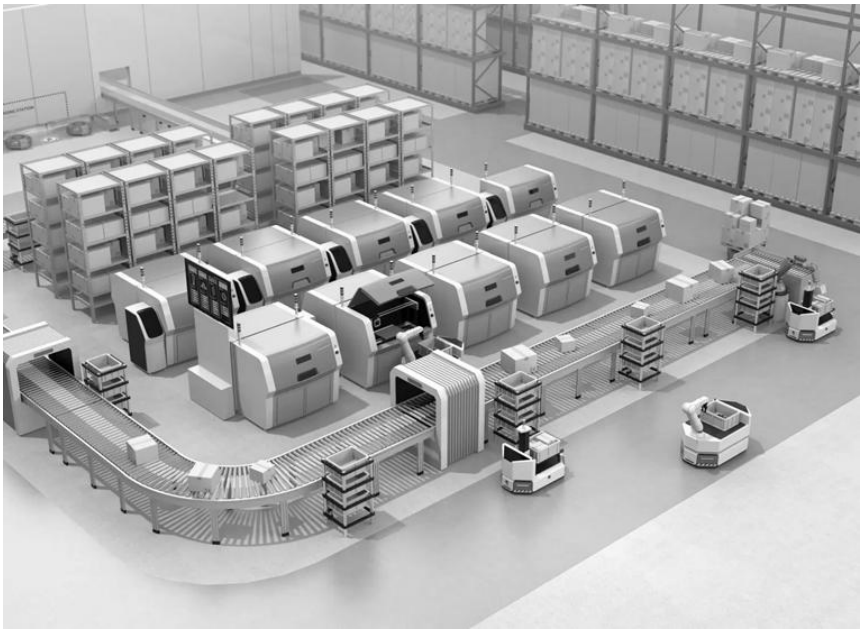


Figure 1: AGV in warehouse (Source: JHCTECH)

The growth of e-commerce has accelerated warehouse automation worldwide. Companies such as Amazon and Alibaba are investing significant amounts of money in robotic logistics centers to meet the ever-growing consumer demand for fast delivery services.

ARTIFICIAL INTELLIGENCE AND BIG DATA ANALYTICS

Artificial intelligence (AI) and big data analytics have radically transformed decision-making processes in the supply chain. Modern supply chains generate vast amounts of data from transportation systems, warehouses, sensors, customer transactions, and manufacturing operations.

Big data analytics improves supply chain visibility and operational transparency. Real-time data processing enables companies to identify disruptions quickly and respond proactively to changing

market conditions (Wamba et al., 2017). Example: top innovations in the supply chains (see also Figure 2).

Applications of AI in supply chains include:
- demand forecasting,
- predictive maintenance,
- route optimization,
- inventory optimization,
- supplier risk analysis,
- customer behavior analysis.

BLOCKCHAIN TECHNOLOGY AND SUPPLY CHAIN TRANSPARENCY

Blockchain technology has emerged as a promising innovation in the field of supply chain management. Blockchain is a decentralized digital ledger system that enables secure, transparent, and immutable data sharing among supply chain participants.

One of the major advantages of blockchain technology is improved traceability. Companies can track products from raw materials to final consumers, which increases transparency and reduces risks for fraud (Saberi et al., 2019).

Blockchain applications in supply chains include:
- product traceability,
- smart contracts,
- anti-counterfeiting systems,
- transaction security,
- supplier verification,
- sustainability monitoring.

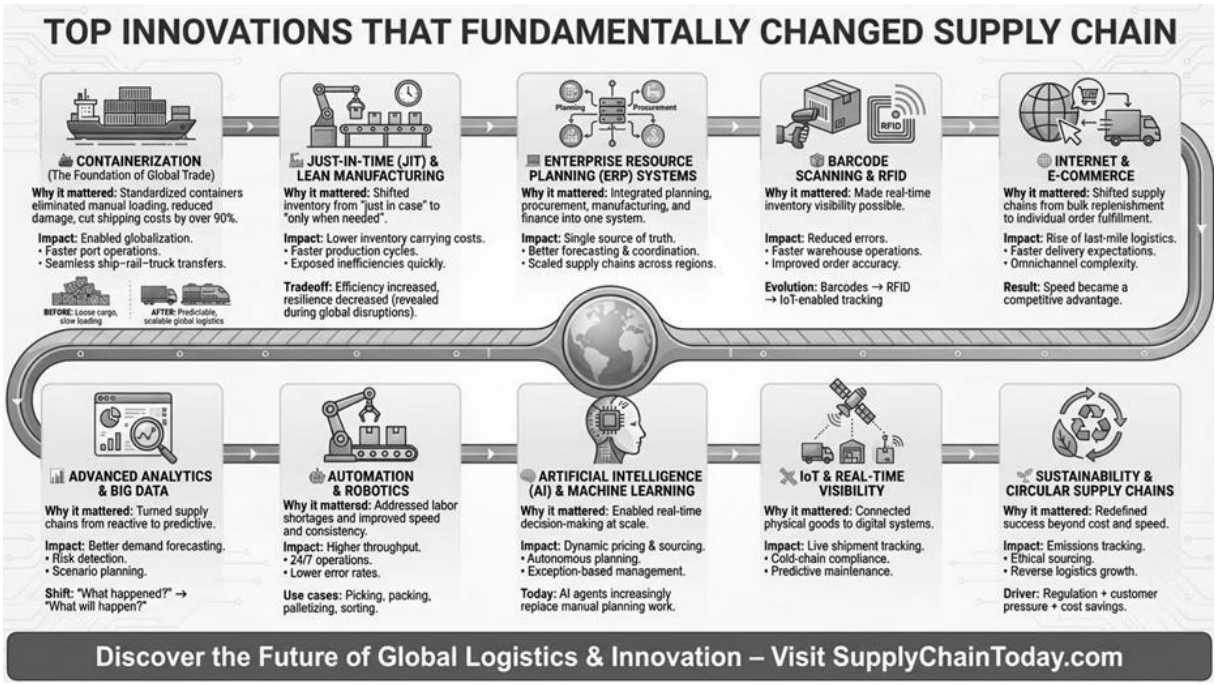


Figure 2: Top innovations in the supply chains (Source: Supply Chain Today)

INTERNET OF THINGS (IOT) AND SMART SUPPLY CHAINS

The Internet of Things (IoT) refers to interconnected devices and sensors capable of collecting and exchanging data through digital networks. IoT technologies have significantly improved supply chain visibility and monitoring capabilities.

IoT systems are especially important in cold chain logistics, where temperature-sensitive products require continuous monitoring. Real-time tracking improves transportation security and reduces the risk of product damage (Ben-Daya et al., 2019).

Smart sensors installed in vehicles, warehouses, and containers provide real-time information regarding:
- location,
- temperature,
- humidity,
- vehicle condition,
- inventory levels,
- delivery status.

SUSTAINABILITY AND GREEN SUPPLY CHAIN INNOVATION

Sustainability has become a central strategic priority in supply chain management. Governments, customers, and investors increasingly expect companies to reduce environmental impacts and adopt sustainable business practices.

Technological innovation plays a crucial role in achieving sustainability objectives. Route optimization software, AI-supported transportation planning, and automated warehouse systems can reduce energy consumption and emissions significantly (Srivastava, 2007).

The green supply chain innovation includes:
- alternative fuel transportation,
- electric vehicles,
- energy-efficient warehouses,
- reverse logistics,
- recyclable packaging,
- carbon footprint reduction strategies.

Sustainable technologies often require substantial financial investment, which may create barriers for smaller enterprises. Example: innovations in supply chain management (see also Figure 3).

CONCLUSION

Innovation and technological change have fundamentally transformed modern supply chains. At the same time, technological transformation also poses significant challenges, including high implementation costs, cybersecurity threats, difficulties in workforce adaptation, and regulatory complexity.

Future supply chains are expected to become increasingly autonomous, interconnected, data-driven, and sustainable. Therefore, organizations must continuously invest in innovation, the development of technological capabilities, and employee training to remain competitive in an ever-changing global business environment.

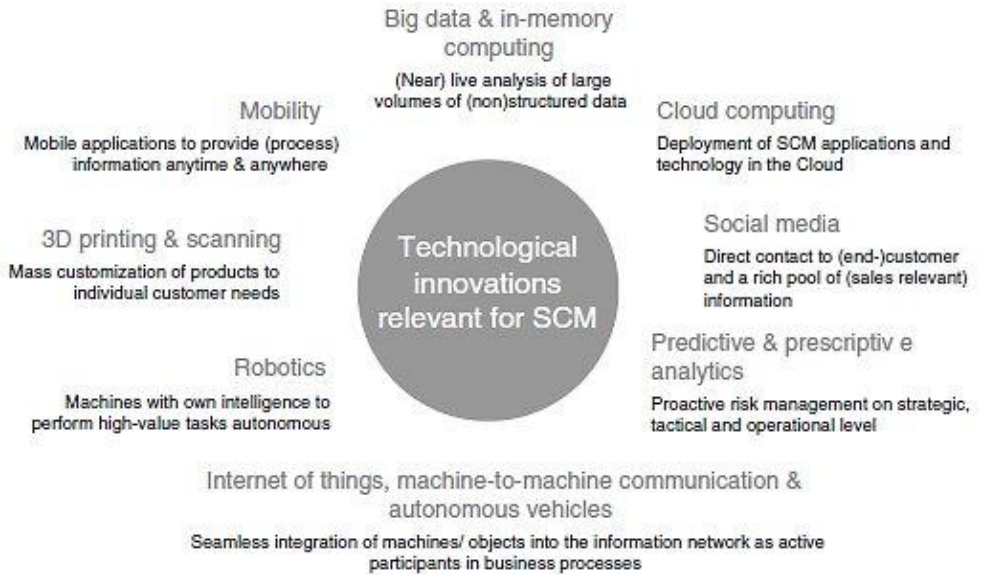


Figure 3: Innovations in supply chain management (Source: Farahani et al., 2017)

Companies that successfully integrate advanced technologies into their supply chain operations can gain significant competitive advantages through improved operational performance and increased customer satisfaction. Furthermore, technological innovation supports sustainability goals and helps organizations respond more effectively to global disruptions and market uncertainty.

REFERENCES

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of Things and supply chain management: A literature review. *International Journal of Production Research, 57*(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140

Farahani, P., Meier, C., & Wilke, J. (2017). Digital supply chain management agenda for the automotive supplier industry. In *Shaping the digital enterprise* (pp. 157–172). Springer.

Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. *International Journal of Production Research, 58*(10), 2904–2915. https://doi.org/10.1080/00207543.2020.1750727

JHCTECH. (2026). *Intelligent AGV logistics warehousing solution*. Retrieved May 20, 2026, from https://www.jhc-technology.com/intelligent-agv-logistics-warehousing-solution

Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. *International Journal of Operations & Production Management, 37*(1), 10–36. https://doi.org/10.1108/IJOPM-02-2015-0078

Queiroz, M. M., Ivanov, D., Dolgui, A., & Wamba, S. F. (2022). Impacts of epidemic outbreaks on supply chains: Mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Annals of Operations Research, 319*, 1159–1196. https://doi.org/10.1007/s10479-020-03685-7

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research, 57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Srivastava, S. K. (2007). Green supply-chain management: A state-of-the-art literature review. *International Journal of Management Reviews, 9*(1), 53–80. https://doi.org/10.1111/j.1468-2370.2007.00202.x

Supply Chain Today. (2026). *Top supply chain innovations that transformed the global economy*. Retrieved May 20, 2026, from https://www.supplychaintoday.com/top-supply-chain-innovations-that-transformed-the-global-economy/

Wamba, S. F., Gunasekaran, A., Akter, S., Ren, S. J.-F., Dubey, R., & Childe, S. J. (2017). Big data analytics and firm performance: Effects of dynamic capabilities. *Journal of Business Research, 70*, 356–365. https://doi.org/10.1016/j.jbusres.2016.08.009

Winkelhaus, S., & Grosse, E. H. (2020). Logistics 4.0: A systematic review towards a new logistics system. *International Journal of Production Research, 58*(1), 18–43. https://doi.org/10.1080/00207543.2019.1612964

LINKING ORGANIZATIONAL CULTURE, QUALITY AND AGILITY TO BUSINESS PERFORMANCE: A CROSS-COUNTRY CLUSTER ANALYSIS OF A TRANSPORTATION SUPPLY CHAIN

DOI: 10.5937/EMC26099S

Vesna Spasojević Brkić
University of Belgrade, Faculty of Mechanical Engineering Belgrade, Republic of Serbia
E-mail: vspasojevic@mas.bg.ac.rs
Branislav Tomić
Bombardier Aerospace, Canada
Iva Savić
University of Belgrade, Faculty of Mechanical Engineering Belgrade, Republic of Serbia
Martina Perišić Jokić
University of Belgrade, Faculty of Mechanical Engineering Belgrade, Republic of Serbia
Abdulghder Alsharif
University of Belgrade, Faculty of Mechanical Engineering Belgrade, Republic of Serbia

ABSTRACT

This paper develops a configurational, cross-country taxonomy of organizational culture and quality management practices in a global transportation supply chain. Data were collected from 47 companies across 25 countries within the supply chain of a multinational railway transport manufacturer. Four composite indices - Human Capital, Agility, Communication and Formalization, and Quality, were measured through a structured Likert-scale questionnaire and its reliability is validated using Cronbach's alpha. Hierarchical cluster analysis is done by Ward's method and has identified four distinct organizational clusters, statistically validated by one-way ANOVA. The Mann-Whitney U-test was then applied to compare the resulting clusters in terms of business performance. Results show that the cluster combining strong agility, developed human capital and high-quality practices significantly outperform clusters with weak agility or underdeveloped quality systems, while a cluster characterized by mature, highly formalized quality and communication practices achieves comparable performance. The study confirms that two distinct organizational configurations can lead to top-tier business performance and offers practical implications for multinational manufacturers managing geographically dispersed suppliers.

Keywords: Organizational culture, Supply chain, Cluster analysis, Quality management, Business performance

INTRODUCTION

The transportation supply chain operates as a globally distributed system where all providers from culturally diverse environments coordinate to deliver complex products (Czerniachowicz, 2017), and operational excellence depends not only on technology and process efficiency (Tortorella et al., 2021), but increasingly on aligning organizational culture, human capital practices, communication systems and quality methodologies across geographically dispersed organizations (Spasojević-Brkić, 2013; Tomic et al., 2017). Organizational culture is identified as a critical antecedent of performance, agility and competitiveness (Carvalho et al., 2017, 2023; Felipe Llanos et al., 2017; Tomic et al., 2017). However, empirical studies examining how these dimensions co-occur across countries within a supply chain remain limited, particularly in the railway transportation industry, where lead times are long and safety requirements are stringent (Gholamizadeh et al., 2022; Hajiaghaei-Keshteli et al., 2014). This paper aims to address this gap by developing an empirically grounded taxonomy of organizational profiles within the transportation supply chain of a multinational railway manufacturer. Drawing on data from 47 companies across 25 countries, 4 composite indices are constructed as inputs in hierarchical cluster analysis and later compared in terms of business performance to test if organizations integrating a strong quality culture with developed human capital practices achieve superior business performance. After introduction, section 2 reviews prior research, section 3 outlines methodology, section 4

presents cluster analysis, section 5 gives performance comparisons, and the paper concludes with findings, implications, and limitations.

PREVIOUS RESEARCH

The relationship between organizational culture and operational performance has attracted considerable academic attention over the past two decades. Foundational work by Naor et al. (2008) demonstrated, on a sample of 189 manufacturing plants across nine countries, that organizational culture is a significant antecedent of infrastructure quality management practices, which in turn drive manufacturing performance more strongly than core quality techniques alone. Naor et al. (2010) further showed that organizational culture can attenuate the influence of national culture on operational strategy, suggesting that strong corporate cultures partially "neutralize" cross-country differences within supply chains. Hult et al. (2007) argued that a culture of competitiveness and continuous knowledge development is a determinant of strategic supply chain performance. Kaynak and Hartley (2008) extended quality management to the supply chain level and confirmed positive operational and financial effects. Sila et al. (2006) provided early empirical evidence that quality practices are unevenly distributed across supply chain partners and that this heterogeneity affects overall chain performance.

Recent studies (Spasojević Brkić, 2013; Tomic et al., 2017) confirmed, in a multinational transportation supply chain context, the joint effect of quality tools, organizational culture and human capital practices on business performance. Building on this stream, Tomic & Spasojević Brkić (2018) further demonstrated that ISO 9001 improvement requirements in multinational supply chains directly shape customer satisfaction outcomes, reinforcing the link between standardized quality practices and downstream business performance. Supply chain agility has emerged as a parallel research stream. Braunscheidel and Suresh (2009) identified internal organizational antecedents, such as learning orientation and integration, of supply chain agility used for risk mitigation, while Chan et al. (2017) combined agility and flexibility to improve performance results. The recent meta-analysis by Alfalla-Luque et al. (2023), based on 63 empirical studies and 14,469 firms, established a large and positive correlation between supply chain agility and performance, highlighting persistent heterogeneity across industries and economic regions. Geyi et al. (2020) further demonstrated that agile capabilities are necessary, though not sufficient, conditions for sustainable supply chain performance, while Kim and Chai (2017) emphasized the role of supplier innovativeness and information sharing as agility enablers. The framework has recently been extended to digital and smart supply chains by Sharma et al. (2024).

The configurational perspective, on which this paper builds, had less empirical attention. Cao et al. (2015) applied a contingency and configuration approach and identified organizational culture profiles: Hierarchical, Flexible, Flatness, and Across-the-Board, with significantly different supply chain integration outcomes. Zanon et al. (2021) showed using grey clustering combined with fuzzy cognitive maps, that supply chain performance depends on coherent cultural configurations. Despite these advances, empirical configurational studies that simultaneously examine human capital, agility, communication and formalization, and quality across countries within a transportation supply chain remain scarce. The present paper addresses this gap.

METHODOLOGY

Data were collected from 47 companies, as units of analysis, across 25 countries worldwide, within the supply chain of a multinational railway transport manufacturer, where structured questionnaires were distributed to employees of the transportation supply chain. The questionnaire is designed to be answered by the Likert five-point scale (1 represents ‘strongly disagree’, 5 reflects ‘strongly agree’). The general structure of the questionnaire described in detail in Spasojević Brkić et al. (2013) and Tomic et al. (2017) herein is organized into 4 main groups, which obtain key features (indexes) for the analysis. The Human Capital Index measures employee care levels, reward systems, expectations of employees in terms of their professional development and advancement. The Agility Index evaluates responsiveness when external factors influence internal processes, speeding up operations for achieving competitiveness, cycle-time reduction, structured approval system for innovations, and decision-making processes. The Communication and Formalization Index evaluates communication effectiveness, information availability, its link to motivation, formal and informal

channels, importance of formalization and documentation in organizations. The Quality Index shows the levels of utilization of quality improvement methods such as Plan-Do-Check-Act (PDCA), Kaizen and Six Sigma. The following part of the paper is focused on cluster analysis, which is applied to group similar countries within the transportation supply chain based on these indexes and later on the generated clusters and compared in order to examine links between cluster characteristics and business performance.

The reliability of the 4 conducted indexes is determined by the Cronbach Alpha coefficient, where the obtained scores for each index of the analysis are presented in Table 1. According to Adeniran (2025) and Taber (2018), the preferable values of the Cronbach Alpha are between 0.70 and 0.95, which means that all Cronbach's alpha values (Table 1) are within the acceptable range. The Quality Index achieved the highest score for reliability (0.908), followed by the Human Capital Index (0.854) and the Agility Index (0.812). The Communication and Formalization index obtained lower, but acceptable values for further analysis, 0.724. The results of the One-way ANOVA analysis (Table 1) indicate that there are statistically significant differences between the 4 clusters for all analysed Indexes ($p < 0.01$). The largest differences were identified for the Agility Index ($F = 33.396$). The Human Capital Index has the lowest F values, indicating smaller differences between clusters. Table 2 shows the number of countries grouped in each cluster. Cluster 4 is the largest (32%), followed by Cluster 3 (28%), Cluster 2 (24%), while Cluster 1 is the smallest cluster (16%), half the size of Cluster 4.

Table 1: Cronbach's alpha values and One-way ANOVA results

Index	Cronbach's alpha value	F value	p-value
Human Capital	0.854	8.686	0.001
Agility	0.812	33.396	0.000
Communication and Formalization	0.724	11.783	0.000
Quality	0.908	14.443	0.000

Table 2: Frequency of Clusters in Ward Method

		Frequency	Percent	Cumulative Percent
Valid	1	4	16.0	16.0
	2	6	24.0	40.0
	3	7	28.0	68.0
	4	8	32.0	100.0

Figure 1 depicts dendrogram and clusters formed based on similarities across evaluation indexes. Cluster 1 groups Canada, USA, France and Germany. Cluster 2 groups Mexico, Brazil, Czech Republic, Norway and Poland. Cluster 3 groups Denmark, Italy, Hungary, China, Romania, South Africa and Thailand. Cluster 4 groups Sweden, Switzerland, UK, Austria, Finland, Spain, Australia and India.

The descriptive statistics values in Table 3 are used in order to examine the clusters' performances based on the proposed indexes of the analysis. Cluster 2 is identified as 'Poor' performance Cluster, given that it achieved the drastically lowest values in terms of organizations' agility (1.81), while achieving moderate value in terms of human capital (2.34), that is slightly higher than Cluster 3. Cluster 4 is identified as the overall best performing cluster, defined as 'Excellent' performance cluster, as it achieved the highest overall values in the Agility (3.68) and Human Capital (3.22) Indexes, second highest values for the Quality Index (3.46), and slightly lower values for the Communication and Formalization Index (3.11) compared to Cluster 1. Cluster 1 is defined as the 'Very Good', but smaller in terms of size, performance cluster. It achieved overall highest values for the Communication and Formalization and Quality Indexes, with the mean values of 3.36 and 3.99, but had low values for Agility Index (2.20), while achieving moderate mean values in terms of Human Capital Index (2.58). Cluster 3 is the 'Moderate' performance cluster, given its high value for Agility Index, that is drastically higher than Cluster 2 values, but still achieved lower overall values for the other 3 Indexes. Cluster 2 and 3 achieved similar scores in Human Capital Index.

In order to test the hypothesis regarding the potential relationship between cluster performance in terms of generated indexes, and the new area of analysis, as proposed, business performance of the organizations, further statistical analysis is conducted, for assessing the clusters' effectiveness in the aspects of their market and

financial achievements, operations and process progress and improvements, employees commitment, plans and possibilities for investments and customer related aspects (Spasojević-Brkić, 2013; Tomic et al., 2017). Descriptive statistics of business performance across the four clusters (Table 4) provides values for the number of the non-missing values as valid N, mean, median, minimum and maximum, range, standard deviation (SD), and coefficient of variation (CV). Cluster 4 contains the largest number of obtained values (240), followed by Cluster 3 (210), while Cluster 2 and Cluster 1 have fewer, 150 and 120. Highest mean values are achieved by Cluster 1, followed by Cluster 4, while Cluster 2 and 3 show lower values. All CV values for the identified clusters are below 30%, indicating moderate dispersion of the responses.

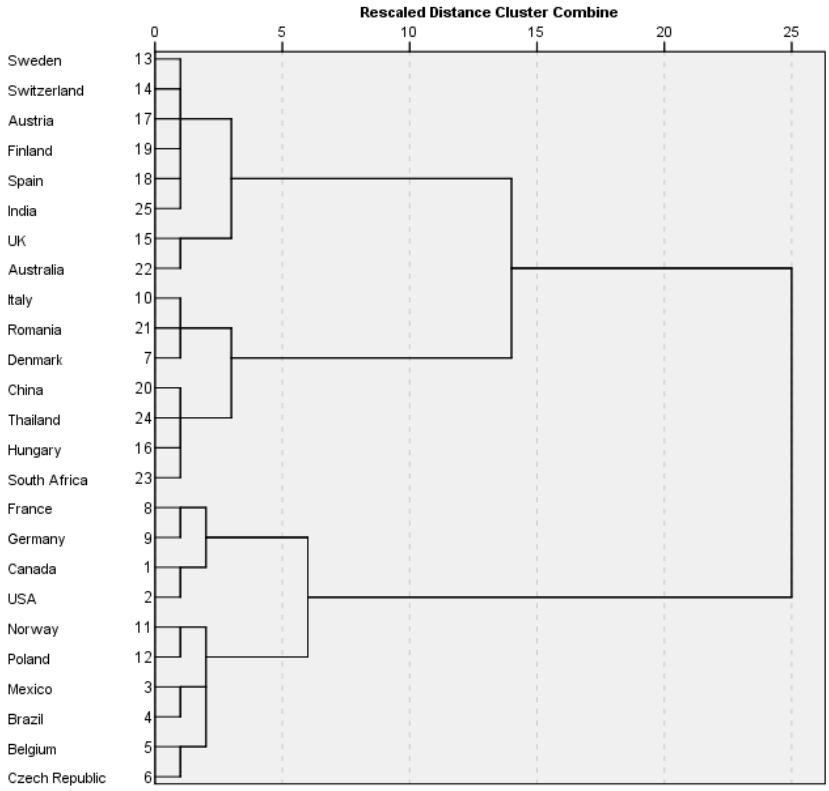


Figure 1: Dendrogram using Ward Linkage

Table 3: Mean values of clusters – Ward Method

Ward Method		Agility Index	Communication and Formalization Index	Human Capital Index	Quality Index
1	Mean	2.2000	3.3583	2.5729	3.9954
	SD	0.2828	0.1658	0.4557	0.2584
2	Mean	1.8111	2.8667	2.3444	3.0185
	SD	0.3513	0.2338	0.4925	0.3401
3	Mean	3.1619	2.3595	2.3095	2.7910
	SD	0.4821	0.3641	0.3276	0.2576
4	Mean	3.6825	3.1088	3.2206	3.4632
	SD	0.3306	0.3313	0.3261	0.3678
Total	Mean	2.8504	2.8808	2.6516	3.2534
	SD	0.8517	0.4633	0.5486	0.5206

In order to assess the normality of data distribution, the Kolmogorov-Smirnov test is applied (Table 4). In all cases, the p-values are below 0.01 indicating the rejection of the null hypothesis and concluding that the data do not follow the normal distribution and it is justified to use further non-parametric tests. The goal of the paper is to examine and determine if the organizations that integrate a high-quality culture with strong human capital achieve superior financial/business performance results.

The Mann Whitney U-test results in Table 5 present comparisons between Cluster 4 and Clusters 1, 2, and 3. Significant differences are identified between Cluster 4 and Clusters 2& 3 ($p < 0.05$), indicating higher business

performance in Cluster 4. No significant difference is observed between Cluster 4 and Cluster 1 ($p > 0.05$), suggesting similar performance levels even though higher rank sum values are reported in the case of Cluster 4.

Table 4: The results of descriptive statistical analysis and Kolmogorov-Smirnov test clusters

Variable	Descriptive statistical analysis								Kolmogorov-Smirnov test	
	Valid N	Mean	Median	Min	Max	Range	SD	CV (%)	d	p
Cluster 1	120	3.1965	3.00	1.00	5.00	4.00	0.75	23.33	0.1789	<0.01
Cluster 2	150	2.8178	3.00	1.00	5.00	4.00	0.73	26.10	0.2821	<0.01
Cluster 3	210	2.6905	3.00	1.00	5.00	4.00	0.71	26.59	0.2612	<0.01
Cluster 4	240	3.0579	3.00	1.00	5.00	4.00	0.74	24.34	0.2268	<0.01

Table 5: The results of the Mann Whitney U-test - Clusters

Rank Sum Cluster 4	Rank Sum		U	Z*	p-value
41614.00	Cluster 1	23366.00	28126.50	-1.94	0.052807
47141.50	Cluster 2	25367.00	10578.50	3.97	0.000073
62112.50	Cluster 3	39362.50	11760.50	6.27	0.000000

DISCUSSION AND CONCLUSION

The four-cluster solution obtained through Ward's method reveals that companies within the transportation supply chain do not converge towards a single managerial template, despite operating under shared corporate standards. Instead, four distinct configurations emerge, each combining the four indices in a different way and producing markedly different business performance outcomes. Cluster 4 ("Excellent"), grouping predominantly Western and Northern European countries together with Australia and India, achieves the highest mean values for Agility (3.68) and Human Capital (3.22), together with high values for Quality (3.46). This balanced profile is consistent with the literature suggesting that operational excellence emerges from the simultaneous cultivation of employee-centered practices and structured improvement methodologies, rather than from any single dimension in isolation. Cluster 1 ("Very Good"), comprising Canada, USA, France and Germany, shows the opposite logic since it scores highest on Quality (3.99) and Communication and Formalization (3.36), but considerably lower on Agility (2.20). This profile reflects mature, formalized organizations in which standardized quality systems are deeply embedded but responsiveness to change is constrained by hierarchical decision-making. Cluster 3 ("Moderate") displays a high Agility score (3.16) combined with the lowest values for Quality and Communication and Formalization, indicating responsiveness without the structural support of formalized quality systems. Cluster 2 ("Poor"), which includes several emerging-market and selected European countries, shows the lowest Agility (1.81) and weak performance across all dimensions, suggesting underdeveloped managerial infrastructures.

The Mann-Whitney U-test results provide partial support for the central hypothesis. Cluster 4 statistically outperforms Cluster 2 and Cluster 3 in business performance, confirming that the integration of agility, quality and human capital is associated with superior outcomes. However, no statistically significant difference is found between Cluster 4 and Cluster 1, implying that strong quality culture combined with developed communication systems can compensate for lower agility and deliver comparable business results. This nuance refines the prevailing view in the literature that there is more than one viable pathway to high performance in transportation supply chains. It means that a balanced "agile-quality" model and a "formalized-quality" model both prove effective, while configurations weak in quality or agility consistently underperform.

These findings have practical implications for multinational manufacturers managing geographically dispersed suppliers. Rather than imposing a uniform managerial template, headquarters should diagnose the cultural-organizational profile of each region and develop differentiated improvement programs by reinforcing agility and human capital in formalized environments, and strengthening quality systems and communication where agility already exists.

This paper develops an empirically grounded taxonomy of organizational culture and quality management practices within a global transportation supply chain consisting of 47 companies across 25 countries and there four distinct clusters were identified through Ward's hierarchical clustering and validated by one-way ANOVA, which confirmed statistically significant differences between clusters across all four indices. The comparative analysis of business performance, conducted via the Mann-Whitney U-test, shows that the cluster combining high agility, developed human capital and strong quality practices (Cluster 4) significantly outperforms clusters characterized by weak agility or underdeveloped quality systems (Clusters 2&3), while the cluster dominated by mature, highly formalized quality and communication systems (Cluster 1) achieves business performance statistically comparable to Cluster 4. The proposed hypothesis that organizations integrating a high-quality culture with strong human capital achieve superior business performance is confirmed, with the additional finding that two distinct organizational configurations can lead to top-tier performance. The main contribution of the paper lies in offering a configurational rather than variable-centered view of operational excellence in transportation supply chains, and in demonstrating that managerial practices cluster along recognizable national-regional patterns. From a practical side, the results suggest that multinational chains should adopt differentiated, profile-specific improvement strategies for suppliers rather than uniform global programs. The study has limitations regarding generalizability and response bias. Future research should extend sample, incorporate longitudinal data to capture dynamics, and examine moderating effects of national culture.

ACKNOWLEDGEMENT

This research was supported by MSTDI Serbia project E!20498 and contracts no. 337-00-216/2023-05/244 and 451-03-34/2026-03/200105.

REFERENCES

Adeniran, A. (2025). *Understanding Cronbach's Alpha in Social and Management Studies*. *2*(2), 11–16. https://csrbjournal.org/index.php/csrb

Alfalla-Luque, R., Lujan, D., & Marin-Garcia, J. A. (2023). Supply chain agility and performance: Evidence from a meta-analysis. *International Journal of Operations & Production Management*, *43*(10), 1587–1633. https://doi.org/10.1108/IJOPM-05-2022-0316

Braunscheidel, M. J., & Suresh, N. C. (2009). The organizational antecedents of a firm's supply chain agility for risk mitigation and response. *Journal of Operations Management, Special Issue: Perspectives on Risk Management in Supply Chains*, *27*(2), 119–140. https://doi.org/10.1016/j.jom.2008.09.006

Cao, Z., Huo, B., Li, Y., & Zhao, X. (2015). The impact of organizational culture on supply chain integration: A contingency and configuration approach. *Supply Chain Management: An International Journal*, *20*(1), 24–41. https://doi.org/10.1108/SCM-11-2013-0426

Carvalho, A. M., Sampaio, P., Rebentisch, E., Mcmanus, H., Carvalho, J., & Saraiva, P. (2023). Operational excellence, organizational culture, and agility: Bridging the gap between quality and adaptability. *Total Quality Management & Business Excellence*, *34(11–12), 1598–1628.* https://doi.org/10.1080/14783363.2023.2191844

Carvalho, A. M., Sampaio, P., Rebentisch, E., & Saraiva, P. (2017). Quality, excellence and culture in the pursuit of organizational agility. *2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 1714–1718. https://doi.org/10.1109/IEEM.2017.8290184

Chan, A. T. L., Ngai, E. W. T., & Moon, K. K. L. (2017). The effects of strategic and manufacturing flexibilities and supply chain agility on firm performance in the fashion industry. *European Journal of Operational Research*, *259*(2), 486–499. https://doi.org/10.1016/j.ejor.2016.11.006

Czerniachowicz, B. (2017). Cultural Conditions in Diversity Management: The case study of the corporation operating in the transportation and logistics industry. *Journal of Corporate Responsibility and Leadership*, *3*(3), 9. https://doi.org/10.12775/JCRL.2016.013

Felipe Llanos, C., Roldán, J., & Leal-Rodríguez, A. (2017). Impact of organizational culture values on organizational agility. *Sustainability*, *9*(12), 2354. https://doi.org/10.3390/su9122354

Geyi, D. G., Yusuf, Y., Menhat, M. S., Abubakar, T., & Ogbuke, N. J. (2020). Agile capabilities as necessary conditions for maximising sustainable supply chain performance: An empirical investigation. *International Journal of Production Economics*, *222*, 107501. https://doi.org/10.1016/j.ijpe.2019.09.022

Gholamizadeh, K., Zarei, E., & Yazdi, M. (2022). Railway transport and its role in the supply chains: overview, concerns, and future direction. In *The Palgrave Handbook of Supply Chain Management* (pp. 1–28). Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-89822-9_95-1

Hajiaghaei-Keshteli, M., Aminnayeri, M., & Fatemi Ghomi, S. M. T. (2014). Integrated scheduling of production and rail transportation. *Computers & Industrial Engineering*, *74*, 240–256. https://doi.org/10.1016/j.cie.2014.05.026

Hult, G. T. M., Ketchen, D., & Arrfelt, M. (2007). Strategic supply chain management: improving performance through a culture of competitiveness and knowledge development. *Strategic Management Journal*, *28*(10), 1035–1052. https://doi.org/10.1002/smj.627

Kaynak, H., & Hartley, J. (2008). A replication and extension of quality management into the supply chain. *Journal of Operations Management*, *26*(4), 468–489. https://doi.org/10.1016/j.jom.2007.06.002

Kim, M., & Chai, S. (2017). The impact of supplier innovativeness, information sharing and strategic sourcing on improving supply chain agility: Global supply chain perspective. *International Journal of Production Economics*, *187*, 42–52. https://doi.org/10.1016/j.ijpe.2017.02.007

Naor, M., Goldstein, S., Linderman, K., & Schroeder, R. (2008). The role of culture as driver of quality management and performance: infrastructure versus core quality practices. *Decision Sciences*, *39*(4), 671–702. https://doi.org/10.1111/j.1540-5915.2008.00208.x

Naor, M., Linderman, K., & Schroeder, R. (2010). The globalization of operations in Eastern and Western countries: Unpacking the relationship between national and organizational culture and its impact on manufacturing performance. *Journal of Operations Management*, *28*(3), 194–205. https://doi.org/10.1016/j.jom.2009.11.001

Sharma, M., Antony, R., Sharma, A., & Daim, T. (2024). Can smart supply chain bring agility and resilience for enhanced sustainable business performance? *The International Journal of Logistics Management*, *36*(2), 501-555. https://doi.org/10.1108/IJLM-09-2023-0381

Sila, I., Ebrahimpour, M., & Birkholz, C. (2006). Quality in supply chains: An empirical analysis. *Supply Chain Management: An International Journal*, *11*(6), 491–502. https://doi.org/10.1108/13598540610703882

Spasojević Brkić, V. K., Djurdjević, T., Dondur, N., Klarin, M. M., & Tomic, B. (2013). An empirical examination of the impact of quality tools application on business performance: Evidence from Serbia. *Total Quality Management & Business Excellence*, *24*(5-6), 607-618.

Taber, K. S. (2018). The use of cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tomic, B., & Spasojevic Brkic, V. K. (2018). Customer satisfaction and ISO 9001 improvement requirements in the supply chain. *The TQM Journal*, *31*(2), 222–238. https://doi.org/10.1108/TQM-07-2017-0072

Tomic, B., Spasojević Brkić, V., Karapetrovic, S., Pokrajac, S., Milanović, D. D., Babić, B., & Djurdjevic, T. (2017). Organizational culture, quality improvement tools and methodologies, and business performance of a supply chain. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *231*(13), 2430–2442. https://doi.org/10.1177/0954405416629100

Tortorella, G., Cauchick-Miguel, P., Li, W., Staines, J., & McFarlane, D. (2021). What does Operational Excellence mean in the Fourth Industrial Revolution era? *International Journal of Production Research*, *60*(9), 2901–2917. https://doi.org/10.1080/00207543.2021.1905903

Zanon, L. G., Marcelloni, F., Gerolamo, M. C., & Ribeiro Carpinetti, L. C. (2021). Exploring the relations between supply chain performance and organizational culture: A fuzzy grey group decision model. *International Journal of Production Economics*, *233*, 108023. https://doi.org/10.1016/j.ijpe.2020.108023

MANAGING THE STRATEGIC LOGISTICS POSITION OF THE REPUBLIC OF SERBIA IN REGIONAL AND EUROPEAN SUPPLY CHAINS

DOI: 10.5937/EMC26106U

Stefan Ugrinov
University of Novi Sad, Technical Faculty „Mihajlo Pupin “, Zrenjanin, Republic of Serbia
E-mail: stefan.ugrinov@tfzr.rs
Edit Terek Stojanović
University of Novi Sad, Technical Faculty „Mihajlo Pupin “, Zrenjanin, Republic of Serbia
Sanja Stanisavljev
University of Novi Sad, Technical Faculty „Mihajlo Pupin “, Zrenjanin, Republic of Serbia
Mila Kavalić
University of Novi Sad, Technical Faculty „Mihajlo Pupin “, Zrenjanin, Republic of Serbia
Verica Gluvakov
University of Novi Sad, Technical Faculty „Mihajlo Pupin “, Zrenjanin, Republic of Serbia
Mića Đurđev
University of Novi Sad, Technical Faculty „Mihajlo Pupin “, Zrenjanin, Republic of Serbia

ABSTRACT

The paper examines the strategic logistics position of the Republic of Serbia in regional and European supply chains. Serbia’s geographic location, transport corridors, access to the Danube, and links with neighbouring markets create a basis for stronger logistics development and supply chain integration. However, these advantages require adequate management, since logistics potential depends on strategic planning, investment decisions, institutional coordination, digital support, and cooperation between public and private actors. The paper analyses Serbia’s logistics position through road, rail, river, port, and intermodal connections, with attention to the importance of the Rhine-Danube transport area and regional freight flows. It also discusses management factors that influence the use of logistics resources and the development of logistics centres, digital systems, and coordinated transport operations. Special attention is given to challenges such as uneven infrastructure development, border procedures, limited intermodal capacity, and the need for stronger digital coordination. The paper points to strategic directions that can support Serbia’s integration into regional and European supply chains and strengthen its position as a logistics hub in Southeast Europe.

Key words: strategic logistics management, supply chain, integration, transport corridors, logistics potential.

INTRODUCTION

The logistics position of a country is an important factor of economic competitiveness, trade connectivity, and supply chain integration. The Republic of Serbia has a favourable geographic position between Central Europe, Southeast Europe, and wider European markets. This position creates opportunities for stronger participation in regional and European supply chains, especially through road, rail, river, and intermodal transport connections(Aćimović, Mijušković, & Bugarčić, 2022).

However, geographic position alone is not sufficient for stronger logistics performance. The value of logistics potential depends on the quality of management, strategic planning, investment decisions, institutional coordination, and cooperation between public and private actors(Aćimović, Mijušković, Marković, et al., 2022). In this context, Serbia’s logistics potential should be observed as a management issue, not only as an infrastructural or geographic advantage(Bugarčić et al., 2024).

The subject of this paper is the strategic logistics position of the Republic of Serbia in regional and European supply chains (Bugarčić et al., 2024). The aim of the paper is to examine how this position can support stronger supply chain integration through adequate management of logistics resources, transport infrastructure, logistics centres, and institutional support. The paper also considers the main challenges that limit the use of Serbia's logistics potential and points to strategic directions for its further development.

STRATEGIC LOGSITICS POSITION OF SERBIA

Serbia's strategic logistics position is based on its geographic location, transport corridors, and potential connection with regional and European markets. The country is located between Central Europe, Southeast Europe, and the wider European transport area. This position creates conditions for the movement of goods between the European Union, the Western Balkans, and markets toward the East and South. Serbia is not a coastal country, but its road, rail, river, and intermodal links provide a basis for stronger participation in international logistics flows(Stanojevic et al., 2017).

The Danube has special importance for Serbia's logistics position. It connects Serbia with the Rhine-Danube transport area and creates opportunities for inland waterway transport, port development, and multimodal logistics(J. Milanković et al., 2018). The Rhine-Danube Corridor is one of the main west-east transport axes in Europe, and Serbia is included among the neighbouring countries connected with this corridor. This connection gives Serbia an opportunity to develop stronger links with European freight flows, especially through better use of river transport and port infrastructure(M. Maksin et al., 2017).

Road and railway corridors also have high importance for the logistics position of Serbia. Corridor X connects Serbia with Hungary, Croatia, North Macedonia, Bulgaria, and Greece. This gives Serbia a transit function in Southeast Europe and supports links between the Western Balkans and the European Union. The modernisation of the Belgrade-Niš railway section shows the strategic importance of this corridor for freight transport, trade, and integration with EU railway networks. EU-supported investment in this section aims to improve railway capacity and support faster movement of goods and services(Biljana Stojanović-Višić et al., 2023).

The logistics position of Serbia also depends on the development of logistics centres, intermodal terminals, and port connections. Belgrade has a significant position because it is located at the intersection of the Rhine-Danube Corridor and road and railway Corridor X. The planned development of the new Port of Belgrade and its connection with railway infrastructure can support stronger transshipment results and better multimodal integration. This shows that Serbia's logistics potential is closely related to the ability to connect different transport modes into one coordinated system(D. Dimitrijević, 2017).

Strategic logistics position of Serbia should not be observed only through geography and infrastructure. Its value depends on management capacity, investment priorities, institutional coordination, and cooperation between public and private actors. Efficient logistics development requires clear planning of transport infrastructure, better border procedures, stronger digital support, and development of logistics services. Without coordinated management, geographic advantages may remain underused and may not lead to stronger competitiveness.

Serbia has the potential to strengthen its position as a regional logistics hub, especially if transport corridors, inland waterways, logistics centres, and intermodal systems are managed as connected elements. This requires a strategic approach that links national logistics development with regional and European supply chain needs. In that sense, Serbia's logistics position represents both an opportunity and a management challenge. Its future value will depend on the ability to transform geographic and infrastructural advantages into reliable, efficient, and well-coordinated logistics performance(Pajić et al., 2024).

MANAGEMENT OF SERBIA'S LOGISTICS PONTENTIAL

Serbia's logistics potential depends on the way in which transport infrastructure, logistics services, institutional support, and market needs are managed as part of one coordinated system. Geographic position and transport corridors create a basis for logistics development, but management decisions determine the level of their practical use. This includes investment planning, coordination between transport modes, development of logistics centres, support for digital systems, and alignment between national priorities and supply chain requirements.

Strategic management of logistics potential should connect public policy with the needs of companies, transport operators, and logistics service providers. Public institutions define infrastructure priorities, regulatory conditions, customs procedures, and investment frameworks. Private actors use these conditions through transport services, warehousing, distribution, freight forwarding, and supply chain coordination. A stronger connection between these actors can support better use of road, rail, river, and intermodal capacities in Serbia(Dašić et al., 2022).

Investment management is one of the main factors in the development of Serbia's logistics potential. Investments should not be directed only toward individual infrastructure projects. They should also support the connection between transport corridors, industrial zones, logistics centres, ports, and border crossings. Such an approach can reduce fragmentation and create better conditions for freight movement across regional and European supply chains. The development of intermodal terminals and logistics centres is especially important because it connects different transport modes and supports more efficient distribution flows(Ilic & Tesic, 2016).

Digital management also has high relevance for Serbia's logistics potential. Digital systems can support transport planning, shipment tracking, customs procedures, warehouse operations, and information exchange between supply chain actors(Rejman Petrovic et al., 2024). In this context, digitalisation should be observed as a management tool that can improve coordination and reduce delays in logistics processes. Better use of data can also support decision-making in transport planning, risk assessment, and capacity allocation (Todorovic et al., 2022).

The management of Serbia's logistics potential should therefore be based on coordinated planning, investment logic, digital support, intermodal development, and cooperation between public and private actors. Such an approach can help Serbia use its geographic and infrastructural advantages in a more effective way. It can also support stronger integration into regional and European supply chains, where reliability, connectivity, and coordination are increasingly important factors of logistics competitiveness.

CHALLENGES AND STRATEGIC DIRECTIONS

Serbia's integration into regional and European supply chains depends on the ability to address several logistics and management challenges. The first challenge refers to uneven development of transport infrastructure. Road transport has a dominant position, while railway and inland waterway transport still require stronger operational use. This creates pressure on road networks and limits the wider application of intermodal logistics. A better balance between transport modes is needed in order to support more reliable and cost-efficient freight flows(Mešić et al., 2022).

Border procedures and administrative processes also affect supply chain integration. Delays at border crossings can reduce the predictability of transport operations and increase logistics costs. This issue is especially important for companies that participate in time-sensitive supply chains. Greater coordination between customs authorities, transport operators, inspection services, and logistics companies can support smoother movement of goods. Digital documentation, electronic data exchange, and simplified procedures can also reduce delays and increase the reliability of cross-border logistics(Lidija Barjaktarović & Danko Kalkan, 2023).

Another challenge refers to the limited development of logistics centres and intermodal terminals. Serbia has a favourable position for logistics activities, but this potential requires stronger spatial planning and better connection between industrial zones, ports, railways, highways, and distribution centres. Logistics centres should not be observed only as storage facilities. They should function as points of coordination between transport, warehousing, customs services, distribution, and information flows.

Strategic directions for supply chain integration should include the development of intermodal transport, stronger use of the Danube, modernisation of railway infrastructure, and better connection between logistics centres and industrial areas. These directions can reduce dependence on road transport and support more sustainable logistics flows. The development of port infrastructure and river transport can also improve Serbia's position in regional freight movements, especially when combined with railway and road connections.

Digital transformation should also be part of the strategic direction for logistics development. Digital systems can support shipment visibility, transport planning, customs procedures, warehouse operations, and coordination between supply chain actors. Better data exchange can improve decision-making and reduce uncertainty in logistics processes. For this reason, digital tools should be connected with broader management practices, rather than treated as isolated technical solutions(Dušan Puhar, 2022).

Supply chain integration also requires stronger cooperation between public institutions, private companies, logistics providers, transport operators, and international partners. Serbia's logistics position can support regional and European supply chains only if infrastructure development is matched with clear management priorities. The main direction should be the creation of a coordinated logistics system that connects transport corridors, logistics centres, border procedures, digital systems, and market needs. This approach can support stronger competitiveness and a more stable position of Serbia within regional and European supply chains(Stojanović & Veličković, 2025).

CONCLUSION

Serbia has a favourable logistics position due to its geographic location, transport corridors, access to the Danube, and links with regional and European markets. These advantages create a basis for stronger participation in supply chain flows across Southeast Europe and the wider European transport area. However, the value of this position depends on the quality of logistics management and the ability to connect infrastructure, institutions, companies, and transport modes into a coordinated system.

The paper shows that Serbia's logistics potential should not be observed only through physical infrastructure. Strategic planning, investment management, digital support, risk management, and public-private cooperation are also important factors. These elements can improve the use of road, rail, river, port, and intermodal capacities, while also supporting more reliable logistics performance.

Future development should be directed toward stronger intermodal transport, better use of the Danube, railway modernisation, efficient border procedures, logistics centre development, and digital coordination. Such directions can support Serbia's integration into regional and European supply chains. They can also strengthen its position as a logistics hub in Southeast Europe, provided that logistics development remains connected with clear management priorities.

REFERENCES

Aćimović, S., Mijušković, V., Marković, D., & Todorović-Spasenić, A. (2022). The relationship between logistics and organizational performance in a supply chain context. *Serbian Journal of Management*, *17*(2), 333–349. https://doi.org/10.5937/sjm17-37401

Biljana Stojanović-Višić, Sanja Jelisavac-Trošić, & Miodrag Simić. (2023). Development of the Belt and Road Initiative in Serbia. *Ekonomika Preduzeca*. https://doi.org/10.5937/ekopre2303230s

Bugarčić, F. Ž., Stanišić, N., & Marinković, V. (2024). Assessing the effects of logistics performance on export and competitiveness using SEM methodology: Evidence from firm-level data. *The International Journal of Logistics Management*, *35*(6), 1847–1866. https://doi.org/10.1108/IJLM-07-2023-0289

D. Dimitrijević. (2017). Chinese Investments in Serbia—A Joint Pledge for the Future of the New Silk Road. *Baltic Journal of European Studies*, *7*, 64–83. https://doi.org/10.1515/bjes-2017-0005

Dašić, M., Trajković, S., & Jakšić, K. (2022). Influence of service quality on customer satisfaction in Serbian logistics practice. *BizInfo Blace*, *13*(1), 19–24. https://doi.org/10.5937/bizinfo2201019D

Dušan Puhar. (2022). River information systems: Review, applictions, and current examples from Serbia. *Zbornik Radova Departmana Za Geografiju, Turizam i Hotelijerstvo*. https://doi.org/10.5937/zbdght2201025p

Ilic, D., & Tesic, A. (2016). The relationship between supply chain management strategy, marketing, logistics and company performance for breweries in Serbia. *Ekonomika Poljoprivrede*, *63*(4), 1157–1168. https://doi.org/10.5937/ekoPolj1604157I

J. Milanković, D. Pavić, Jasmina P. Đorđević, A. Dragin, S. Vučkovic, & M. Mészáros. (2018). *The Danube inland waterway transport and its role in Serbia's economic development*. *4*, 105–114. https://doi.org/10.15826/RECON.2018.4.3.015

Lidija Barjaktarović & Danko Kalkan. (2023). Are Serbian companies ready for the German supply chain due diligence act? *Proceedings of the 10th International Scientific Conference - FINIZ 2023*. https://doi.org/10.15308/finiz-2023-143-153

M. Maksin, Marina Nenković-Riznić, S. Milijić, & V. Ristić. (2017). The impacts of spatial planning on the sustainable territorial development of the Rhine-Danube Trans-European Transport Corridor through Serbia. *European Planning Studies*, *25*, 278–297. https://doi.org/10.1080/09654313.2016.1260691

Mešić, A., Miškić, S., Stević, Ž., & Mastilo, Z. (2022). Hybrid MCDM Solutions for Evaluation of the Logistics Performance Index of the Western Balkan Countries. *ECONOMICS*, *10*(1), 13–34. https://doi.org/10.2478/eoik-2022-0004

Pajić, V., Andrejić, M., Jolović, M., & Kilibarda, M. (2024). Strategic Warehouse Location Selection in Business Logistics: A Novel Approach Using IMF SWARA–MARCOS—A Case Study of a Serbian Logistics Service Provider. *Mathematics*, *12*(5), 776. https://doi.org/10.3390/math12050776

Rejman Petrovic, D., Krstic, A., Nedeljković, I., & Mimovic, P. (2024). Efficiency of digital business transformation in the Republic of Serbia. *VINE Journal of Information and Knowledge Management Systems*, *54*(4), 725–744. https://doi.org/10.1108/VJIKMS-12-2021-0292

Stanojevic, P., Miskovic, V., & Jeftic, Z. (2017). Overview of elements of national logistics system in the Republic of Serbia. *Vojno Delo*, *69*(4), 96–120. https://doi.org/10.5937/vojdelo1704096S

Stojanović, Đ., & Veličković, M. (2025). Hidden vital players in supply chain – Freight forwarders from nineteenth century to date in Serbia. *The Journal of Transport History*, 00225266251406295. https://doi.org/10.1177/00225266251406295

Todorovic, T., Medic, N., Delic, M., Zivlak, N., & Gracanin, D. (2022). Performance Implications of Organizational and Technological Innovation: An Integrative Perspective. *Sustainability*, *14*(5), 2836. https://doi.org/10.3390/su14052836

16th International Symposium Engineering Management and Competitiveness 2026 (EMC 2026)
June, 19-20, 2026, Zrenjanin, Serbia

Session B: HUMAN RESOURCE MANAGEMENT

Papers (pp. 113-168):

Ali Reza Afshari, Dragan Ćoćkalo
IDENTIFYING AND PRIORITIZING BEHAVIORAL COMPETENCIES OF PROJECT MANAGERS IN MASHHAD METRO PROJECTS ...113

Milica Bogdanov, Jasmina Poštin
COMPARATIVE ANALYSIS OF HR PROFESSIONALS' COMPETENCIES IN DIFFERENT SECTORS BETWEEN DEVELOPED AND DEVELOPING COUNTRIES ...120

Aneta Guteša, Dijana Vašaš Kuručev, Milica Bogdanov, Jasmina Poštin
SUSTAINABLE HUMAN RESOURCE PRACTICES AND EMPLOYEE WELLBEING IN DIGITALIZED WORK ENVIRONMENTS ...126

Mirjana Jokanović Đajić, Brankica Čomić, Obrad Spaić, Mirjana Miljanović
BETWEEN FAILURE AND SUCCESS: THE ROLE OF PROJECT MANAGER'S LEADERSHIP IN ACHIEVING PROJECT SUCCESS DIMENSIONS ...132

Dragana Kovač, Edit Terek Stojanović, Stefan Ugrinov,
Melita Ćoćkalo-Hronjec, Milovan Cvjetković
THE IMPORTANCE OF CREATIVITY IN HIGHER EDUCATION FOR THE DEVELOPMENT OF MODERN BUSINESS ...138

Ljubiša Malešev, Jasmina Pekez, Mila Kavalić,
Nikola Jerković, Nadežda Ljubojev
HUMAN RESOURCES AS A DETERMINANT OF THE SUCCESSFUL INTEGRATION OF CBAM REQUIREMENTS INTO THE PRODUCT CARBON FOOTPRINT MANAGEMENT SYSTEM ...144

Leontina Pap
ETHICAL MANAGEMENT OF ARTIFICIAL INTELLIGENCE IN GLOBAL BUSINESS: COMPETITIVENESS, RISKS AND REGULATORY FRAMEWORKS ...151

Marko Pavlović, Dragana Đurić, Marija Perić,
Mirjana Dunić, Miodrag Simić
HUMAN RESOURCES MANAGEMENT IN INSURANCE COMPANIES: CASE STUDY WIENER STADTISCHE ...157

Ana-Marija Vukić, Dragana Sajfert, Marko Kihler
THE IMPACT OF DIGITAL COMPETENCIES ON HUMAN RESOURCE MANAGEMENT PRACTICES ...163

IDENTIFYING AND PRIORITIZING BEHAVIORAL COMPETENCIES OF PROJECT MANAGERS IN MASHHAD METRO PROJECTS

DOI: 10.5937/EMC26113C

Ali Reza Afshari
Islamic Azad University, Department of Construction Management, Shirvan Branch, Shirvan, Iran
Dragan Ćoćkalo
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: dragan.cockalo@tfzr.rs

ABSTRACT

This study examines the behavioral competencies of project managers in Mashhad metro projects using the Fuzzy Analytical Hierarchy Process (FAHP). Due to the complexity of urban railway projects and the involvement of multiple stakeholders, behavioral competencies are considered important for effective project management. The study combined literature review, expert evaluation, and FAHP analysis based on the opinions of 10 experts with experience in metro construction projects. The results show that Communication Competencies represent the most important category, followed by Interaction and Leadership Competencies. At the individual level, Creating Positive Interactions, Negotiation Ability, and Crisis Management ranked as the most important competencies. The findings highlight the importance of communication and interaction-related competencies in the selection and evaluation of project managers in large-scale infrastructure projects.

Keywords: Behavioral Competencies, Project Manager, FAHP, Metro Projects.

INTRODUCTION

Large-scale urban infrastructure projects, particularly metro systems, are among the most complex and capital-intensive construction projects due to their technical demands, multiple stakeholders, long implementation periods, and high financial investments (Moradi et al., 2019). In Iran, metro development projects such as the Mashhad metro system play an important role in improving urban transportation, reducing traffic congestion, and increasing public transport efficiency (Tabasi & Abubakr, 2018). However, such projects frequently face delays, budget overruns, coordination problems, and stakeholder-related challenges, where the role of the project manager becomes especially important (Safaei & Arizaei, 2013; Turner, 2019).

Traditionally, project manager selection in the construction industry has focused mainly on technical competencies such as planning, cost estimation, scheduling, and contract management (Bagheri & Jafari, 2019). Nevertheless, previous studies indicate that behavioral competencies—including communication, negotiation, leadership, conflict resolution, crisis management, and emotional intelligence—also significantly influence project performance, particularly in complex construction environments (Dainty et al., 2005; Crawford et al., 2012; Spencer & Spencer, 2023). These competencies support effective interaction with project teams and stakeholders and improve managerial responses in uncertain project situations.

The concept of competency has been widely discussed in human resource and project management literature since the work of McClelland and later competency-based management approaches (Boyatzis, 1982). International frameworks such as the Project Management Institute (PMI) competency framework and the IPMA ICB4 standard also recognize behavioral competencies as an important dimension of project management practice (PMI, 2017; IPMA, 2018).

Despite the recognized importance of behavioral competencies, limited research has specifically examined their prioritization in Iranian metro construction projects. Existing studies have mainly focused on technical competencies or general construction management issues (Mombini & Norouzi, 2019). In addition, the absence of structured competency evaluation models may contribute to subjective project manager selection processes and reduced managerial effectiveness (Alizadeh & Ghorbani, 2019; Khoshnevis & Azizi, 2014).

Accordingly, this study aims to identify and prioritize the behavioral competencies of project managers in Mashhad metro projects using the Fuzzy Analytical Hierarchy Process (FAHP). FAHP, developed from the traditional AHP approach introduced by Saaty (1980), incorporates fuzzy logic principles to support decision-making under uncertainty (Buckley, 1985). The method is considered suitable for evaluating subjective and qualitative criteria such as behavioral competencies (Azar & Faraji, 2006; Hsieh et al., 2004). The research combines literature review, expert evaluation, and fuzzy analysis to determine the relative importance of key behavioral competencies relevant to large-scale metro projects. The findings may support project manager selection and evaluation processes in infrastructure organizations and construction projects (Varajao & Cruz-Cunha, 2023).

LITERATURE REVIEW

Competency-based approaches have been widely discussed in human resource management and project management literature since the work of McClelland and subsequent competency models developed in organizational studies (Alvani, 2017; Boyatzis, 1982). Competencies are commonly understood as combinations of knowledge, skills, abilities, and behavioral characteristics associated with effective job performance (Turner, 2019; Rahiminia et al., 2012). Various authors have also linked competencies with motivation, personality traits, communication abilities, managerial effectiveness, and superior work performance (Whiteman & Marshall, 2016; Mousavi Nik et al., 2012). Over time, competency-based approaches have become important tools in personnel selection, performance evaluation, succession planning, and managerial development.

In project management, competency frameworks developed by organizations such as PMI and IPMA recognize behavioral competencies as an important dimension alongside technical and managerial competencies (PMI, 2017; IPMA, 2018). According to these approaches, project manager competencies include not only technical knowledge, but also communication, leadership, negotiation, interpersonal relations, conflict management, and behavioral effectiveness. Previous studies have also linked project manager competencies with project success criteria such as time, cost, quality, stakeholder satisfaction, and organizational effectiveness (Westerveld, 2003; Wateridge, 2018; Kerzner, 2019; Qazi Moradi et al., 2015). Fram (2017) additionally emphasized the coordinating and knowledge-transfer role of project managers in complex projects.

In construction projects, behavioral competencies are particularly important because project managers must coordinate multiple stakeholders, manage conflicts, respond to uncertainty, and maintain effective communication within dynamic project environments (Crawford et al., 2012). Several studies in Iran have also emphasized the importance of managerial competency, resource management, and organizational effectiveness in construction and industrial projects (Rezaeian et al., 2014). Previous research further suggests that project success depends not only on technical expertise, but also on interpersonal and behavioral capabilities, especially in large and complex infrastructure projects.

Recent studies in construction management literature increasingly emphasize people-oriented leadership and interpersonal competencies. Rehan et al. (2024) identified communication, collaborative working, and relationship-building as critical behavioral practices in successful construction projects. Kassa et al. (2024) reported that emotional intelligence and behavioral characteristics significantly influence teamwork and project coordination in construction organizations. Other studies also highlight communication ability, conflict management, problem-solving, interpersonal relations, technical expertise, and leadership capabilities as essential competencies for effective project managers.

Although competency frameworks and previous studies recognize the importance of behavioral competencies, limited research has specifically examined their prioritization in the context of Iranian metro construction projects. To address this gap, the present research focuses on the behavioral competencies of project managers in Mashhad metro projects using the Fuzzy Analytical Hierarchy Process (FAHP).

BEHAVIORAL COMPETENCIES AND THE APPLICATION OF FAHP IN PROJECT MANAGEMENT EVALUATION

Recent studies have increasingly applied fuzzy multi-criteria decision-making methods in project management research. Zia et al. (2024) used the Fuzzy Delphi Method (FDM) and FAHP to identify critical success factors in manufacturing projects, while Mohammed et al. (2025) applied FAHP to evaluate sustainability challenges in construction projects. Rehan et al. (2025) emphasized the importance of leadership and interpersonal behavioral practices in construction project management, and Zemlińska-Sikora (2023) highlighted emotional intelligence and behavioral competencies as emerging requirements for modern project managers. These studies demonstrate the growing relevance of behavioral competencies and fuzzy decision-making approaches in project management research.

The Fuzzy Analytical Hierarchy Process (FAHP) was applied to identify and prioritize the behavioral competencies of project managers in Mashhad metro projects. FAHP combines the traditional Analytical Hierarchy Process (AHP) developed by Saaty (1980) with fuzzy set theory introduced by Zadeh (1965) to support decision-making under conditions of uncertainty and subjective judgment. The method is considered suitable for evaluating qualitative and behavioral criteria where expert opinions are expressed through linguistic assessments rather than precise numerical values (Azar & Faraji, 2006).

Triangular fuzzy numbers (TFNs), represented as lower, middle, and upper values, were used to express expert judgments in pairwise comparisons. Buckley's (1985) geometric mean method was applied to calculate fuzzy weights and determine the relative importance of competencies. The study involved a panel of 10 experts with extensive experience in Mashhad metro projects. Expert evaluations were collected through pairwise comparison questionnaires using linguistic assessment scales. The use of fuzzy logic in competency evaluation has also been discussed in previous studies addressing subjective and multidimensional decision-making problems (Hsieh et al., 2004).

The FAHP procedure included the development of a hierarchical competency structure, design of pairwise comparison matrices, collection of expert judgments, calculation of fuzzy geometric means and fuzzy weights, defuzzification, normalization, consistency checking, and final ranking of competencies. Consistency of pairwise comparison matrices was evaluated using the consistency ratio (CR), where values below 0.10 were considered acceptable. In construction management research, FAHP has previously been applied in areas such as contractor selection, project risk assessment, sustainability evaluation, and competency prioritization.

FINDINGS AND COMPETENCY PRIORITIZATION

This section presents the results of the research on identifying and prioritizing the behavioral competencies of project managers in Mashhad metro projects using the Fuzzy Analytical Hierarchy Process (FAHP). A panel of 10 experts with experience in metro construction projects participated in the analysis. Based on the literature review and expert evaluation process, 13 behavioral competencies were identified and classified into three categories: Communication Competencies, Leadership Competencies, and Interaction Competencies.

All competencies received mean scores above the acceptance threshold in the preliminary expert evaluation and were therefore included in the FAHP analysis. The consistency ratios (CR) for all

pairwise comparison matrices were below 0.10, confirming acceptable reliability and consistency of expert judgments. The geometric mean method was used to aggregate expert responses and calculate the relative importance of competencies.

Communication Competencies achieved the highest normalized weight of 0.687, followed by Interaction Competencies (0.204) and Leadership Competencies (0.109). This indicates that communication-related behavioral capabilities are considered significantly more important than traditional managerial and planning-oriented competencies in the context of Mashhad metro projects.

Within the Communication Competencies category, "Creating Positive Interactions" ranked first with a normalized weight of 0.533, followed by "Negotiation Ability" (0.304). "Interpersonal Communication" and "Effective Communication" received substantially lower values. The findings suggest that experts place greater importance on relationship-building and stakeholder coordination than on routine communication functions.

Within the Leadership Competencies category, "Conflict Management" received the highest weight (0.772), considerably exceeding "Decision Making" (0.129) and "Planning" (0.100). This result reflects the complexity of metro construction projects, where disputes among contractors, design modifications, resource allocation issues, and stakeholder disagreements require continuous managerial intervention and negotiation.

In the Interaction Competencies category, "Crisis Management" ranked first with a weight of 0.570, followed by "Expectation Management" (0.194) and "Risk Management" (0.113). The prominence of crisis management indicates the importance of rapid response and coordination capabilities in large-scale infrastructure environments characterized by uncertainty and operational pressure.

The final overall ranking of behavioral competencies was obtained by combining the weights of the main competency categories and their corresponding sub-competencies – Table 1.

Table 1: Final Ranking of Behavioral Competencies

Competency	Final Weight	Rank
Creating Positive Interactions	0.366	1
Negotiation Ability	0.208	2
Crisis Management	0.116	3
Conflict Management	0.084	4
Interpersonal Communication	0.056	5
Effective Communication	0.055	6
Expectation Management	0.040	7
Risk Management	0.023	8
Decision Making	0.014	9
Change Management	0.013	10
Interaction Management	0.012	11
Planning	0.011	12

The results show that "Creating Positive Interactions" emerged as the most important behavioral competency overall with a final global weight of 0.366, followed by "Negotiation Ability" (0.208) and "Crisis Management" (0.116). Together, these three competencies accounted for approximately 70% of the total importance weights obtained through the FAHP analysis.

The relatively low ranking of "Planning" does not suggest that planning is unimportant in project management practice. Rather, it indicates that technical planning capabilities are considered baseline expectations for project managers, while behavioral competencies are viewed as the differentiating factors in managing complex metro construction projects.

Overall, the findings indicate that communication, stakeholder interaction, conflict resolution, and crisis response capabilities play a dominant role in the successful management of Mashhad metro projects. The results also suggest that behavioral competencies should receive greater attention in project manager selection, evaluation, and professional development processes within large-scale infrastructure organizations.

CONCLUSION

This study examined the behavioral competencies of project managers in Mashhad metro projects using the Fuzzy Analytical Hierarchy Process (FAHP). Behavioral competencies related to communication, interaction management, and crisis response are considered more important than traditional managerial and planning-oriented competencies in the context of large-scale urban infrastructure projects.

Among the analyzed competency categories, Communication Competencies achieved the highest overall importance, while "Creating Positive Interactions," "Negotiation Ability," and "Crisis Management" emerged as the most influential individual competencies. The results suggest that the ability to manage stakeholder relations, maintain effective collaboration, and respond to uncertain project situations plays a central role in complex metro construction environments.

A similar emphasis on interpersonal leadership practices has been reported in previous studies emphasizing the importance of interpersonal and people-oriented leadership practices in construction project management (Rehan et al., 2024; Varajao et al., 2023). At the same time, the strong emphasis on crisis management reflects the specific operational conditions of Mashhad metro projects, including technical uncertainty, coordination complexity, and high public visibility.

From a practical perspective, the results suggest that employer organizations should place greater emphasis on behavioral competencies during project manager selection, evaluation, and professional development processes. In addition to technical qualifications, greater attention should be given to communication abilities, conflict resolution, negotiation capabilities, and crisis response skills.

This study is limited by the relatively small expert sample and its focus on a specific project environment. Future research may expand the analysis to other infrastructure projects and compare competency priorities across different construction contexts. Further studies may also combine behavioral, technical, and contextual competencies within broader project manager evaluation models and apply alternative multi-criteria decision-making approaches such as Fuzzy DEMATEL or ANP.

REFERENCES

Boyatzis, R. E. (1982). *The competent manager: A model for effective performance*. John Wiley & Sons.

Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy Sets and Systems, 17*(3), 233–247. https://doi.org/10.1016/S0165-0114(85)80090-9

Faisal, M. N., Al Subaie, A. A., Sabir, L. B., & Sharif, K. J. (2023). PMBOK, IPMA and fuzzy-AHP based novel framework for leadership competencies development in megaprojects. *Benchmarking: An International Journal, 30*(9), 2993–3020. https://doi.org/10.1108/BIJ-01-2022-0025

International Project Management Association (IPMA). (2018). *Reference guide ICB4 in an agile world* (Version 2.3). IPMA.

Kassa, R., Ogundare, T. I., Lines, B., Smithwick, J., & Sullivan, K. (2024). Comparative analysis of human traits and tendencies: General vs. specialty contractor project managers. *International Journal of Construction Education and Research, 20*(3), 284–300. https://doi.org/10.1080/15578771.2023.2246541

Kerzner, H. (2017). *Project management: A systems approach to planning, scheduling, and controlling* (12th ed.). John Wiley & Sons.

Mohammed, G. A., Jaf, D. K., & Öztaş, A. (2025). Application of fuzzy analytic hierarchy process (FAHP) for assessing sustainability challenges in construction projects. *IOP Conference Series: Earth and Environmental Science, 1545*, 012125. https://doi.org/10.1088/1755-1315/1545/1/012125

Moradi, S., Kahkonen, K., & Aaltonen, K. (2019). Comparison of research and industry views on project managers' competencies. *International Journal of Managing Projects in Business, 12*(4), 876–895. https://doi.org/10.1108/IJMPB-04-2018-0085

Project Management Institute (PMI). (2017a). *A guide to the project management body of knowledge (PMBOK® guide)* (6th ed.). Project Management Institute.

Project Management Institute (PMI). (2017b). *Project manager competency development framework (PMCDF)* (3rd ed.). Project Management Institute.

Rehan, A., Thorpe, D., & Heravi, A. (2024). Project managers' leadership behavioural practices: A systematic literature review. *Asia Pacific Management Review, 29*(2), 165–178. https://doi.org/10.1016/j.apmrv.2023.12.005

Rehan, A., Thorpe, D., & Heravi, A. (2025). An empirical study on project managers' leadership behavioral practices impacting project success: The Australian construction sector. *International Journal of Construction Education and Research*. Advance online publication. https://doi.org/10.1080/15578771.2024.2359378

Saaty, T. L. (1980). *The analytic hierarchy process*. McGraw-Hill.

Spencer, L. M., & Spencer, S. M. (1993). *Competence at work: Models for superior performance*. John Wiley & Sons.

Turner, J. R. (2019). *The handbook of project-based management* (5th ed.). McGraw-Hill.

Varajão, J., & Cruz-Cunha, M. M. (2013). Using AHP and the IPMA competence baseline in the project managers selection process. *International Journal of Production Research, 51*(11), 3342–3354. https://doi.org/10.1080/00207543.2012.753646

Westerveld, E. (2003). The Project Excellence Model®: Linking success criteria and critical success factors. *International Journal of Project Management, 21*(6), 411–418. https://doi.org/10.1016/S0263-7863(02)00112-6

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control, 8*(3), 338–353. https://doi.org/10.1016/S0019-9958(65)90241-X

Zemlińska-Sikora, U. (2023). IT project manager's competencies: Systematic literature review. *Organizacja i Kierowanie, 194*(3), 131–150.

Zia, M. N., Shah, A., Khan, S. A., & Najib, A. (2024). Identification of critical success factors (CSFs) for successful project management in manufacturing sector. *Journal of Enterprise Information Management, 37*(4), 1282–1300. https://doi.org/10.1108/JEIM-08-2022-0298

Aćimović, S., Mijušković, V., & Bugarčić, F. (2022). Logistics system as a factor of business development: The case of the Republic of Serbia. *Ekonomika Preduzeca*, *70*(5–6), 325–334. https://doi.org/10.5937/EKOPRE2206325A

Aćimović, S., Mijušković, V., Marković, D., & Todorović-Spasenić, A. (2022). The relationship between logistics and organizational performance in a supply chain context. *Serbian Journal of Management, 17*(2), 333–349. https://doi.org/10.5937/sjm17-37401

Biljana Stojanović-Višić, Sanja Jelisavac-Trošić, & Miodrag Simić. (2023). Development of the Belt and Road Initiative in Serbia. *Ekonomika Preduzeca*. https://doi.org/10.5937/ekopre2303230s

Bugarčić, F. Ž., Stanišić, N., & Marinković, V. (2024). Assessing the effects of logistics performance on export and competitiveness using SEM methodology: Evidence from firm-level data. *The International Journal of Logistics Management, 35*(6), 1847–1866. https://doi.org/10.1108/IJLM-07-2023-0289

D. Dimitrijević. (2017). Chinese Investments in Serbia—A Joint Pledge for the Future of the New Silk Road. *Baltic Journal of European Studies, 7*, 64–83. https://doi.org/10.1515/bjes-2017-0005

Dašić, M., Trajković, S., & Jakšić, K. (2022). Influence of service quality on customer satisfaction in Serbian logistics practice. *BizInfo Blace, 13*(1), 19–24. https://doi.org/10.5937/bizinfo2201019D

Dušan Puhar. (2022). River information systems: Review, applictions, and current examples from Serbia. *Zbornik Radova Departmana Za Geografiju, Turizam i Hotelijerstvo*. https://doi.org/10.5937/zbdght2201025p

Ilic, D., & Tesic, A. (2016). The relationship between supply chain management strategy, marketing, logistics and company performance for breweries in Serbia. *Ekonomika Poljoprivrede, 63*(4), 1157–1168. https://doi.org/10.5937/ekoPolj1604157I

J. Milanković, D. Pavić, Jasmina P. Đorđević, A. Dragin, S. Vučkovic, & M. Mészáros. (2018). *The Danube inland waterway transport and its role in Serbia's economic development*. *4*, 105–114. https://doi.org/10.15826/RECON.2018.4.3.015

Lidija Barjaktarović & Danko Kalkan. (2023). Are Serbian companies ready for the German supply chain due diligence act? *Proceedings of the 10th International Scientific Conference - FINIZ 2023*. https://doi.org/10.15308/finiz-2023-143-153

M. Maksin, Marina Nenković-Riznić, S. Milijić, & V. Ristić. (2017). The impacts of spatial planning on the sustainable territorial development of the Rhine-Danube Trans-European Transport Corridor through Serbia. *European Planning Studies*, *25*, 278–297. https://doi.org/10.1080/09654313.2016.1260691

Mešić, A., Miškić, S., Stević, Ž., & Mastilo, Z. (2022). Hybrid MCDM Solutions for Evaluation of the Logistics Performance Index of the Western Balkan Countries. *ECONOMICS*, *10*(1), 13–34. https://doi.org/10.2478/eoik-2022-0004

Pajić, V., Andrejić, M., Jolović, M., & Kilibarda, M. (2024). Strategic Warehouse Location Selection in Business Logistics: A Novel Approach Using IMF SWARA–MARCOS—A Case Study of a Serbian Logistics Service Provider. *Mathematics*, *12*(5), 776. https://doi.org/10.3390/math12050776

Rejman Petrovic, D., Krstic, A., Nedeljković, I., & Mimovic, P. (2024). Efficiency of digital business transformation in the Republic of Serbia. *VINE Journal of Information and Knowledge Management Systems*, *54*(4), 725–744. https://doi.org/10.1108/VJIKMS-12-2021-0292

Stanojevic, P., Miskovic, V., & Jeftic, Z. (2017). Overview of elements of national logistics system in the Republic of Serbia. *Vojno Delo*, *69*(4), 96–120. https://doi.org/10.5937/vojdelo1704096S

Stojanović, Đ., & Veličković, M. (2025). Hidden vital players in supply chain – Freight forwarders from nineteenth century to date in Serbia. *The Journal of Transport History*, 00225266251406295. https://doi.org/10.1177/00225266251406295

Todorovic, T., Medic, N., Delic, M., Zivlak, N., & Gracanin, D. (2022). Performance Implications of Organizational and Technological Innovation: An Integrative Perspective. *Sustainability*, *14*(5), 2836. https://doi.org/10.3390/su14052836

COMPARATIVE ANALYSIS OF HR PROFESSIONALS' COMPETENCIES IN DIFFERENT SECTORS BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

DOI: 10.5937/EMC26120B

Milica Bogdanov
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: milica_bogdanov@yahoo.com
Jasmina Poštin
University Union "Nikola Tesla" Faculty of management, Sremski Karlovci, Republic of Serbia

ABSTRACT

HR professionals' competencies represent a set of knowledge, skills, abilities and behaviours necessary for effective human resource management and adaptation to changes in the labour market. This paper analyses the importance of HR competencies across different sectors, comparing developed and developing countries. The aim of the research is to identify the key competencies required of HR professionals and to examine how they change under the influence of digitalisation, organisational changes, the legislative framework and employees' needs. The methodological framework is based on a qualitative analysis of relevant secondary sources, including scientific papers, reports of international organisations, case studies and available comparative data. The results indicate a significant gap between developed and developing countries, particularly in the areas of digital skills, data analytics, strategic HR management and the application of modern HR technologies.

Keywords: HR competencies, human resources, labour market

INTRODUCTION

Effective human resource management is a key factor for achieving productivity and organisational success (Gilli et al., 2022). Its main task is to identify and use employees' potential in order to achieve organisational goals (Krušković et al., 2022). This requires accurate assessment of existing competencies, mapping of competencies required for specific jobs, and identification of gaps between acquired and required competencies (Bohlouli et al., 2020; Taleric, 2022). Since human resources have a specific role compared to other organisational resources, competency recognition represents an important basis for HR systems such as talent management and succession planning, contributing to better performance, productivity and sustainable competitive advantage (Gilli et al., 2022; Farahni et al., 2021). At the same time, HR management has become more complex due to changes in the external environment and new employee expectations. Employees value belonging, teamwork, timely feedback and recognition of the importance of their work, including in remote work settings (Mura et al., 2017). Therefore, HR management includes recruitment, training, evaluation, rewarding, employment relations, health and safety, and fairness, with the aim of achieving both organisational and individual goals (Opatha, 2021; Ravi et al., 2023; Chen, 2019).

METHODOLOGICAL FRAMEWORK OF THE RESEARCH

The research focuses on the analysis of HR competencies in different sectors, comparing developed countries and developing countries. The research problem arises from the fact that rapid changes in the global labor market require HR professionals to continuously develop competencies that enable them to respond to new economic, technological, legislative, and social challenges.

The main objective of the research is to compare the competencies of HR professionals in developed and developing countries, identify the key differences in labor market requirements between these two contexts, and determine how different economic, technological and organizational conditions influence the development of HR competencies. The research also aims to formulate recommendations for improving HR competencies based on relevant international experiences and contemporary labor market trends. The research is guided by the following questions: which competencies HR professionals should develop in response to contemporary labor market needs, how the required competencies differ between developed and developing countries, and which factors shape HR practices in relation to international trends. The research is based on the analysis of secondary data, including reports and publications of international organizations such as the International Labour Organization, the World Bank, and renowned consulting firms specialized in human resource management.

THEORETICAL FRAMEWORK OF THE RESEARCH

Understanding the Competencies of HR Experts

The competencies of HR experts can be defined as a combination of knowledge, skills, abilities, personal characteristics and behaviors that enable effective work performance and contribution to organizational goals (Gilli et al., 2022). These competencies include professional knowledge and skills, as well as traits such as integrity, empathy, flexibility, self-confidence, problem-solving, decision-making, and the ability to motivate employees. In this sense, HR competencies are not limited only to technical expertise, but also include proactive behavior and the capacity to improve the working atmosphere, employee engagement and team performance (Wong, 2020; Gilli et al., 2022). Important contributions to the development of HR competency models have been made by the Society for Human Resource Management (SHRM, 2018) and the Chartered Institute of Personnel and Development (CIPD, 2018). The SHRM model includes behavioral competencies and professional knowledge organized around leadership, interpersonal communication and business competencies, such as ethical practice, relationship management, communication, business acumen, consultation and critical evaluation. Similarly, the CIPD professional map identifies core, behavioral and specialized competencies, emphasizing people practice, organizational culture, business environment, analytics, value creation, digital technologies and change management (CIPD, 2018; Yuliantar et al., 2019).

Models of HR Competencies According to SHRM and CIPD Frameworks

Different models of HR competencies offer structured approaches to understanding the key skills and knowledge needed for successful human resource management. SHRM and CIPD have developed comprehensive competency models that integrate the leadership, interpersonal and professional abilities of HR experts. Transferable competencies are key for HR managers, because they enable the application of acquired skills in different business contexts and industries (Kolot et al., 2022). Both models provide a foundation for the development of the competencies of HR experts, but they differ in approach: the SHRM model focuses more on leadership and interpersonal competencies, which is useful for strategic HR positions. The CIPD model adds analytical, digital and adaptive skills, which are important for the modern HR sector. The integration of both approaches would enable HR experts to be effective leaders, strategic decision-makers and adaptable professionals in the contemporary business environment (Zeoli et al., 2019) and crisis situations (Dirani et al., 2020; Sthapit, 2021).

HR Competencies in Developed Countries

According to global labor market research and recruitment reports for the period 2020–2021, the key competencies required of HR experts in developed countries include communication, leadership, change management, coaching, problem-solving, analytical and critical thinking, adaptability, teamwork, empathy, time management, digital literacy, data analytics and the use of HR technologies (Kolot et al., 2022). These competencies show that the role of HR professionals is increasingly moving beyond traditional administrative tasks toward strategic, analytical and employee-oriented functions.

Particular emphasis is placed on transferable skills, such as cooperation, decision-making, initiative, professionalism, multitasking and relationship building. These skills increase employee competitiveness in the labor market and contribute to job satisfaction and organizational performance (Olsen et al., 2019). HR experts are expected not only to possess these competencies themselves, but also to develop them among employees through training, talent development and organizational learning strategies.

Research also highlights the importance of cognitive and analytical competencies, including critical thinking, analysis, synthesis, data interpretation and informed decision-making (Collins-Nelsen et al., 2021). These skills enable HR professionals to understand labor market changes, improve recruitment and employee development strategies, and adapt HR policies to contemporary business needs. In addition, communication, teamwork, leadership, adaptability, reflexivity and openness to learning are essential for effective HR work in a dynamic and changing business environment.

PRESENTATION OF RESEARCH RESULTS

In order to identify the main differences in HR competency requirements, the following table provides a comparative overview of key competencies of HR experts in developed and developing countries.

Table 1: Key Competencies of HR Experts in Developed Countries and Developing Countries (%)

Competencies	Developed Countries (%)	Developing Countries (%)
Strategic HR management	75	50
Technological literacy	80	45
Data analysis	70	40
Recruitment skills	85	65
Employee development and training	78	55
Talent management	82	60
Knowledge of labor law	88	72

In developed countries, HR experts have a greater focus on strategic management, technological literacy, data analysis, recruitment, employee development, talent management and knowledge of labor law. On the other hand, in developing countries, these competencies are present to a lesser extent, with lower percentages. The greatest difference is in technological literacy and data analysis, where developed countries have a significantly higher percentage (Talerco, 2021).

Table 2: Key Challenges of the HR Sector in Developed Countries and Developing Countries (%)

Challenges	Developed Countries (%)	Developing Countries (%)
Attracting talent	60	80
Retaining employees	65	75
Digitalization of processes	75	40
Flexible work models	85	50
Leadership development	70	55
Compliance with regulations	90	60

The results show (Table 3.) that developed countries have a greater focus on digitalization, flexibility and regulations, while developing countries pay more attention to attracting and retaining talent.

The results in Table 4. show that developed countries have better developed professional, interpersonal and organizational skills in the HR sector, while developing countries have a lower level of these competencies.

In developed countries, strategic planning is highly developed, while in developing countries it is moderately developed. Additionally, in developed countries in the industrial sector, focus is also placed on transferable skills that HR experts must have. These include continuous learning skills (Ana et al., 2022), cooperation skills, communication skills, critical thinking skills in problem-solving, finding

solutions and creativity. The results from Table 7 show that nowadays the competencies of HR experts are important because they can strategically contribute to different industries (Ozdemir et al., 2021).

Table 3: Comparison of the Competencies of HR Experts in Developed and Developing Countries

Competencies	Developed Countries	Developing Countries	Comparasiom
Professional skills	High level	Medium level	Developed countries use HR technology more (Bresciani et al., 2021)
Interpersonal skills	High level	Medium level	Developed countries have more training for the development of emotional intelligence
Organizational skills	High level	Low to medium level	In developing countries there is less application of strategic HR.

Table 4: Comparative Analysis of the Competencies of HR Experts in Different Work Sectors

Sector	Key competencies	Developed countries	Developing countries
Industrial	Strategic planning	Highly developed	Moderately developed
IT sector	Human resource management	Highly developed	Low level
Educational sector	Understanding legislation	Highly developed	Moderately developed
Healthcare	Training and development	Highly developed	Low level

DISCUSSION OF THE RESEARCH RESULTS

The results of this research indicate that developed countries set higher standards for the competencies expected from HR experts, while the expansion of international companies into developing markets creates pressure for adaptation and modernization of HR practices. However, traditional business approaches and insufficient education of personnel in some developing countries often limit the development of contemporary HR competencies.

A key difference between developed and developing countries is reflected in the level of HR competencies related to employee well-being, emotional intelligence, active listening and crisis management. Developed countries more effectively recognize employee needs and workplace challenges, which enables proactive measures for preventing burnout and reducing stress (Wang et al., 2022). In contrast, in developing countries, these competencies are often not sufficiently recognized as priorities (Ilić, 2021). The importance of HR competencies is especially visible in crisis situations, which developed countries have recognized as an important factor of organizational success (Afriati et al., 2022). Burnout remains a widespread problem with negative consequences for individuals, organizations and society (Ravi et al., 2023).

HR experts therefore have an important role in creating healthier working environments. Gabriel et al. (2022) emphasize measures such as stress management interventions, employee participation in shaping work tasks, social support, involvement in decision-making and quality performance management systems. In addition, HR leaders are expected to think more innovatively (Schultz, 2019), while future HR practitioners should act as creative innovators in the world of work (Dhanpat et al., 2020; Gigauri, 2020). Cohesion is also recognized as one of the most important drivers of an innovative organizational culture (Rush, 2020).

FINAL CONSIDERATIONS

This research contributes to the development of existing theories in the field of human resources by examining the differences in HR competencies between developed and developing countries. The findings may also support the creation of educational and professional policies aimed at improving HR competencies and aligning education and training with contemporary labor market needs.

The results indicate that HR professionals in developed countries are increasingly expected to possess digital literacy, data analytics skills, strategic management competencies, and the ability to support employee well-being, including the prevention of burnout and the promotion of work-life balance. In contrast, HR professionals in developing countries often operate within more traditional business models, where HR practices are still focused on administration, operational tasks, leadership, and adaptation to ongoing labor market changes.

The research confirms the need for continuous improvement of HR competencies, especially in the areas of digital skills, HR technology, strategic HR management, talent management, data-based decision-making, and employee satisfaction. Based on international experiences, the key recommendations include the development of specialized training programs, courses, and certifications for HR professionals, as well as stronger integration of HR practices into organizational business strategies.

The main limitations of the research are related to the reliance on secondary sources and the limited availability of systematic and comparable data on HR competencies across different countries and sectors. Future research should include empirical studies with HR professionals, employers, and sector representatives, as well as broader comparative analyses between developed and developing countries. This would provide a more comprehensive understanding of how international HR trends can be adapted to different labor market contexts and organizational environments.

REFERENCE

Afriati, M. J., & Ahmad, M. (2022). Quality management human resource training and development. *Journal of Curriculum Indonesia, 5*(1), 63–69.

Ana, A., Alhapip, L., Barliana, M. S., Rahmawati, Y., Anon, M., & Dwiyanti, V. (2020). Transferable skills needed in the workplace. *Journal of Engineering Education Transformations, 34*, 95–101. https://doi.org/10.16920/jeet/2020/v34i0/157858

Bohlouli, M., Mittas, N., Kakarontzas, G., Theodosiou, T., Angelis, L., & Fathi, M. (2020). *Competence assessment as an expert system for human resource management: A mathematical approach*. arXiv. https://doi.org/10.48550/arXiv.2001.09797

Bresciani, S., Ferraris, A., Romano, M., & Santoro, G. (2021). Human resource management and digitalisation. In *Digital transformation management for agile organizations: A compass to sail the digital world* (pp. 117–138). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80043-171-320211007

Chartered Institute of Personnel and Development. (2018). *The profession map*. https://peopleprofession.cipd.org/Images/full-standards-download-dec-2020_tcm29-50113.pdf

Chen, K. (2019). Empirical research on competency model of human resources management personnel in enterprises based on work and quality.

Collins-Nelsen, R., Koziarz, F., Levinson, B., Allard, E., Verkoeyen, S., & Raha, S. (2021). Social context and transferable skill development in experiential learning. *Innovations in Education and Teaching International*. https://doi.org/10.1080/14703297.2021.1886970

Dhanpat, N., Buthelezi, Z. P., Joe, M. R., Maphela, T. V., & Shongwe, N. (2020). Industry 4.0: The role of human resource professionals. *SA Journal of Human Resource Management, 18*, Article a1302. https://doi.org/10.4102/sajhrm.v18i0.1302

Dirani, K. M., Abadi, M., Alizadeh, A., Barhate, B., Garza, R. C., & Gunasekara, N. (2020). Leadership competencies and the essential role of human resource development in times of crisis: A response to COVID-19 pandemic. *Human Resource Development International, 23*(4), 380–394. https://doi.org/10.1080/13678868.2020.1780078

Farahni, S., Ghorbanizadeh, V., Taghavifard, M., & Rangriz, H. (2021). The competency model of human resource managers in Iran's top universities. *Public Management Researches, 13*(50). https://doi.org/10.22111/jmr.2021.34473.5099

Gabriel, K. P., & Aguinis, H. (2022). How to prevent and combat employee burnout and create healthier workplaces during crises and beyond. *Business Horizons, 65*(2), 183–192.

Gigauri, I. (2020). Influence of COVID-19 crisis on human resource management and companies' response: The expert study. *International Journal of Management Science and Business Administration, 6*(6), 15–24.

Gilli, K., Nippa, M., & Knappstein, M. (2023). Leadership competencies for digital transformation: An exploratory content analysis of job advertisements. *German Journal of Human Resource Management, 37*(1), 50–75. https://doi.org/10.1177/23970022221087252

Ilić, B., & Đukić, G. (2021). *Management and new tendencies of human resources: A comparison of Japan, America, and Serbia*.

Kolot, A., Lopushniak, H., Kravchuk, O., Varis, I., & Ryabokon, I. (2022). Transferable competencies of HR manager under global socio-economic changes. *Problems and Perspectives in Management, 20*(1), 322–341. https://doi.org/10.21511/ppm.20(1).2022.27

Krušković, T., Ilić, B., & Anđelić, S. (2022). Research and development of human resource management in Serbian organizations. In *PaKSoM* (pp. 181–186). https://doi.org/10.978/86-82602-00-2

Mura, L., Ključnikov, A., Tvaronavičienė, M., & Androniceanu, A. (2017). Development trends in human resource management in small and medium enterprises in the Visegrad Group. *Acta Polytechnica Hungarica*.

Olsen, K. M., Sverdrup, T. E., & Kalleberg, A. L. (2019). Turnover and transferable skills in a professional service firm. *Journal of Professions and Organization, 6*(1), 2–16. https://doi.org/10.1093/jpo/joy022

Opatha, H. (2021). A simplified study of definitions of human resource management. *Sri Lankan Journal of Human Resource Management, 11*.

Ozdemir, S., & Eroglu, U. (2021). Competencies of HR professionals: A study on the HR competencies of university students. *Journal of Life Economics*, 47–60.

Ravi, B. S., & Sumathi, G. N. (2023). Impact of HR managers' competencies on organizational effectiveness: Mediating role of innovative HR practices. *Problems and Perspectives in Management, 21*(2), 667–681. https://doi.org/10.21511/ppm.21(2).2023.60

Rush, C. (2020). How do you build a culture of innovation when 80% of your workforce is working from home? https://www.hcamag.com/nz/specialisation/employee-engagement/how-can-hr-encourage-innovation-during-covid-19/230364

Schultz, C. M. (2019). Future expectations from human resource managers: A qualitative perspective. *International Journal of Management and Applied Science, 5*(9), 6–9.

Society for Human Resource Management. (2018). *The SHRM body of competency and knowledge*. https://www.shrm.org

Sthapit, A. (2021). HR competency: The key to managing in the pandemic-induced era. *ACE Quarterly, 17*(2), 5–10.

Talerico, C. (2021). HR analytic competencies: A comparison of developed versus developing country HR practitioner skill sets. In *Proceedings of the 3rd International Conference on Business, Management and Finance*.

Taleric, C. K. M. (2022). *Assessing the analytic competency gap for HR professionals: Providing HR a roadmap to data-driven decision-making*. Florida Institute of Technology.

Wang, Y., & Chen, H. (2022). Are human resource managers with good listening competency more likely to avoid job burnout? *BMC Public Health, 22*, Article 246. https://doi.org/10.1186/s12889-022-12618-x

Wong, S. C. (2020). Competency definitions, development and assessment: A brief review. *International Journal of Academic Research in Progressive Education and Development, 9*(3), 95–114.

Yuliantari, P. D., & Martini, I. A. O. (2019). Implementation of HR development to improve employee performance. *International Research Journal of Management, IT & Social Sciences, 6*(6), 194–200. https://doi.org/10.21744/irjmis.v6n6.791

Zeoli, M. L., & Billeter, K. (2019). Transforming HR to be more digital and more human. *Workforce Solutions Review, 10*(1), 4–7.

SUSTAINABLE HUMAN RESOURCE PRACTICES AND EMPLOYEE WELLBEING IN DIGITALIZED WORK ENVIRONMENTS

DOI: 10.5937/EMC26126G

Aneta Guteša
University of Ljubljana, Faculty of Arts, Ljubljana, Slovenia
E-mail: anetagutesa@yahoo.com
Dijana Vašaš Kuručev
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Milica Bogdanov
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Jasmina Poštin
University of UNION "Nikola Tesla" Faculty of management, Sremski Karlovci, Republic of Serbia

ABSTRACT

This paper examines sustainable human resource practices and their impact on employee wellbeing in digitalized work environments. The study focuses on practices such as transparent performance evaluation, digital training, workload management, employee participation, data privacy, and flexible work arrangements. Digital work conditions are analyzed through communication platforms, automation, monitoring systems, and access to tools. The findings indicate that these practices are implemented through structured policies supported by digital systems. Their influence is visible across physical, mental, and social aspects of wellbeing. Clear evaluation and workload policies reduce stress and improve fairness. Training supports competence and reduces uncertainty. Flexible work improves balance between professional and personal life, while communication rules reduce overload. The results show that balanced use of digital tools leads to better job satisfaction, lower stress, and improved employee experience in modern work environments.

Key words: Sustainable human resource management, Employee wellbeing, Digital work environments, Digitalization, Work-life balance

INTRODUCTION

Sustainable human resource management has gained attention due to changes in organizational structures and work conditions. Digital technologies influence how human resource practices are designed and implemented. Organizations aim to align long-term development goals with responsible management of employees. This includes fair treatment, continuous learning, and support for work conditions. Digital tools enable data-based decision making, but they also introduce new challenges related to control and monitoring. Human resource practices need to address both efficiency and employee needs in a balanced manner.

Employee wellbeing has become an important topic in modern organizations. It includes physical health, mental stability, and overall satisfaction with work conditions. Digitalized environments create flexibility in time and location of work. At the same time, constant connectivity may lead to fatigue and pressure. Employees often face increased expectations due to fast communication and information flow. Organizations need to consider how digital tools affect daily work experiences and personal boundaries. Human resource practices should aim to reduce negative effects while supporting positive aspects of digital work. Digitalization changes the way employees interact, communicate, and perform tasks. Work processes become more automated and data-driven. Employees rely on digital platforms for collaboration and decision making. This can increase productivity, but it may also reduce direct social interaction. Lack of clear boundaries between work and private life can create additional stress.

Organizations need to understand how digital environments shape employee behavior and attitudes. Adaptation to these changes requires both technical skills and organizational support.

Sustainability and employee wellbeing are closely connected within human resource management. Sustainable practices focus on long-term outcomes for both employees and organizations. This includes fair policies, stable work conditions, and support for employee development. Digital tools can support these goals through better communication and access to information. However, they can also create risks if not managed properly. Organizations need to integrate sustainability principles into daily human resource practices. This integration can lead to improved employee satisfaction and organizational performance. The present study addresses the need to understand the relationship between sustainable human resource practices and employee wellbeing in digitalized work environments. The focus is on how organizations adapt their practices to new technological conditions. It is important to examine whether these practices support employee wellbeing or create additional challenges.

Based on this, two research questions are defined.

RQ1: The first research question is: What sustainable human resource practices are applied in digitalized work environments?

RQ2: The second research question is: How these practices influence employee wellbeing in such environments?

LITERATURE BACKGROUND

Sustainable human resource management in digital environments focuses on alignment between organizational goals and employee needs over time. Organizations develop policies that support stable employment, fair evaluation, and continuous development (Papalexandris, 2023; Zhang & Chen, 2024). Digital systems enable collection and analysis of employee data, which supports planning and monitoring of human resource activities (Nicolás-Agustín et al., 2022). These systems improve transparency in performance evaluation and career progression. However, increased reliance on digital tools raises concerns related to privacy and control. Employees may feel monitored, which can influence trust and satisfaction (Lutsenko et al., 2025; Saini, 2025). Human resource practices need to balance efficiency and employee comfort while ensuring ethical use of data (Umer et al., 2025). Training and development represent an important component of sustainable human resource management. Digital platforms provide access to learning materials and support skill development (Zhang & Chen, 2024). Organizations introduce online courses, internal knowledge bases, and virtual workshops to support continuous learning. This approach improves adaptability to technological changes (Demir et al., 2023). However, not all employees adapt equally to digital learning environments. Some face difficulties due to limited technical skills or motivation. Human resource departments need to provide guidance and structured learning paths to ensure participation and engagement.

Work organization changes significantly in digital environments. Remote work and flexible schedules become more common due to digital communication tools (Shirmohammadi et al., 2022). Employees can perform tasks from different locations and manage time more independently. This flexibility can improve satisfaction and reduce commuting time (García-Salirrosas et al., 2023). However, unclear boundaries between work and private life may create pressure and extended working hours (Arthi & Gita, 2024). Sustainable human resource management requires clear policies regarding availability, communication, and workload distribution.

Employee wellbeing includes physical, mental, and social dimensions that require attention in digital contexts. Physical wellbeing relates to workspace conditions, especially in remote work settings. Inadequate setups may lead to discomfort and health issues. Mental wellbeing becomes a concern due to constant connectivity and increased workload (Akbar et al., 2025; Gupta et al., 2024). Employees may experience stress due to frequent communication and high expectations. Social wellbeing is also affected, as reduced face-to-face interaction may lead to isolation (Cavicchioli et al., 2025). Digital

platforms support interaction but cannot fully replace direct communication. Organizations need to promote regular communication and social engagement. Job satisfaction is closely linked to overall wellbeing. Digital environments improve access to information and simplify task execution (Xu et al., 2025). However, standardized processes may reduce autonomy and create repetitive tasks. Human resource practices should ensure that employees maintain a sense of purpose and control over their work (Dhand, 2025). Recognition and fair feedback contribute to positive work experiences. Organizations increasingly introduce wellbeing programs such as online counseling and stress management initiatives (Sini et al., 2025). Clear communication about available support improves participation. Digitalization also changes communication patterns and performance monitoring. Employees rely on digital platforms for coordination and collaboration. These tools enable faster information flow but may increase workload due to frequent messages (Lorentzon et al., 2024). Organizations need clear communication guidelines to reduce overload. Monitoring systems provide data for performance evaluation but may create pressure if not implemented transparently (Lutsenko et al., 2025). Employees need clear information about how data is collected and used.

Automation further influences work experiences. Repetitive tasks are replaced by automated systems, allowing employees to focus on more complex activities (Xu et al., 2025). This shift requires new skills and adaptation. Some employees may experience uncertainty due to changes in roles. Training and development are necessary to support this transition. Sustainable human resource management ensures fair treatment, equal opportunities, and safe working conditions in digital environments (Papalexandris, 2023). Work-life balance remains a central issue in digital contexts. Flexible work arrangements support personal and professional responsibilities, but constant connectivity may extend working hours (Shirmohammadi et al., 2022). Organizations need clear boundaries regarding availability. Employee participation also contributes to sustainable practices. Digital tools enable feedback collection and communication, which supports engagement (Nicolás-Agustín et al., 2022). Ethical considerations remain important, especially regarding data privacy and monitoring practices (Saini, 2025). Continuous evaluation and adaptation of human resource practices are necessary to address evolving digital work conditions and maintain employee wellbeing.

Based on the analyzed literature a model for improving employee wellbeing in digitalized work environments within the sustainable human resource practices was developed. The model is presented on Figure 1.

Sustainable human resource practices shape digital work environments and influence employee wellbeing outcomes. Fair and transparent performance evaluation reduces negative perceptions of digital monitoring and supports mental wellbeing. Continuous digital training improves competence in using systems, which reduces frustration and increases job satisfaction. Clear workload policies help manage task distribution through digital tools and prevent overload, which supports work-life balance. Employee participation in decision processes improves alignment between digital systems and actual work needs, which increases satisfaction and social wellbeing. Data privacy practices build trust in digital environments and reduce stress. Support for flexible work arrangements connects digital tools with better balance between work and personal life. Digital work environment characteristics also affect wellbeing outcomes. Collaborative platforms improve communication and coordination, but excessive use may reduce social interaction. Automation reduces repetitive tasks and increases efficiency, but it may create uncertainty without proper support. Reliable technical infrastructure reduces disruptions and stress. Clear communication guidelines help manage information flow and reduce pressure. Performance monitoring influences perceived control, where balanced monitoring supports motivation and excessive monitoring creates tension. Accessibility of digital tools ensures equal participation and smooth task execution, which contributes to overall wellbeing.

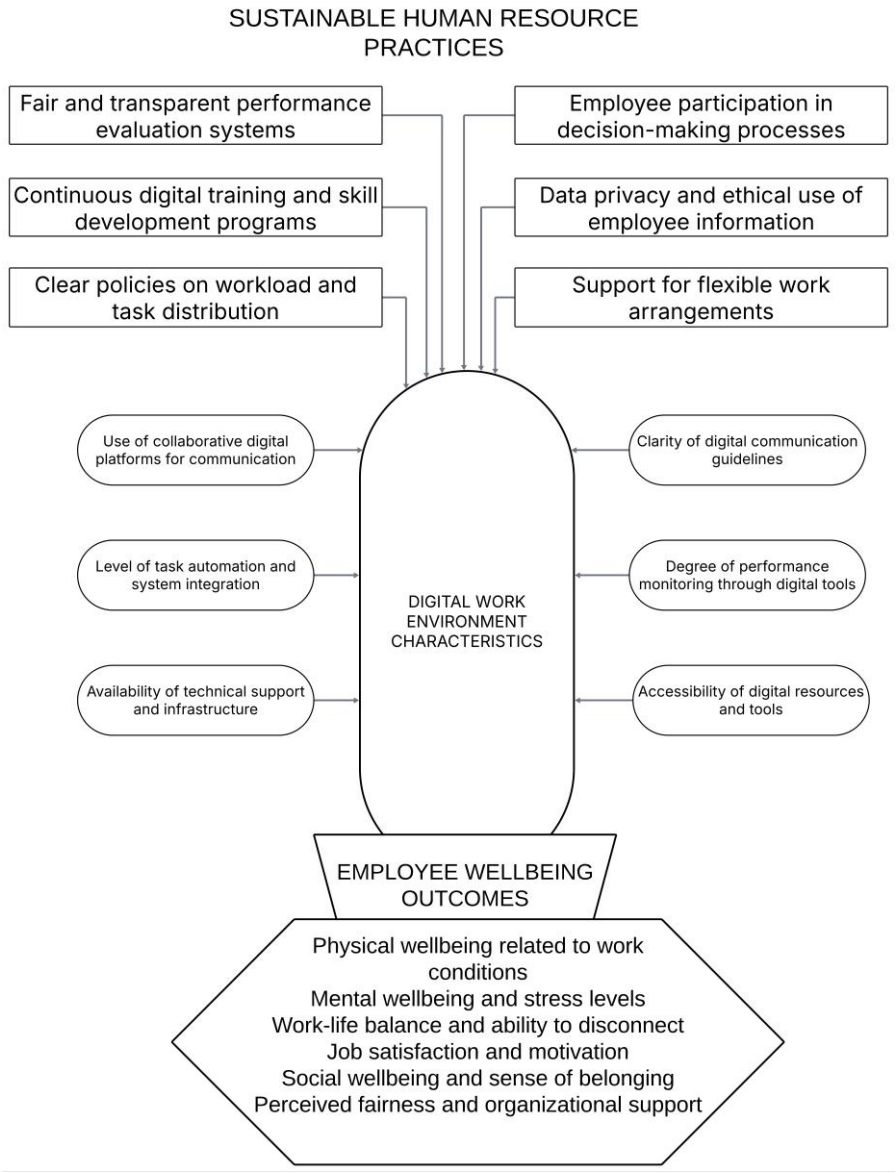


Figure 1: Model for improving employee wellbeing in digitalized work environments within the sustainable human resource practices

SUGGESTION AND GUIDELINES

Based on the developed model and analyzed literature, the following strategies and actions for improving employee wellbeing in digitalized work environments within the sustainable human resource practices are noted:

- Establish clear and transparent performance evaluation systems. Evaluation criteria should be communicated in advance and applied consistently across employees.
- Provide continuous digital training and structured skill development programs. Training should match job requirements and support adaptation to new technologies.
- Define clear workload policies and task distribution rules. Work expectations should be realistic and aligned with available time and resources.
- Develop communication guidelines for digital platforms. Rules should define response time, message priority, and appropriate communication channels.
- Support flexible work arrangements with clear boundaries. Working hours and availability should be defined to protect personal time.

- Ensure data privacy and ethical use of employee information. Employees should be informed about data collection and its purpose.
- Limit excessive digital performance monitoring. Monitoring systems should focus on outcomes rather than constant activity tracking.
- Improve access to reliable digital tools and technical support. Systems should function without interruptions and support efficient task completion.
- Encourage employee participation in decision-making processes. Feedback mechanisms should be active and lead to visible changes in practice.
- Promote social interaction through digital and occasional in-person activities. Team engagement should be supported to reduce isolation and strengthen connections.

CONCLUSION

The analysis shows that sustainable human resource practices in digitalized work environments include transparent performance evaluation, continuous digital training, defined workload policies, employee participation, data privacy protection, and support for flexible work arrangements. These practices are structured to align organizational goals with employee needs under conditions shaped by digital technologies. The findings indicate that such practices are implemented through formal policies and supported by digital systems that organize work processes, communication, and evaluation. This provides a clear answer to the first research question, which concerns the identification of sustainable human resource practices in digitalized environments.

The second research question addresses the influence of these practices on employee wellbeing. The results indicate that sustainable human resource practices have a direct and indirect impact on physical, mental, and social aspects of wellbeing. Transparent evaluation and fair workload distribution reduce stress and improve perceived fairness. Continuous training supports competence and reduces uncertainty related to digital tools. Flexible work arrangements improve work-life balance, while clear communication guidelines reduce overload. At the same time, the effect of these practices depends on how digital systems are designed and used. Balanced implementation of monitoring, communication, and automation contributes to higher job satisfaction, better mental stability, and stronger sense of belonging among employees.

REFERENCES

Akbar, M. A., Varias, V., Risa, T. D., Bhirawa, M. A., & Nugraha, R. (2025). Workplace stress in the era of digital transformation: A psychological approach to employee well-being. RIGGS: Journal of Artificial Intelligence and Digital Business, 4(3), 3496-3506.

Arthi, R., & Gita, P. C. (2024). Remote work demands and work-life balance: Moderating effect of perceived leadership behavior. Journal of Asian Scientific Research, 14(1), 1. https://doi.org/10.55493/5003.v14i1.4961

Cavicchioli, M., Demaria, F., Nannetti, F., Scapolan, A. C., & Fabbri, T. (2025). Employees' attitudes and work-related stress in the digital workplace: An empirical investigation. Frontiers in Psychology, 16, 1546832.

Demir, M., Yaşar, E., & Demir, Ş. Ş. (2023). Digital transformation and human resources planning: the mediating role of innovation. Journal of Hospitality and Tourism Technology, 14(1), 21-36. https://doi.org/10.1108/JHTT-04-2021-0105

Dhand, S. (2025). Human-centric digital workplace: Designing for employee wellbeing and productivity. In Human-centric, sustainable, and resilient organizations in the digital age (pp. 125-146). IGI Global Scientific Publishing.

García-Salirrosas, E. E., Rondon-Eusebio, R. F., Geraldo-Campos, L. A., & Acevedo-Duque, Á. (2023). Job satisfaction in remote work: The role of positive spillover from work to family and work–life balance. Behavioral Sciences, 13(11), 916.

Gupta, P., Lakhera, G., Sharma, M., & Joshi, S. (2024, March). Digital Stress Effect on Employee quality of life: Overcoming barriers Towards Sustainable Development. In 2024 International Conference on Recent Innovation in Smart and Sustainable Technology (ICRISST) (pp. 1-6). IEEE. https://doi.org/10.3390/bs13110916

Lorentzon, J. I., Fotoh, L. E., & Mugwira, T. (2024). Remote auditing and its impacts on auditors' work and work-life balance: auditors' perceptions and implications. Accounting Research Journal, 37(1), 1-18. https://doi.org/10.1108/ARJ-06-2023-0158

Lutsenko, O. Y., Hryhorenko, D. A., Tykhonovych, O. Y., Gryn, D. V., & Pavlichenko, H. V. (2025). Legal regulation of employee monitoring in the digital age: between security and privacy. International Journal of Law and Information Technology, 33, eaaf008.

Nicolás-Agustín, Á., Jiménez-Jiménez, D., & Maeso-Fernandez, F. (2022). The role of human resource practices in the implementation of digital transformation. International Journal of Manpower, 43(2), 395-410. https://doi.org/10.1108/IJM-03-2021-0176

Papalexandris, N. (2023, June). Sustainable Development and Its Link with Human Resource Management in the Digital Era. In LMDE Conference (pp. 277-292). Cham: Springer Nature Switzerland.

Saini, S. (2025). Workplace Monitoring, Digital Tracking and Employee Privacy: A Legal Assessment. International Journal of Research & Technology, 13(4), 588-598.

Shirmohammadi, M., Au, W. C., & Beigi, M. (2022). Remote work and work-life balance: Lessons learned from the covid-19 pandemic and suggestions for HRD practitioners. Human Resource Development International, 25(2), 163-181. https://doi.org/10.1080/13678868.2022.2047380

Sini, V. T., Shibin, E., Sanitha, T. P., Suhaila, T. K., & Divya, M. (2025). Enhancing employee well-being through Digital HRM: Investigating 'Work-Life Balance'as a Mediator in the IT Sector. Advances in Consumer Research, 2, 349-356.

Umer, W., Furnaz, R., Sadiq, B., Naseem, A., & Bashir, T. (2025, December). Artificial Intelligence in HRM: Linking Ethical Design, Digital Well-being, and Green HRM for Sustainable Performance. In 2025 Horizons of Information Technology and Engineering (HITE) (pp. 1-6). IEEE.

Xu, G., Zheng, Z., Zhang, J., Sun, T., & Liu, G. (2025). Does digitalization benefit employees? A systematic meta-analysis of the digital technology–employee nexus in the workplace. Systems, 13(6), 409.

Zhang, J., Chen, Z. Exploring Human Resource Management Digital Transformation in the Digital Age. J Knowl Econ 15, 1482–1498 (2024). https://doi.org/10.1007/s13132-023-01214-y

BETWEEN FAILURE AND SUCCESS: THE ROLE OF PROJECT MANAGER'S LEADERSHIP IN ACHIEVING PROJECT SUCCESS DIMENSIONS

DOI: 10.5937/EMC26132J

Mirjana Jokanović Đajić
University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina
E-mail: mirjana.jokanovic@fpm.ues.rs.ba
Brankica Čomić
University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina
Obrad Spaić
University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina
Mirjana Miljanović
University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina

ABSTRACT

Project success is a complex, multidimensional concept in project management, lacking a universally accepted framework for its definition and measurement. Among the numerous factors influencing project outcomes, the leadership role of the project manager has gained increasing academic and practical attention. This paper examines the relationship between project manager leadership competencies and the achievement of five dimensions of project success: project efficiency, team satisfaction, customer/client satisfaction, business success, and future capacity building.The theoretical part systematizes eight key leadership factors — self-awareness, team motivation, human resource management, human resource development, sensitivity, team empowerment, influence on team members, and critical thinking — and analyzes their contribution to effective project management.The empirical part applies a quantitative approach based on a survey conducted among 257 respondents from Bosnia and Herzegovina, Serbia, and Montenegro. Descriptive statistical analysis, along with reliability and validity testing, was used to examine the perceived influence of leadership competencies on each success dimension.The findings confirm that leadership competencies significantly influence all examined dimensions of project success, with team satisfaction (M = 4.45) and project efficiency (M = 4.33) emerging as the most strongly affected outcomes.

Key words: project success, project manager leadership, leadership factors, project success dimensions

INTRODUCTION

Despite the well-developed body of knowledge in the field of project management, a universal agreement among authors has still not been reached regarding the definition and measurement of project success that would be suitable for all projects, given the different human, budgetary, and technical variables of each project. The criteria for measuring project success have evolved from the easily measurable parameters of the iron triangle (time, scope, and cost) to complex multidimensional frameworks that adopt a long-term perspective and encompass both efficiency and organizational impact. Contemporary researchers are increasingly focusing on measuring project success through the impact that projects have on the organization. Emphasis is placed on the achievement of organizational goals, the purpose of the project, and customer satisfaction (Albert et al., 2017). Shenhar and Dvir proposed a new way of viewing project success, emphasizing that projects should not be assessed solely through the fulfillment of deadlines and budgets, but in a broader sense. They introduced a model based on five dimensions of project success that are evaluated at different periods following project completion. This model includes the following dimensions (Shenhar & Dvir, 2007): project efficiency, impact on the customer, impact on the team, business success, and preparing for the future.

Given the increasing complexity of modern projects and the growing importance of soft skills in project environments, leadership competencies of project managers have become a critical determinant of project outcomes. In addition to technical expertise, project managers are expected to demonstrate behavioral and emotional capabilities that enable them to coordinate teams, manage stakeholder expectations, and ensure alignment between project objectives and organizational goals. Therefore, understanding the specific leadership factors that contribute to different dimensions of project success is essential for improving both project performance and overall organizational effectiveness.

This study empirically examines the influence of project manager leadership competencies on five dimensions of project success. The applied quantitative approach combines descriptive statistics with reliability and validity testing to ensure robust measurement and interpretation of findings.

LITERATURE REVIEW

Leading a project and its associated team toward success requires project managers to perform their duties efficiently and effectively. The leadership aspect of project management is multidimensional, encompassing technical, behavioral, and emotional competencies that collectively determine a project manager's effectiveness (Maqbool et al., 2017; Geoghegan & Dulewicz, 2008; Nguyen & Hadikusumo, 2017). These competencies, summarized in Table 1, extend beyond interpersonal skills to include human resource management as a whole (Demirkesen & Ozorhan, 2017). Despite their recognized importance, technical and scientific professionals often lack the leadership capabilities necessary to manage people effectively (Thite, 2000).

The project manager represents the main driving force behind a project, and team performance largely depends on the manager's individual leadership style (Gruden & Stare, 2018). The role of leadership competence in improving project performance is crucial, as the project manager must select the management style most appropriate for the type and complexity of the project (Ahmed & Anantatmula, 2017; Müller & Turner, 2010). Beyond technical coordination, effective leadership requires understanding team members' needs, expectations, and motivations, and ensuring that personal interests align with project goals. In this regard, emotional intelligence plays a particularly important role — project managers with higher levels of emotional intelligence tend to adopt open communication and transformational leadership styles, fostering proactive behavior and trust within the team (Afzal et al., 2018). These emotional attributes help teams integrate their specific knowledge and skills, ultimately ensuring that projects are completed effectively within budget and time constraints (Sunindijo et al., 2007).

Additionally, leadership may influence project success by creating an environment in which project teams actively contribute to successful outcomes. Gundersen et al. argue that transformational leadership provides clarity regarding performance standards and reduces role ambiguity within projects, ultimately leading to project success (Gundersen et al., 2012). More specifically, transformational leaders possess a clear vision of what the project should become and how success can be achieved, thereby exerting a direct positive influence on project outcomes (Ahmed & Anantatmula, 2017). The leader’s vision, in turn, should be communicated to team members so that they believe in it and become motivated and enthusiastic about achieving it (Aga et al., 2016).

Project management literature consistently calls for more empirical studies on transformational leadership, given that poorly developed leadership practices are cited as a primary driver of project failure (Zaman et al., 2019; Raziq et al., 2018; Maqbool et al., 2017). The leadership competencies examined in this study are summarized in Table 1.

Recent meta-analytic evidence further confirms that transformational leadership significantly outperforms transactional leadership in achieving project success across different sectors and contexts (Abbas & Ali, 2023). Furthermore, the empowerment dimension of leadership has emerged as a particularly critical mechanism: Fareed et al. (2023) demonstrated that psychological empowerment

mediates the relationship between transformational leadership and project success, while Nauman et al. (2022) showed that an empowerment climate strengthens the beneficial effects of team-building on project outcomes.

Table 1: Leadership competences of the project managers

Competence	Reference
– self-awareness, – team motivation, – human resource management, – human resource development, – sensitivity, – team empowerment, – project manager's influence on team members, – critical thinking	Maqbool et al, 2017; Taherdoost, Keshavarzsaleh, 2016; Nguyen and Hadikusumo, 2017; Newton, 2009; Thite, 2000; PMBOK Guide, 2017; Geoghegan, Dulewicz, 2008; Taherdoost, Keshavarzsaleh, 2016

RESEARCH METHODOLOGY

This research is both descriptive and explanatory in nature and, using a quantitative approach, was conducted through a survey method implemented via the SurveyMonkey platform over a period of approximately three months. The questionnaire was distributed electronically through communication channels and the database of the global Project Management Institute (PMI) network, specifically local offices in Bosnia and Herzegovina, Serbia, and Montenegro. The distribution process was conducted according to the Dillman approach (Dillman & Smyth, 2008), allowing only one response per participant. In this way, the anonymity of respondents was preserved, while multiple submissions were disabled on the SurveyMonkey platform to ensure a single response from each participant.

This research involves the evaluation of a cluster of leadership competencies and their influence on the achievement of specific dimensions of project success, namely: project efficiency, team member satisfaction, customer/client satisfaction, business success, preparing for the future. All variables were measured using a 5-point Likert scale ranging from "very low impact" to "very high impact".

The target group consisted of individuals who had either previously participated in a project or were currently involved in one. This ensured inclusion of respondents with relevant experience in project management, regardless of whether their organization is primarily project-oriented or not. In addition, organizations that periodically execute projects alongside their core activities were also included.

The geographical distribution of respondents covered Bosnia and Herzegovina, Serbia, and Montenegro. A total of 281 questionnaires were collected, out of which 257 valid responses were retained for analysis. The obtained sample size is considered adequate for quantitative analysis.

The sample was diverse in terms of demographics, experience, and organizational representation. The gender distribution was almost equal, with 129 female respondents (50.2%) and 128 male respondents (49.8%). The age of respondents ranged from 23 to 70 years. All respondents were highly educated, with the majority holding a doctoral degree (49.8%). The internal consistency of the leadership competency scale was tested using Cronbach's alpha coefficient, which indicated good reliability of the measurement instrument ($\alpha = 0.875$).

In addition, construct validity was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). The results confirmed strong construct reliability and convergent validity. The CR value was 0.93, exceeding the recommended threshold of 0.70, while AVE was 0.65, above the recommended value of 0.50. These results confirm that the measurement instrument is reliable and valid for further empirical analysis.

RESULTS

In this section, the data related to cluster evaluation are presented in tabular form, along with their impact on the achievement of specific project success dimensions, *table 2*.

Table 2: Evaluation of Leadership Style (Project Manager Leadership) on Project Success Dimensions

Impact level	Project efficiency	Team satisfaction	Customer/client satisfaction	Business success	Future capacity building
Very low impact	2 (0.7%)	0	0	1 (0.4%)	0
Low impact	0	5 (1.8%)	9 (3.2%)	4 (1.4%)	4 (1.4%)
Medium impact	19 (6.8%)	18 (6.5%)	30 (10.8%)	35 (12.5%)	29 (10.4%)
High impact	88 (31.5%)	58 (20.8%)	75 (26.9%)	67 (24.0%)	68 (24.4%)
Very high impact	90 (32.3%)	118 (42.3%)	85 (30.5%)	92 (33.0%)	98 (35.1%)
Total valid responses	199	199	199	199	199
Missing	80	80	80	80	80
TOTAL	279	279	279	279	279

After presenting the frequency distribution of responses, additional descriptive statistical analysis was conducted in order to obtain a clearer understanding of the perceived influence of project manager leadership on different project success dimensions. Mean values and standard deviations were calculated based on Likert-scale responses, and the results are presented in Table 3.

Table 3: Descriptive Statistics of Project Success Dimensions

Project success dimension	N	Mean (M)	Standard Deviation (SD)	Rank
Team satisfaction	199	4.45	0.76	1
Project efficiency	199	4.33	0.73	2
Future capacity building	199	4.31	0.79	3
Business success	199	4.23	0.84	4
Customer/client satisfaction	199	4.19	0.85	5

Descriptive statistics indicate a high perceived influence of project manager leadership across all project success dimensions, with mean values ranging from 4.19 to 4.45. The highest mean value was recorded for team satisfaction ($M = 4.45$, $SD = 0.76$), suggesting that leadership competencies are perceived as particularly important for team-related outcomes. This was followed by project efficiency ($M = 4.33$, $SD = 0.73$), future capacity building ($M = 4.31$, $SD = 0.79$), and business success ($M = 4.23$, $SD = 0.84$). The lowest mean value was observed for customer/client satisfaction ($M = 4.19$, $SD = 0.85$), although it still indicates a high level of perceived leadership influence. The relatively low standard deviation values suggest a consistent perception among respondents regarding the importance of leadership for project success.

DISCUSSION

All project success dimensions show a very high perceived influence of project manager leadership (means > 4.0), indicating strong respondent agreement that leadership competencies significantly contribute to project success.

The results reveal a clear pattern across all five dimensions. Team satisfaction emerged as the most strongly influenced dimension ($M = 4.45$), underscoring the centrality of motivational and relational leadership competencies — particularly transformational leadership and emotional intelligence — in shaping team dynamics. Project efficiency followed closely ($M = 4.33$), confirming that leadership is directly associated with operational performance, including planning, coordination, and budget control. Future capacity building ($M = 4.31$) and business success ($M = 4.23$) also recorded high values, indicating that the influence of leadership extends beyond immediate project delivery toward broader organizational and strategic outcomes.

Although customer/client satisfaction recorded the lowest mean value (M = 4.19, SD = 0.85), the result still indicates a strong perceived influence of leadership. This may suggest that external stakeholder satisfaction is additionally shaped by factors beyond the direct control of project managers, such as market conditions and client expectations.

The relatively low standard deviation values indicate a consistent perception among respondents regarding the importance of leadership across all project success dimensions. Overall, the findings support the multidimensional view of project success proposed by Shenhar and Dvir (2007), emphasizing that project success extends beyond traditional time, cost, and scope constraints.

The present findings are consistent with recent empirical studies that have examined similar dimensions of project outcomes. Abbas and Ali (2023), in a meta-analytic review of 50+ studies, confirmed that transformational leadership positively influences project success across diverse organizational contexts, with the strongest effects observed in relation to operational and team-level outcomes, a pattern closely aligned with the current study's finding that project efficiency and team satisfaction record the highest mean values.

Regarding the team empowerment competency, the results echo findings by Fareed et al. (2023) and Nauman et al. (2022), who demonstrated that empowerment, both psychological and climate-based, serves as a key mechanism through which leadership translates into tangible project outcomes. This is particularly relevant to the current study's finding that future capacity building (M = 4.31) is perceived as strongly influenced by leadership, as empowerment practices directly contribute to long-term organizational learning and adaptability.

Furthermore, Han et al. (2024) found that transformational leadership enhances project success through sequential improvements in team flexibility and team agility, dimensions that closely correspond to the 'preparing for the future' success dimension identified in the Shenhar and Dvir (2007) framework used in this study. The relatively lower perceived influence of leadership on customer/client satisfaction (M = 4.19) may also be interpreted in line with Altaher et al. (2024), who noted that customer-facing outcomes are mediated by team collaboration quality and are thus more distal from direct leadership behaviors.

CONCLUSION

The findings demonstrate that project manager leadership is perceived as a highly influential factor across all five examined dimensions of project success. Among these, team satisfaction emerged as the most strongly influenced dimension (M = 4.45), followed by project efficiency (M = 4.33) and future capacity building (M = 4.31), while customer/client satisfaction recorded the lowest, though still high, level of perceived influence (M = 4.19).

The results confirm that leadership plays a crucial role not only in operational project execution but also in broader organizational and strategic outcomes. In particular, competencies such as motivation, communication, emotional intelligence, empowerment, and human resource development contribute significantly to project success.

From a theoretical perspective, the study supports the multidimensional view of project success and reinforces the importance of leadership as a central determinant in project management literature. From a practical perspective, the findings highlight the need for organizations to invest in developing leadership capabilities of project managers in order to improve overall project performance.

The study has several limitations, including the use of self-reported data and a geographically limited sample. Future research could expand the scope by including different industries, larger international samples, and applying more advanced statistical techniques such as structural equation modelling (SEM) to further explore causal relationships.

REFERENCES

Abbas, M., & Ali, R. (2023). Transformational versus transactional leadership styles and project success: A meta-analytic review. *European Management Journal, 41*(1), 125–142. https://doi.org/10.1016/j.emj.2021.10.011

Afzal, A., Khan, M. M., Mujtaba, B. G., & Mujeeb, E. (2018). The impact of organizational culture, leadership style, and perceived organizational support on employee outcomes. *Journal of Applied Business Research, 34*(1), 55–68.

Aga, D. A., Noorderhaven, N., & Vallejo, B. (2016). Transformational leadership and project success: The mediating role of team-building. *International Journal of Project Management, 34*(5), 806–818. https://doi.org/10.1016/j.ijproman.2016.02.012

Ahmed, R., & Anantatmula, V. S. (2017). Empirical study of project managers' leadership competence and project performance. *Engineering Management Journal, 29*(3), 189–205. https://doi.org/10.1080/10429247.2017.1343009

Albert, M., Balve, P., & Spang, K. (2017). Evaluation of project success: A structured literature review. *International Journal of Managing Projects in Business, 10*(4), 796–821. https://doi.org/10.1108/IJMPB-01-2017-0004

Demirkesen, S., & Ozorhon, B. (2017). Investigating the impact of commitment-based HR practices on project management performance. *International Journal of Project Management, 35*(8), 1410–1424. https://doi.org/10.1016/j.ijproman.2017.08.001

Dillman, D. A., & Smyth, J. D. (2008). *Internet, mail, and mixed-mode surveys: The tailored design method* (3rd ed.). Wiley.

Fareed, M. Z., Su, Q., & Aslam, M. U. (2023). Transformational leadership and project success: The mediating role of psychological empowerment. *SAGE Open, 13*(1). https://doi.org/10.1177/21582440231154796

Geoghegan, L., & Dulewicz, V. (2008). Do project managers' leadership competencies contribute to project success? *Project Management Journal, 39*(4), 58–67. https://doi.org/10.1002/pmj.20084

Gruden, N., & Stare, A. (2018). The influence of behavioral competencies on project performance. *Project Management Journal, 49*(3), 98–109. https://doi.org/10.1177/8756972818770840

Gundersen, G., Hellesøy, B. T., & Raeder, S. (2012). Leading international project teams: The effectiveness of transformational leadership in dynamic work environments. *Journal of Leadership & Organizational Studies, 19*(1), 46–57. https://doi.org/10.1177/1548051811429573

Han, H., Ma, F., & Liu, X. (2024). Transformational leadership and project success: The serial mediating roles of team flexibility and team agility. *Frontiers in Built Environment, 9*, Article 1334413. https://doi.org/10.3389/fbuil.2023.1334413

Maqbool, R., Sudong, Y., Manzoor, N., & Rashid, Y. (2017). The impact of emotional intelligence, project managers' competencies, and transformational leadership on project success. *Project Management Journal, 48*(3), 58–75. https://doi.org/10.1177/875697281704800304

Müller, R., & Turner, R. (2010). Leadership competency profiles of successful project managers. *International Journal of Project Management, 28*(5), 437–448. https://doi.org/10.1016/j.ijproman.2009.09.003

Nauman, S., Musawir, A. U., Munir, H., & Rasheed, I. (2022). Enhancing the impact of transformational leadership and team-building on project success: The moderating role of empowerment climate. *International Journal of Managing Projects in Business, 15*(2), 423–447. https://doi.org/10.1108/IJMPB-02-2021-0031

Newton, R. (2009). *The project manager: Mastering the art of delivery*. Pearson Education.

Nguyen, T. S., & Hadikusumo, B. H. W. (2017). Effects of human resource development on engineering, procurement, and construction project success. *Built Environment Project and Asset Management, 7*(1), 73–85. https://doi.org/10.1108/BEPAM-09-2015-0041

Project Management Institute. (2017). *A guide to the project management body of knowledge (PMBOK® guide)* (6th ed.). Project Management Institute.

Raziq, M. M., Borini, F. M., Malik, O. F., Ahmad, M., & Shabaz, M. (2018). Leadership styles, goal clarity, and project success: Evidence from project-based organizations in Pakistan. *Leadership & Organization Development Journal, 39*(2), 309–323. https://doi.org/10.1108/LODJ-07-2017-0212

Shenhar, A. J., & Dvir, D. (2007). *Reinventing project management: The diamond approach to successful growth and innovation*. Harvard Business School Press.

Sunindijo, R. Y., Hadikusumo, B. H. W., & Ogunlana, S. (2007). Emotional intelligence and leadership styles in construction project management. *Journal of Management in Engineering, 23*(4), 166–170. https://doi.org/10.1061/(ASCE)0742-597X(2007)23:4(166)

THE IMPORTANCE OF CREATIVITY IN HIGHER EDUCATION FOR THE DEVELOPMENT OF MODERN BUSINESS

DOI: 10.5937/EMC26138K

Dragana Kovač
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: milosavljevd@yahoo.com
Edit Terek Stojanović
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Stefan Ugrinov
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Melita Ćoćkalo-Hronjec
High school "Laza Kostić", Novi Sad, Republic of Serbila
Milovan Cvjetković
Higher educational institution "Economics Academy", Brčko District, Bosnia and Herzegovina

ABSTRACT

In contemporary business, creativity is increasingly viewed as a strategic competence that enables innovation, adaptation to change and the resolution of complex organisational problems. Starting from this premise, the paper examines the importance of creativity in higher education for the development of competences relevant to business practice. The theoretical part points to the relationship between creativity, interdisciplinary learning, innovation and the responsible application of artificial intelligence. The empirical part is based on a survey conducted among 55 students of the Engineering Management study programme at the Technical Faculty "Mihajlo Pupin" in Zrenjanin. The results show that students largely recognise their own creative potential, particularly in terms of connecting knowledge from different fields, seeking alternative approaches and improving ideas on the basis of feedback. At the same time, the findings indicate that assignments requiring original solutions are not sufficiently systematically represented. The paper concludes that higher education can contribute more strongly to the development of modern business if it more frequently includes interdisciplinary, problem-based and open-ended assignments.

Key words: creativity, higher education, modern business.

INTRODUCTION

In the context of an increasingly globalised economy, creativity is no longer merely an aesthetic or individual attribute, but an important driver of sustainable business performance and innovation (Mačerauskienė, 2020). Consequently, contemporary educational institutions are expected to move beyond traditional pedagogical models and develop the ability to solve complex problems, think originally and use artificial intelligence responsibly in rapidly changing market conditions (Gong et al., 2022; Knibbe et al., 2024). Nevertheless, institutional frameworks often find it difficult to move away from standardised assessment towards learning environments that genuinely foster dynamic and creative thinking (Kayyali, 2024). By introducing design thinking, interdisciplinary exercises and transdisciplinary learning, higher education institutions can strengthen the synergy between human originality, critical judgement and strategic innovation, which is particularly important for modern business (Eloranta et al., 2024; Selvalakshmi et al., 2021; Shaznay, 2024). In this process, artificial intelligence should be regarded as support for learning rather than a substitute for human intellect, since its real contribution depends on students' ability to evaluate, contextualise and ethically use generated content (Ma et al., 2025; Rana et al., 2025). Teachers therefore have an important role in guiding students from the passive use of digital tools towards active, critical and responsible

participation in a professional environment shaped by artificial intelligence (Ahmed, 2025; Bozkurt, 2023; Wang et al., 2025).

CREATIVITY IN HIGHER EDUCATION

Creativity is most commonly understood as the ability to create new, original and contextually appropriate solutions to complex problems, expressed across artistic, scientific, educational and business domains (Mahama, 2024). In contemporary conditions, it is increasingly viewed as a developable competence and a prerequisite for competitiveness, because it enables individuals and organisations to adapt to change and to find different ways of solving problems (Alshammari & Thomran, 2023).

In higher education, creativity has become one of the important prerequisites for academic and professional success, as the contemporary economy requires the ability to solve complex problems, connect knowledge and create new approaches (Kayyali, 2024). However, higher education institutions still often rely on disciplinary frameworks, the reproduction of knowledge and rigid assessment criteria, which can push originality and student innovation into the background (Papaleontiou–Louca et al., 2014). Therefore, contemporary pedagogical strategies should encourage inquiry, synthesis, collaborative learning and the use of digital tools rather than passive content acquisition (Hossain et al., 2026). The integration of creative and critical thinking enables students to question dominant patterns, develop autonomy and recognise education as a space for actively shaping knowledge (Bačová & McCrone, 2024; Glăveanu et al., 2023).

THE RELATIONSHIP BETWEEN CREATIVITY, INNOVATION AND MODERN BUSINESS

In modern business, creativity and innovation are related but not identical processes: creativity implies the generation of new ideas, while innovation refers to their implementation in practice. Their synergy represents an important driver of organisational growth, sustainability and competitive advantage (Francis & Rangasamy, 2024; Patil, 2024). Organisations that foster psychological safety, agility and cross-functional collaboration more easily develop new products, services and business models, because employees have space to propose solutions and learn through experimentation (Amora, 2025; Paonessa, 2025; Tariq, 2025). Therefore, leadership should institutionalise creative behaviours as part of business strategy, with the support of digital platforms, recognition systems and HR practices that develop employees' abilities, motivation and opportunities (D'Souza, 2026; Madanchian & Taherdoost, 2025; Westover, 2024; Westover, 2025).

STUDENTS' CREATIVITY AS A FUTURE BUSINESS RESOURCE

The integration of creative competences into management education is important because it facilitates students' transition from theoretical knowledge to the practical application of divergent and convergent thinking (Belur et al., 2022; Knibbe et al., 2024). In this way, academic institutions can better prepare future managers and employees to solve complex business problems, question assumptions and make decisions under uncertainty (Bierwisch & Schmitz, 2024; Bagley et al., 2019). Curricula should therefore be directed towards action-oriented and interdisciplinary approaches, such as case studies, simulations, studio-based work and design thinking, because such methods bring teaching closer to the real requirements of professional practice (Castro & Soledad, 2025; Ryan et al., 2025; Yu et al., 2025). The inclusion of artificial intelligence can further broaden students' creative potential, but only if it is used as support for strategic reasoning rather than as a substitute for independent thinking (Dubey et al., 2026; Simpson, 2026). A hybrid approach that combines human intuition and machine-assisted efficiency enables the development of competences required in a business environment in which innovation is increasingly based on the combination of creativity, analytics and responsible technology use (Bass & Pleggenkuhle-Miles, 2025; Chan & Hu, 2023; Thanh et al., 2023; Mårtensson & Mullins, 2024).

RESEARCH METHODOLOGY AND RESULTS

The research was conducted with the aim of examining the importance of creativity in higher education for the development of competences relevant to modern business. The subject of the research included students' self-assessment of creativity, their attitudes towards teaching practices that encourage original and problem-based thinking, and their perception of educational practices that may contribute to the development of creativity as a future business competence.

A quantitative approach was applied, and the survey was used as the basic research method. The research instrument was a structured anonymous questionnaire comprising several thematic sections: general data on respondents, the frequency of assignments requiring an original solution, self-assessment of creativity, teaching practices, assessment and feedback, and attitudes towards techniques for encouraging creativity. Most statements were measured using a five-point Likert scale, where 1 indicated complete disagreement and 5 complete agreement.

The research was conducted on a sample of 55 students of the Engineering Management study programme at the Technical Faculty “Mihajlo Pupin” in Zrenjanin. Female respondents were more represented in the sample (76.4%), while male respondents accounted for 23.6%. By year of study, third-year students were the most represented (32.7%), followed by second-year students (21.8%), first- and fourth-year students with 16.4% each, while master's students accounted for 14.5% of the sample. The data were processed using descriptive statistics, through frequencies and percentages of responses.

The results show that students recognise creativity as an important ability, but also that as-signments requiring an original solution are not equally strongly represented in the teaching process. The largest share of respondents stated that they have such assignments “sometimes” (45.5%), while 34.5% have them “often” and only 3.6% “very often”. This finding indicates that creative assignments exist, but that they are still not a systematically dominant part of teaching practice.

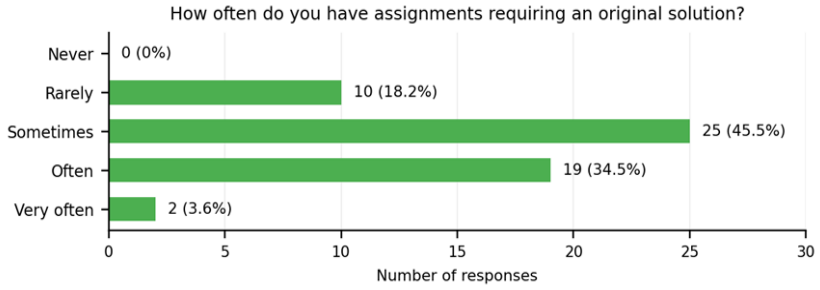


Figure 1: Frequency of assignments requiring an original solution

This result is significant because modern business requires not only the reproduction of exist-ing knowledge, but also the ability to formulate new solutions under conditions of uncertainty. If creativity is viewed as the basis of innovation, then open-ended assignments, project work and the solving of real problems should be more strongly represented in higher education.

Regarding the self-assessment of creativity, the selected results indicate a high potential among students for interdisciplinary thinking (Figure 2.). A total of 76.4% of respondents agreed with the state-ment that they often connect knowledge from different fields. This is particularly important for the business context, because real organisational problems can rarely be solved from the per-spective of a single discipline.

Students also show readiness for flexible problem-solving: 70.9% of respondents state that, when they encounter an obstacle, they usually devise an alternative approach. Such an ability represents an important basis for business innovation, because it enables the questioning of routine solutions and the development of different approaches to products, services, processes or organisational practices.

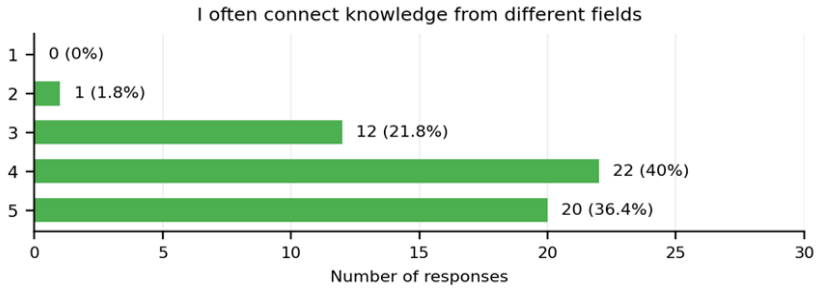


Figure 2: Connecting knowledge from different fields

A particularly positive finding refers to the role of feedback. A total of 87.3% of respondents state that they are able to improve an idea after receiving feedback. This shows that students do not perceive creativity only as spontaneous idea generation, but also as a process of develop-ment, correction and adaptation.

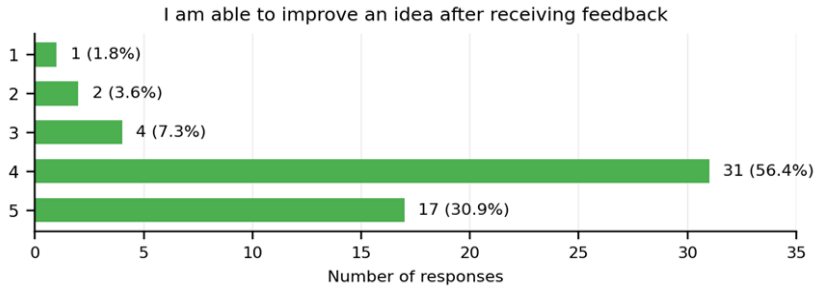


Figure 3: Improvement of an idea after feedback

This finding is important because, in a business environment, ideas rarely develop in isolation. They are tested, commented on, aligned with user needs and adapted to organisational goals. Therefore, the ability to accept feedback and transform it into a better solution represents a sig-nificant professional competence.

The results related to techniques for encouraging creativity further confirm the need for teach-ing that is closer to real business situations. The strongest support was recorded for interdisci-plinary assignments: 78.2% of respondents believe that connecting subjects would increase their creativity.

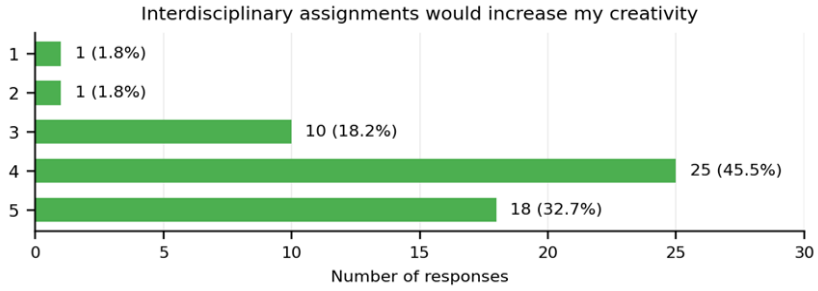


Figure 4. Attitude towards the importance of interdisciplinary assignments for creativity development

This result clearly indicates that students recognise the value of connecting different fields of knowledge. In the context of modern business, this is particularly important because innova-tions most often emerge at the intersection of different knowledge areas, functions and perspec-tives. Interdisciplinary assignments, case studies, simulations and practice-based projects can therefore contribute to developing students' creative potential as a concrete business compe-tence.

Based on the selected findings, it can be concluded that students have a pronounced potential for creative and interdisciplinary thinking, but that the teaching process should be further di-rected towards assignments requiring originality, practical application of knowledge and the development of multiple possible solutions. In this way, higher education would more strongly connect academic learning with the requirements of modern business.

CONCLUSION

Creativity in higher education represents an important prerequisite for the development of competences required by modern business. The results of the research show that Engineering Management students largely recognise their own creative potential, particularly through the connection of knowledge from different fields, the search for alternative approaches and the readiness to improve ideas on the basis of feedback.

At the same time, the findings indicate that creative assignments are not sufficiently systemati-cally represented. Although students occasionally work on assignments requiring original solu-tions, there is room for teaching to be further directed towards open-ended, interdisciplinary and problem-based activities. It is particularly significant that students recognise interdiscipli-nary assignments as a form of work that could increase their creativity, which is in line with the needs of a business environment in which problems are complex and multidimensional.

The development of creativity should therefore not be viewed solely as a pedagogical objective, but also as an important contribution to the development of future business resources. Higher education institutions can play a significant role in preparing students for innovative, flexible and responsible business if the teaching process is organised in a way that encourages inde-pendent thinking, the connection of knowledge, the reasoned presentation of ideas and the itera-tive improvement of solutions.

REFERENCES

Ahmed, S. (2025). Reimagining education in the coming decade: What AI reveals about what really matters. *Frontiers in Education, 10*. https://doi.org/10.3389/feduc.2025.1699106

Alshammari, A., & Thomran, M. (2023). Towards enhancing creativity and innovation in education system for youth in Hail region. *Advanced Education*, *10*(22), 122–136. https://doi.org/10.20535/2410-8286.279776

Amora, A. (2025). Innovation and creativity in management (pp. 298–312). https://doi.org/10.51767/ic250223

Bačová, D., & McCrone, G. (2024). Creativity in education: International perspectives. *Educational Review*, *77*(3), 1021–1022. https://doi.org/10.1080/00131911.2024.2401730

Bagley, C. E., Sulkowski, A. J., Nelson, J. S., Waddock, S., & Shrivastava, P. (2019). A path to developing more insightful business school graduates: A systems-based, experimental approach to integrating law, strategy, and sustainability. *Academy of Management Learning & Education, 19*(4), 541–568. https://doi.org/10.5465/amle.2018.0036

Bass, E., & Pleggenkuhle-Miles, E. G. (2025). The BIG activity: Using generative AI for hybrid strategic decision-making with business students. *Proceedings of the Annual Hawaii International Conference on System Sciences*. https://doi.org/10.24251/hicss.2025.597

Belur, J., Patil, S. V., Mahantshetti, S., & Patil, S. (2022). The boosters that foster creativity competencies among MBA students: Identifying and modelling the relationships. *Higher Education for the Future*, *9*(2), 216–233. https://doi.org/10.1177/23476311221108228

Bierwisch, A., & Schmitz, M. (2024). Futures thinking: Fostering creativity for a sustainable world (pp. 117–139). https://doi.org/10.1108/978-1-83549-464-620241008

Castro, M. P., & Soledad, M. (2025). Transformative economies and complex thinking: Enhancing sustainability competencies in business education. *The International Journal of Management Education, 23*(3), 101223. https://doi.org/10.1016/j.ijme.2025.101223

Chan, C. K. Y., & Hu, W. (2023). Students' voices on generative AI: Perceptions, benefits, and challenges in higher education. *International Journal of Educational Technology in Higher Education, 20*(1). https://doi.org/10.1186/s41239-023-00411-8

D'Souza, C. (2026). Navigating global turbulence in 2026: Turning volatility into opportunity. *The Journal of Applied Management Accounting Research, 24*(1), 13–22. https://doi.org/10.52153/oaj0132124

Dubey, D. A., Baghel, D., Kalita, R., Sharma, D. M., & Lashkari, S. (2026). The AI co-founder: Fostering entrepreneurial and design-thinking mindsets in engineering and management education. *Journal of Engineering Education Transformations, 39*, 32–41. https://doi.org/10.16920/jeet/2026/v39is3/26095

Eloranta, V., Hakanen, E., & Shaw, C. M. (2024). Teaching for paradigm shifts: Supporting the drivers of radical creativity in management education. *Educational Research Review, 45*, 100641. https://doi.org/10.1016/j.edurev.2024.100641

Francis, S., & Rangasamy, S. (2024). Innovation journey. In *Advances in Business Information Systems and Analytics* (pp. 114–127). IGI Global. https://doi.org/10.4018/979-8-3693-3354-9.ch006

Glăveanu, V. P., Ince, A., Brown, N., Ramlackhan, K., Bergström, S. E., Kühne, S., Lundgren, M., Schlick, M., Dalton-Puffer, C., McAllister, Á., Ahn, K., Ohn, J. D., Balbontín-Alvarado, R., Rivas-Morales, C., Swanson, C. J., Bullough, L., Souto, A.-M., Lappalainen, S., Niemi, A.-M., ... Rivas, C. (2023). *Creativity in education: International perspectives*. UCL Press. https://doi.org/10.14324/111.9781800080638

Gong, Z., Soomro, S. A., Nanjappan, V., & Georgiev, G. V. (2022). The gap in design creativity education between China and developed countries. *Proceedings of the Design Society, 2*, 871–880. https://doi.org/10.1017/pds.2022.89

Hossain, A., Khan, W. A., Roy, P., Bhattacharjee, S., & Ansari, M. S. H. (2026). How higher education students in West Bengal perceive creative thinking in their learning process: A theoretical exploration. *International Journal of Research and Innovation in Social Science*, *10*(3), 1702–1712. https://doi.org/10.47772/ijriss.2026.100300118

Kayyali, M. (2024). Understanding innovation in higher education. In *Advances in Educational Marketing, Administration, and Leadership* (pp. 117–138). IGI Global. https://doi.org/10.4018/979-8-3693-6880-0.ch006

Knibbe, J., Peschl, R., & Osiyevskyy, O. (2024). Unleashing creative potential. In *Advances in Educational Technologies and Instructional Design* (pp. 405–428). IGI Global. https://doi.org/10.4018/979-8-3693-2418-9.ch015

Ma, Y., Yufang, S., Ming-da, L., Zhang, Y., Chai, W., Huang, A., & Zhao, X. (2025). Preparing students for an AI-driven world: Generative AI and curriculum reform in higher education. *Frontiers of Digital Education*, *2*(4). https://doi.org/10.1007/s44366-025-0067-6

Mačerauskienė, N. (2020). Building a culture of creative thinking in business studies. *Society. Integration. Education. Proceedings of the International Scientific Conference, 2*, 15. https://doi.org/10.17770/sie2020vol2.5023

Madanchian, M., & Taherdoost, H. (2025). Innovation leadership (pp. 153–173). https://doi.org/10.1108/978-1-83708-046-520251008

Mahama, I. (2024). The role of culture and environment in shaping creative thinking. In *IntechOpen eBooks*. IntechOpen. https://doi.org/10.5772/intechopen.1007481

Mårtensson, P., & Mullins, J. (2024). Generative AI and the roles of business school teachers. In *Routledge eBooks* (pp. 135–140). Informa. https://doi.org/10.4324/9781003500629-23

Paonessa, M. (2025). How creativity unlocks innovation, collaboration, and mental agility. *Public Humanities, 1*. https://doi.org/10.1017/pub.2025.3

Papaleontiou-Louca, E., Varnava-Marouchou, D., Mihai, S., & Konis, E. (2014). Teaching for creativity in universities. *Journal of Education and Human Development*, *3*(4). https://doi.org/10.15640/jehd.v3n4a13

Patil, R. (2024). Nurturing innovation and creativity for business success. *JCMM's Kaleidoscope Journal of Management Research, 1*(1). https://doi.org/10.62801/jkjmr-v1i1-12

Rana, V., Verhoeven, B., & Sharma, M. (2025). Generative AI in design thinking pedagogy: Enhancing creativity, critical thinking, and ethical reasoning in higher education. *Journal of University Teaching and Learning Practice*, *22*(4). https://doi.org/10.53761/tjse2f36

Ryan, A., Morel, C., Goodman, J., Hermes, J., Rehman, M. A., Louche, C., Keränen, A., & Juntunen, M. (2025). Learning to learn differently: Studio-based education for responsible management. *The International Journal of Management Education, 23*(3), 101177. https://doi.org/10.1016/j.ijme.2025.101177

Selvalakshmi, M., Suresh, V., & Kolluru, M. (2021). Pedagogy innovation for management graduates: Application of design thinking. *International Journal of Innovation Science, 14*, 659–674. https://doi.org/10.1108/IJIS-10-2020-0188

Shaznay, N. (2024). Bridging the industry–higher education gap with critical design futures thinking and GenAI for innovation (pp. 268–288). https://doi.org/10.1201/9781003469551-11

Simpson, E. (2026). *Business school 2030: A manifesto for the AI operating environment*. Zenodo. https://doi.org/10.5281/zenodo.18325925

Tariq, M. U. (2025). Innovation and agility: Adapting business strategies for sustainable growth in dynamic markets (pp. 113–140). https://doi.org/10.4018/979-8-3373-2048-9.ch005

Thanh, B. N., Vo, D. T. H., Nhat, M. N., Pham, T. T. T., Thai, H., & Son, H. X. (2023). Race with the machines: Assessing the capability of generative AI in solving authentic assessments. *Australasian Journal of Educational Technology, 39*(5), 59–81. https://doi.org/10.14742/ajet.8902

Wang, F., Li, N., Cheung, A., & Wong, G. K. W. (2025). In GenAI we trust: An investigation of university students' reliance on and resistance to generative AI in language learning. *International Journal of Educational Technology in Higher Education, 22*(1). https://doi.org/10.1186/s41239-025-00547-9

Westover, J. (2024). Fostering an innovator's mindset: How leaders can cultivate creativity and drive change. *Human Capital Leadership, 11*(3). https://doi.org/10.70175/hclreview.2020.11.3.4

Westover, J. (2025). How to tap into your creative genius at work. *Human Capital Leadership, 18*(4). https://doi.org/10.70175/hclreview.2020.18.4.4

Yu, G., Ramayah, T., & Lin, Z. (2025). Toward understanding the role of generative AI in entrepreneurship education: A systematic review. *Computers and Education: Artificial Intelligence, 9*, 100470. https://doi.org/10.1016/j.caeai.2025.100470

HUMAN RESOURCES AS A DETERMINANT OF THE SUCCESSFUL INTEGRATION OF CBAM REQUIREMENTS INTO THE PRODUCT CARBON FOOTPRINT MANAGEMENT SYSTEM

DOI: 10.5937/EMC26144M

Ljubiša Malešev
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Jasmina Pekez
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Mila Kavalić
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Email: mila.kavalic@uns.ac.rs
Nikola Jerković
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
Nadežda Ljubojev
University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia

ABSTRACT

The subject of this paper is the consideration of HRM determinants in relation to the quality of Product Carbon Footprint (PCF) data and the success of the integration of CBAM requirements. The framework is based on the Carbon Border Adjustment Mechanism (CBAM), which is implemented as an instrument of the European Union (EU) for equalizing the carbon price in imported products. Calculations, change significantly depending on methodological choices. The transparency of the calculation is often limited, making it difficult to use data in regulatory compliance confirmation processes. Green HRM points out that training, organizational culture and systemic HRM practices contribute to sustainability and performance, emphasizing the role of employee training and intermediary mechanisms through supply chains. The empirical part of the paper is designed as a quantitative-qualitative analysis of the data collected through the survey. The results indicate that organizational readiness and support from top management are key predictors of successful integration of CBAM requirements, while PCF data quality is a critical operational factor, and the impact of HRM practices is significant, but indirect. In conclusion, the integration of CBAM requires a multidimensional approach that goes beyond individual functions and requires the coordinated action of organizational, technological and management capacities.

Key words: Carbon Border Adjustment Mechanism, product carbon footprint, human resource management, data quality, compliance

INTRODUCTION

CBAM is an EU mechanism that introduces a "fair carbon price" for emissions embedded in imports of carbon-intensive goods, with a transitional phase from October 2023 to the end of 2025 and a definitive regime starting in 2026. Although the transitional period focused primarily on reporting, the introduction of the definitive regime, covering authorization, registries, certificates, and annual obligations, raises the issue to the level of systemic compliance (Document 32023R0956, 2023). This requires companies, including exporters outside the EU, to develop the capacity to consistently collect, process, and substantiate data on embedded emissions and PCF. Such a task cannot be reduced to one-off calculations; rather, it requires the management of a comprehensive data system. In parallel with regulatory pressure, methodological literature indicates that PCF results differ significantly depending on the protocol applied (e.g., DEFRA, the GHG Protocol Product Standard, ISO 14067), system boundaries, the treatment of biogenic carbon, cut-off rules, and end-of-life scenarios (Wang et al., 2018). In addition, the transparency and comparability of calculations are often limited. Study (Lange

et al., 2022) presents a 22-item checklist for the transparency of carbon footprint calculations and finds that the average transparency score is low, implying a structural risk for the verifiability of PCF practice (Lange et al., 2022). In practice, CBAM requires the management of precisely those aspects that comparative analyses of PCF protocols identify as challenging: inventory quality, methodological consistency, database selection, and auditability (Wang et al, 2018). Therefore, the central research question of this paper is: Which HRM determinants explain the success of integrating CBAM requirements into the PCF management system through improving PCF data quality and organizational compliance capacities?

LITERATURE REVIEW

CBAM: implications for firms and the need for integration into management systems

Research on CBAM has predominantly applied quantitative and simulation-based approaches to assess effects on trade, investment, carbon leakage, and sectoral vulnerability (Liu et al., 2025; Ren et al., 2025; Siy et al., 2023; Huang et al., 2022). The CBAM mechanism, in fact, serves to counter these risks by imposing a carbon price on imports of certain goods originating outside the EU.

One of the analytical methods used is Difference-in-Differences (DID), a quantitative econometric method applied to estimate the causal effect of a policy or intervention. The method is based on comparing changes in observed variables between an experimental group affected by the policy and a control group not covered by it. Observations are made across two time periods: before and after the implementation of the intervention. In this way, the effect of the policy can be isolated from other factors that may influence the observed change. The DID method is particularly useful in analyses of public policy, labor markets, tax reforms, and environmental regulation. It enables a relatively reliable estimation of causal relationships in situations where controlled experiments are not possible. Using this method, available analysis of Chinese firms finds a positive effect of CBAM on foreign greenfield investment through mechanisms of trade restructuring and innovation incentives (Liu et al., 2025). The Multi-Regional Input-Output (MRIO) model expands traditional input-output models by including multiple regions or countries, thereby enabling analysis of international supply chains and the global distribution of production. Such models are particularly important in research dealing with global trade flows, the analysis of embedded carbon dioxide emissions in products, and the assessment of the environmental effects of international trade. The MRIO approach identifies vulnerable industries and the scenario range of CBAM levies, as well as the buffering role of domestic carbon prices (Ren et al., 2025). Global Trade Analysis Project (GTAP) modeling provides scenario-based estimates of welfare and exports while emphasizing sensitivity to the design of the CBAM mechanism (Siy et al., 2023). Supporting this view, research examining CBAM through evolutionary games—between two key actors, the state and exporting firms and through GTAP-E simulations considers its effects on exports, prices, and trade structure (Huang et al., 2022).

Previous studies systematically indicate that CBAM constitutes a “shock” requiring adaptation in strategies, innovation, and data management (Liu et al., 2025; Ren et al., 2025; Siy et al., 2023; Huang et al., 2022). It is therefore important to emphasize that CBAM is not merely a customs issue but a problem of organizational capability: the capacity to generate and maintain credible PCF data and records throughout the supply chain within the deadlines and formats of the predefined reporting system.

PCF/LCA and data quality as a precondition for compliance

Accurate measurement and management of the product carbon footprint through a verified analysis of its life cycle constitute the basis for ensuring reliable data necessary for regulatory compliance and strategic decision-making. Selected protocols and methodological choices alter PCF results: a comparison of PAS 2050, the GHG Protocol, and ISO 14067 in the MDF case shows significant differences and identifies their causes, including cut-off rules, exclusion rules, and the treatment of carbon storage (Wang et al., 2018). In line with this, a review of LCA simplification approaches

indicates that the LCI phase (inventory) is more data-intensive and that industrial applicability depends on approaches such as parametric models, automation, and screening (Kiemel et al., 2022). A critical review of LCA automation focused on LCI analysis maps automation techniques as a response to the cost and time intensity of data collection (Kock et al., 2023). The quality of results also depends on databases and LCIA implementation: an analysis of packaging shows that database selection (GaBi, ecoinvent 3.6, EF database in openLCA) changes results, especially outside the "climate change" category; and identifies reasons for this, including differences in system boundaries and the regionalization of factors (Pauer et al., 2020). This conclusion is highly important for understanding CBAM, because "embedded emissions" require methodological consistency and verifiable source data. For operational PCF practice, a case study of an Austrian automotive supplier emphasizes the challenges of data collection, the need for structured procedures, and the existence of a large number of PCF calculation and reporting initiatives (Rudele, 2023). Research on parameter uncertainties in carbon footprint calculations shows that such uncertainties affect the magnitude of environmental measures and imply the need for systematic uncertainty management (Rommelfanger et al., 2024). Uncertainty is observed through two components: uncertainty in activity data and uncertainty in the emission factor selected for a given activity. Proper management of uncertainty in these individual components cumulatively results in a better that is, lower overall uncertainty rate in the final calculation.

Green HRM, training, and organizational readiness as determinants of PCF data quality and CBAM integration

Definitions of green human resource management (GHRM) indicate that Green HRM encompasses practices that promote environmentally responsible methods and maps the factors and measurement tools used to assess GHRM (Faisal, 2023). It is a set of good practices aimed at encouraging environmentally responsible employee behavior and integrating sustainability into the everyday functioning of the organization. GHRM is not merely an administrative human resource function; rather, it is an active mechanism through which employee values, competencies, and conscious behavior are shaped for the purpose of environmental protection. Through the long-term cultivation of these principles, firmly embedded in business strategy, organizations achieve ecological maturity, which implies lower risks of errors in the life cycle inventory system, better data quality, and greater confidence in the correct understanding and integration of CBAM reporting through communication patterns directed toward declarants. An evidence-based systematic review further emphasizes the roles of GHRM policies in organizational sustainability, mediated by employees environmental behavior (Benevene, 2020). "Green training" can have both direct effects and indirect effects through supply chain practices, as concluded by a recent scholarly article on environmental training (Barakat et al., 2023). This mechanism is analogous to the focus of the present research: training and HRM policies can influence supplier engagement and the quality of the data required for PCF and CBAM. These insights help organizations align their strategies with environmental sustainability and thereby gain a competitive advantage in the constantly changing business environment of the twenty-first century.

METHODOLOGY

Definitions of key constructs (operationalization of variables)

- Green training intensity (GTI): the degree to which a organization systematically conducts training on LCA/PCF, eco-design, energy efficiency, data management, and CBAM reporting. Knowledge is a fundamental resource of competitive advantage, difficult to obtain through the market but capable of being created through organizational learning (Yu, 2021).
- PCF data quality (PCF-DQ): a multidimensional construct encompassing completeness, consistency and auditability, inspired by transparency and uncertainty issues in PCF studies
- Organizational Green Readiness (OGR): a company readiness to introduce and stabilize sustainability and emissions reporting processes through structures, resources, roles, and culture.

- Top management commitment (TMC): the level of support, investment, strategic priority, and top management involvement in the product carbon management system.
- Supplier engagement (SE): the practice of involving suppliers in providing environmental data, standardizing boundaries, and implementing joint emissions reduction programs.
- ISO 14001 maturity (ISO-M): the degree of institutionalization of the EMS, procedures, internal audits, and continuous improvement as a capacity that may strengthen the implementation of PCF/CBAM processes (Diaz de Junguitu, 2019).
- Success of CBAM requirement integration (CBAM-IS): a producers ability to embed CBAM obligations into operational processes and the PCF system (accuracy and timeliness of reporting, readiness of records for verification, and interoperability with registries and portals).

Research problem and subject matter

The research problem concerns the insufficient understanding of the relationship between human resource management capacities, the quality of carbon footprint data, and the actual readiness of companies in Serbia to respond to the requirements of the European Union's CBAM regulation, particularly in the context of growing regulatory pressures and the need for reliable ESG reporting. Understanding these interdependent elements is exceptionally important because, without adequate human resource management, the competencies required for collecting and processing specific emissions data cannot be developed.

The subject matter of the research encompasses the analysis of the interrelationships among the above-mentioned dimensions at the level of exporting enterprises in Serbia. The study seeks to determine how human resource management capacities in practice affect the quality and reliability of data, and how the quality of those data subsequently shapes an organization's ability to respond effectively to regulatory requirements.

Research objective and Hypotheses

The paper aims to provide companies with a validated organizational-managerial mechanism: HRM - data quality - compliance integration. The research is designed to demonstrate explicitly that, without disciplined management of methodology and data sources, results vary and become difficult to use in regulatory and audit contexts.

The following hypotheses are formulated in the paper:

H0: Human resource management positively affects the successful integration of CBAM requirements into the product carbon footprint management system.
H1: (GTI - PCF-DQ) Greater green training intensity positively affects PCF data quality.
H2: (TMC – OGR) Top management commitment positively affects organizational green readiness.
H3: (OGR - CBAM-IS) Organizational green readiness positively affects the successful integration of CBAM requirements.
H4: SE (mediation) Supplier engagement mediates the GTI - PCF-DQ relationship (training improves suppliers data capture capabilities and collaboration).
H5: (PCF-DQ - CBAM-IS) Higher PCF-DQ positively affects the success of integrating CBAM requirements by reducing non-compliance risk.

Method

The methodological framework of the research is based on a sequential explanatory mixed-method design (QUAN - QUAL), which enables the combination of quantitative and qualitative approaches. The research applies an online survey, the research instrument comprises 30 items distributed across 5 dimensions, including HRM capacities for managing carbon systems, PCF data quality based on standards such as ISO 14067 and the GHG Protocol, CBAM readiness and requirement integration, as well as organizational support and regulatory pressure, along with general company characteristics.

Responses are measured using a five-point Likert scale, enabling the quantification of attitudes. The survey also contains open-ended questions of a qualitative type.

Sample and work plan

The research sample included a total of 10 respondents from companies of different sizes (whose responses represent systems with more than two thousand employees) and industries (iron and steel, aluminum, cement, and others). Most of the companies operate in the European Union market, which further increases the relevance of CBAM regulation for the analyzed context. Linear variables are analyzed by applying a quantitative approach through the analysis of the arithmetic mean of scaled responses within each dimension. Variables examined through the qualitative approach via open-ended questions are based on the analysis of key actors within organizations, such as representatives of HR, ESG, production, procurement, and IT functions, thereby ensuring a deeper interpretation of findings and additional validation of the results.

RESULTS AND DISCUSSION

This chapter presents the results of the empirical research and their interpretation in relation to the defined hypotheses. Figure 1 shows respondents attitudes across the dimensions.

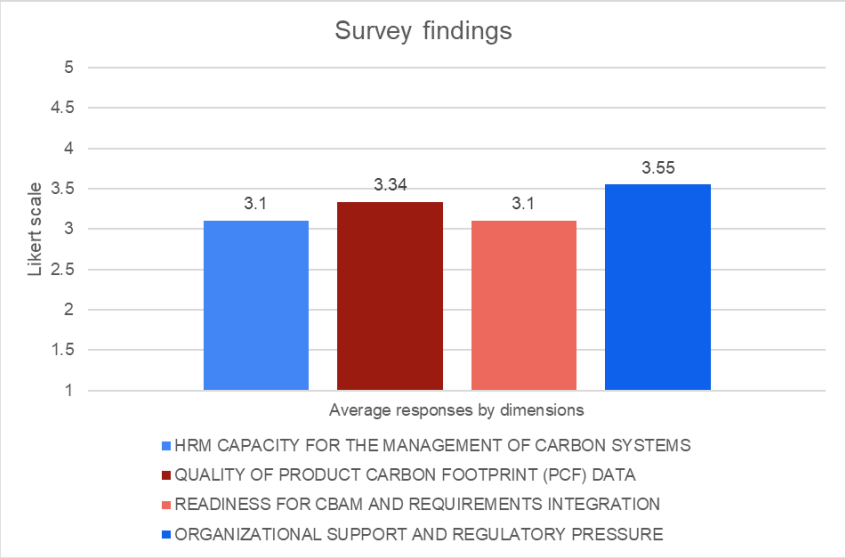


Figure 1: Presentation of respondents attitudes across dimensions

Processing of the collected data showed that all observed research dimensions are positioned within the range between the third and fourth points of the Likert scale (Figure 1). The value 3 on the Likert scale represents the threshold of respondent neutrality. Values above this margin indicate affirmation of the research dimensions, while the intensity of that affirmation is measured by the tendency of the observed dimensions value to approach point 5 on the Likert scale. The results indicate pronounced variability in the implementation of human resource management practices in the field of product carbon footprint (PCF) management. While some companies systematically conduct training and develop internal competencies, a significant number of respondents indicate a low level of institutionalization of these activities. A similar pattern was observed with regard to the quality of carbon footprint data, H1 (PCF-DQ). Large companies show a high level of standardization, reliability, and readiness for external data verification, whereas smaller organizations lag considerably behind, especially in terms of Scope 3 emissions coverage and the development of information technology systems for emissions monitoring. Top management support (TMC) was rated relatively highly in most cases, indicating growing awareness of the importance of decarbonization and regulatory requirements. However, this support is not always accompanied by adequate operational capacities, particularly in the domains of HRM and digital infrastructure. Organizational green readiness (OGR) and the success of CBAM requirement integration (CBAM-IS) show a clear connection with company

size, industry, and exposure to regulatory pressure. Companies exporting to the EU and operating in emission-intensive sectors demonstrate a higher level of readiness and more developed compliance strategies.

The research findings provide insight into the complex nature of integrating CBAM requirements and indicate that this process goes beyond exclusively operational or technical dimensions, simultaneously encompassing strategic, organizational, and human factors. Although the theoretical framework (Faisal, 2023; Benevene, 2020; Barakat et al., 2023) suggests that green training intensity (GTI) has a direct influence on the quality of PCF data, the empirical findings indicate limited strength of this relationship. This suggests that employee competence development, although necessary, is not a sufficient condition for ensuring high data quality. Instead, the results point to the need to integrate HRM practices with technological capacities and standardized methodologies, implying the systemic character of emissions management. Strong confirmation of hypothesis H2 regarding the influence of top management commitment (TMC) on organizational readiness (OGR) confirms the key role of strategic leadership in green transition processes. In addition to directing resources and priorities, management shapes organizational culture and readiness for change, which is further reflected in the company's ability to respond to complex regulatory requirements such as CBAM.

The confirmed relationship between organizational readiness and the successful implementation of CBAM requirements (H3) underscores the importance of a comprehensive approach. Business organizations that possess developed processes, clear responsibilities, and integrated environmental strategies are significantly more successful in adapting to new regulations. A particularly important finding concerns the significance of carbon footprint data quality (H5) as an operational prerequisite for compliance with CBAM regulation. Reliable and verifiable data enable high-quality reporting, as well as strategic emissions management and the reduction of regulatory risk. Unreliable data often lead companies into regulatory non-compliance, which may have serious legal and financial consequences. The role of suppliers (H4) may be described as crucial, particularly in the context of Scope 3 emissions inventories. Qualitative findings indicate that suppliers limited ability to provide relevant data constitutes a significant barrier, thereby confirming the importance of the systemic integration of the supply chain into decarbonization processes. Finally, the results suggest that external factors, such as regulatory requirements and market pressures, are stronger drivers of change than internal human resource management initiatives. This points to the need to redefine the role of HRM as a condition and mediator of change rather than as the primary driver.

CONCLUSIONS

The analyzed research results confirm that the integration of CBAM requirements into the product carbon footprint management system is conditioned by the interaction of strategic, organizational, and operational factors. Within this framework, human resource management has a significant, though not self-sufficient, role. Empirical findings confirm that green training intensity has a limited direct effect on PCF data quality (H1 partially confirmed), whereas the key significance lies in the strong role of top management in shaping organizational readiness (H2 confirmed) and its indirect influence on the successful integration of CBAM requirements (H3 confirmed). In addition, the direct relationship between PCF data quality and the level of compliance with CBAM regulation is confirmed (H5 confirmed), which underscores the importance of reliable, standardized, and verifiable data as the operational foundation of decarbonization. The role of suppliers is identified as an important mediating mechanism in the relationship between training and data quality (H4 qualitatively confirmed). In this sense, the basic hypothesis (H0) may be considered partially confirmed, with the note that the influence of HRM is effective primarily within a broader, integrated management system.

Results that can be applied in practice indicate that companies should move beyond partial approaches and orient themselves toward the systemic integration of HRM patterns, digital solutions for emissions management, and strategic leadership. Special attention should be devoted to improving data quality, developing capacities for managing indirect emissions, and intensifying cooperation with suppliers, who represent a critical link in the value chain. The findings suggest that regulatory and market

pressures remain the dominant drivers of change. This implies the need for additional institutional support mechanisms, especially for small and medium-sized enterprises. Such an integrated approach enables not only compliance with CBAM regulation but also the long-term improvement of business competitiveness and sustainability.

REFERENCES

Barakat, B., Milhem, M., Naji, G. M. A., Alzoraiki, M., Muda, H. B., Ateeq, A., & Abro, Z. (2023). Assessing the impact of green training on sustainable business advantage: Exploring the mediating role of green supply chain practices. *Sustainability, 15*(19), 14144. https://doi.org/10.3390/su151914144

Benevene, P., & Buonomo, I. (2020). Green human resource management: An evidence-based systematic literature review. *Sustainability, 12*(15), 5974. https://doi.org/10.3390/su12155974

Díaz de Junguitu, A., & Allur, E. (2019). The adoption of environmental management systems based on ISO 14001, EMAS, and alternative models for SMEs: A qualitative empirical study. *Sustainability, 11*(24), 7015. https://doi.org/10.3390/su11247015

European Parliament and Council of the European Union. (2023). *Regulation (EU) 2023/956 of 10 May 2023 establishing a carbon border adjustment mechanism*. Official Journal of the European Union. http://data.europa.eu/eli/reg/2023/956/oj

Faisal, S. (2023). Green human resource management—A synthesis. *Sustainability, 15*(3), 2259. https://doi.org/10.3390/su15032259

Huang, T., Liu, Z., & Zhao, T. (2022). Evolutionary game analysis of responding to the EU's carbon border adjustment mechanism. *Energies, 15*(2), 427. https://doi.org/10.3390/en15020427

Kiemel, S., Rietdorf, C., Schutzbach, M., & Miehe, R. (2022). How to simplify life cycle assessment for industrial applications—A comprehensive review. *Sustainability, 14*(23), 15704. https://doi.org/10.3390/su142315704

Köck, B., Friedl, A., Serna Loaiza, S., Wukovits, W., & Mihalyi-Schneider, B. (2023). Automation of life cycle assessment—A critical review of developments in the field of life cycle inventory analysis. *Sustainability, 15*(6), 5531. https://doi.org/10.3390/su15065531

Lange, O., Plath, J., Dziggel, T. F., Karpa, D. F., Keil, M., Becker, T., & Rogowski, W. H. (2022). A transparency checklist for carbon footprint calculations applied within a systematic review of virtual care interventions. *International Journal of Environmental Research and Public Health, 19*(12), 7474. https://doi.org/10.3390/ijerph19127474

Liu, J., Wang, W., Jiang, T., Ben, H., & Dai, J. (2025). Carbon border adjustment mechanism as a catalyst for greenfield investment: Evidence from Chinese listed firms using a difference-in-differences model. *Sustainability, 17*(8), 3492. https://doi.org/10.3390/su17083492

Pauer, E., Wohner, B., & Tacker, M. (2020). The influence of database selection on environmental impact results: Life cycle assessment of packaging using GaBi, Ecoinvent 3.6, and the environmental footprint database. *Sustainability, 12*(23), 9948. https://doi.org/10.3390/su12239948

Ren, L., Wang, J., Zhang, L., Hu, X., Ning, Y., Cong, J., Li, Y., Zhang, W., Xu, T., & Shi, X. (2025). Quantitative assessment of the carbon border adjustment mechanism: Impacts on China–EU trade and provincial-level vulnerabilities. *Sustainability, 17*(4), 1699. https://doi.org/10.3390/su17041699

Rommelfanger, S., Kilchert, S., & Hiermaier, S. (2024). Influence of parameter uncertainties in carbon footprint assessments on the magnitude of product-related ecological measures. *Sustainability, 16*(15), 6373. https://doi.org/10.3390/su16156373

Rüdele, K., & Wolf, M. (2023). Identification and reduction of product carbon footprints: Case studies from the Austrian automotive supplier industry. *Sustainability, 15*(20), 14911. https://doi.org/10.3390/su152014911

Siy, A. L., Wang, A., Zheng, T., & Hu, X. (2023). Research on the impact of the EU's carbon border adjustment mechanism: Based on the GTAP model. *Sustainability, 15*(6), 4761. https://doi.org/10.3390/su15064761

Wang, S., Wang, W., & Yang, H. (2018). Comparison of product carbon footprint protocols: Case study on medium-density fiberboard in China. *International Journal of Environmental Research and Public Health, 15*(10), 2060. https://doi.org/10.3390/ijerph15102060

Tu, Y., & Wu, W. (2021). How does green innovation improve enterprises' competitive advantage? The role of organizational learning. *Sustainable Production and Consumption, 26*, 504–516. https://doi.org/10.1016/j.spc.2020.12.031

ETHICAL MANAGEMENT OF ARTIFICIAL INTELLIGENCE IN GLOBAL BUSINESS: COMPETITIVENESS, RISKS AND REGULATORY FRAMEWORKS

DOI: 10.5937/EMC26151P

Leontina Pap
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: leontinapap@gmail.com

ABSTRACT

Artificial intelligence (AI) has become a primary engine for global business success, redefining how companies handle management, marketing and logistics. While AI brings significant productivity and efficiency, it also raises serious ethical concerns regarding fairness, transparency, accountability, and privacy. This paper examines how AI is used in different business functions and analyzes five major global frameworks for responsible AI governance: OECD AI Principles, UNESCO Recommendation on the Ethics of AI, EU Artificial Intelligence Act, NIST AI Risk Management Framework, and ISO frameworks. With special emphasis on the three tiers of human oversight (HITL, HOTL, HIC) as a universal mechanism for ethical control.

Key words: artificial intelligence, global business, ethical management, AI regulation, competitiveness, human oversight

INTRODUCTION

Contemporary global business operates at the intersection of rapid technological advancement and rising ethical expectations (Xia et al., 2026; Hill & Hult, 2022). Artificial Intelligence (AI) has become a key driver of competitiveness across industries, powering predictive analytics in supply chains, automated financial risk assessment, algorithmic hiring, and personalized marketing (Davenport & Ronanki, 2022; Chatterjee et al., 2023). While AI enables faster and more accurate decision-making, it also raises serious ethical concerns regarding responsibility, algorithmic discrimination, transparency, and the protection of human rights in an environment where technology often outpaces regulation (Raghavan et al., 2022; Jobin et al., 2019). Corporations must navigate a fragmented regulatory landscape. In response, several key instruments have emerged: the OECD's flexible soft-law principles, UNESCO's global ethical framework, the EU AI Act's stringent rules with extraterritorial reach, and the practical tools provided by NIST and ISO/IEC 42001 (OECD, 2024; UNESCO, 2021; European Commission, 2024; NIST, 2023). With that, ethical AI governance is no longer merely a reputational issue, but a strategic necessity with significant legal, sustainability, and long-term competitive implications (Ebers, 2024; Veale & Zuiderveen Borgesius, 2024; Ismail & Ahmad, 2025).

METHODOLOGY

The subject and the problem of the research

Research addresses the growing tension between the rapid adoption of artificial intelligence in global business operations (management, marketing, logistics, and supply chains) and the associated ethical risks, including algorithmic bias, lack of transparency, accountability issues, and privacy concerns.

Although AI enhances efficiency and competitiveness, its unregulated or poorly governed use can lead to discriminatory outcomes, loss of stakeholder trust, and legal non-compliance, particularly in a fragmented global regulatory environment.

Research goals

The main goal of this paper is to provide a systematic overview of AI applications in key business functions, to identify major ethical challenges, and to analyze how five influential global frameworks (OECD AI Principles, UNESCO Recommendation, EU AI Act, NIST AI RMF, and ISO/IEC 42001) together with the three levels of human oversight can support responsible and competitive AI implementation. The study also aims to demonstrate, through selected case studies, that ethical AI governance represents a source of sustainable competitive advantage rather than a limitation.

Research questions

Based on the analyzed literature and frameworks, this paper seeks to answer the following questions:

RQ1: What are the key benefits and ethical risks of applying artificial intelligence in management, marketing, and logistics within global business?
RQ2: How do the major international regulatory and ethical frameworks address these risks, and in what ways do they complement each other?
RQ3: What roles do the three levels of human oversight (HITL, HOTL, and HIC) play in ensuring responsible AI management while maintaining organizational competitiveness

Research method

This study adopts a theoretical and exploratory research approach. It is based on a systematic literature review, combined with critical analysis, synthesis, and deductive reasoning. The research systematically examines scholarly literature, official regulatory documents, and industry reports on artificial intelligence applications in business and associated ethical governance frameworks.

AI IN DIFFERENT BUSINESS FUNCTIONS AND ITS IMPACT ON COMPETITIVENESS

Artificial intelligence has emerged as a strong tool in global business for enhancing efficiency, lowering costs, and obtaining competitive gain. It is applied in various functions that yield measurable benefits but creates new ethical and other problems too.

AI in Management

Artificial intelligence is transforming management by enabling more data-driven and less intuitive decision-making in risk assessment, resource allocation, and strategic planning. Its greatest impact is visible in human resource management, particularly recruitment. Unilever, for example, implemented AI tools such as HireVue and Pymetrics. This resulted in significant cost and time savings (over 70,000 hours), faster hiring, and improved workforce diversity (Hu, 2023; Unilever reports). However, these systems carry significant ethical risks. AI tools analyzing facial expressions, voice, and language can inherit and amplify biases from training data, potentially leading to discrimination based on gender, race, age, or socio-economic status (Raghavan et al., 2022; Andrieux et al., 2024). Therefore, transparency, regular bias audits, and mandatory human oversight are essential for ethical implementation.

AI in Marketing

AI has transformed marketing by enabling hyper-personalization through analysis of customer behavior and preferences, leading to higher conversion rates and loyalty (Chatterjee et al., 2023). Netflix's algorithms, for example, account for ~80% of streamed content (Gomez-Uribe & Hunt, 2015), while Coca-Cola's 2023 'Create Real Magic' GPT-4 and DALL-E campaign turned users into co-creators with strong engagement. However, AI misuse can backfire, as seen when Mango faced backlash in 2024 for using hyper-idealized AI models that promoted unrealistic body standards and

raised authenticity and job displacement concerns. These examples highlight the importance of ethical guidelines and transparency in AI-driven marketing

AI in Logistics and Supply Chains

AI delivers some of the most measurable benefits in logistics and supply chain management. It optimizes routes, predicts disruptions, and automates warehouse operations using real-time data on traffic, inventory, and demand. Amazon Robotics (formerly Kiva) significantly reduced order preparation time and warehouse operating costs (Wurman et al., 2021). DHL has significantly improved warehouse performance through AI-powered automation and robotics. For example, deployments of autonomous mobile robots (AMRs) have achieved up to 50% higher order accuracy in specific implementations, while broader automation initiatives have delivered gains in space utilization and productivity (e.g., DHL Supply Chain with Locus Robotics and related case studies; DHL Trend Reports on AI and robotics, 2023–2024). Nevertheless, heavy reliance on AI and connected systems increases vulnerabilities such as cyberattacks and data breaches.

Major global frameworks

To address the ethical challenges identified in the previous sections, the international community has developed several influential frameworks for responsible AI governance. These frameworks do not compete with one another, instead, they form a complementary ecosystem that provides organizations with ethical foundations, legal obligations, and practical implementation tools. This paper analyzes the five most significant ones, all of which are directly relevant to global business competitiveness because they help companies manage risks, ensure regulatory compliance, build stakeholder trust, and maintain a sustainable competitive position in increasingly regulated markets.

The first one is the OECD AI Principles, which was first adopted in 2019 and updated in May 2024. It represents the most widely supported soft-law framework in the world. It is endorsed by 47 jurisdictions including the European Union. It is built around five core value based pillars: (1) inclusive growth, sustainable development and well-being; (2) respect for human rights, democratic values and the rule of law; (3) transparency and explainability; (4) robustness, security and safety; and (5) accountability. The update which was in 2024, strengthened provisions on generative AI data governance, incident reporting, and post-deployment monitoring, reflecting the rapid evolution of large-scale models. Because to their flexibility, the principles serve as a universal reference adaptable to both developed and emerging economies (OECD, 2024).

The second one is The UNESCO Recommendation on the Ethics of Artificial Intelligence. This was adopted in November 2021, being the first global normative instrument, binding all 194 UNESCO member states. It is based on four core values, but unlike the OECD's voluntary approach, it is officially recognized as formal international ethical standard, obliging members to integrate the principles into their own laws and policies. It is also expected to report back periodically on the implementation. The four values are; respect for human rights and dignity, peace and justice, cultural and linguistic diversity, and environmental sustainability. More specifically it is supported by concrete principles, including proportionality, safety, privacy protection, accountability, transparency, explainability, human oversight, sustainability, awareness-raising, and non-discrimination.

This framework is particularly valuable for global businesses because it explicitly links AI ethics to broader societal goals such as cultural diversity and environmental protection, areas that are increasingly important for corporate reputation and long-term sustainability (UNESCO, 2021, 2024).
On July 12, 2024, the EU AI Act (Regulation (EU) 2024/1689) was published in the Official Journal and will enter into force on August 1, 2024. This Act is the first-ever comprehensive and legally binding horizontal regulatory framework on AI in the world.

It implements a rigorous risk-based system that categorizes AI systems into unacceptable risk (prohibited), high risk, limited risk, or minimal risk category. Systems that pose unacceptable risk will be banned altogether.

An example of this is government social scoring, an even worse example is real-time remote biometric identification of people in public places (with an escape hatch). High-risk systems are defined as Artificial Intelligence technologies used for recruitment, credit scoring, education, and systems and critical infrastructure. They must meet the most stringent obligations, which include risk assessment, high quality data sets, technical documentation, human oversight, transparency, and conformity assessment prior to placement on the market (including CE marking). Systems that have limited risk (like chatbots and generative AI) should make it clear when a user is engaging with such AI. The Act has a global reach which states that any provider or deployer impacting the EU citizens through their AI system shall fall under the Act. For global companies, compliance with the EU AI Act has become an effective global standard in that meeting its requirements will often satisfy expectations in other jurisdictions (European Commission, 2024).

The first international standard for artificial intelligence management systems (AIMS) is ISO/IEC 42001:2023. Launched in late 2023, it follows the High-Level Structure and PDCA (Plan–Do–Check–Act) cycle already used in other ISO management standards (like ISO 9001 and ISO 27001). According to this standard, organizations shall establish the policies, conduct risk management and opportunities assessment, assign the roles and responsibilities, determine the competence and awareness, establish operational controls for the lifetime of AI, conduct internal audits and improve continually. For global businesses, ISO/IEC 42001 certification is increasingly viewed as a competitive differentiator that demonstrates credible, auditable responsible AI practices to customers, partners, and regulators (ISO/IEC, 2023). Taken together, these five frameworks create a robust and layered governance ecosystem. OECD and UNESCO supply the broad ethical and value-based foundations that enjoy near-universal acceptance. The EU AI Act translates those values into enforceable legal obligations with global reach. NIST RMF and ISO/IEC 42001 then provide concrete operational tools and certification pathways for day-to-day implementation

A central and unifying element across all five frameworks is the requirement for appropriate human oversight of AI systems. This ensures that AI remains a supportive tool rather than an autonomous decision-maker in situations involving fundamental rights or high-stakes outcomes. International consensus recognizes three distinct levels of human involvement, each adapted to different risk profiles and operational contexts.

The Role of Human Oversight in Responsible AI Management

A central and unifying element present in all five major AI governance frameworks is the requirement for appropriate human oversight of AI systems. This principle ensures that AI functions as a supportive tool rather than a fully autonomous decision-maker in contexts involving fundamental rights or high-stakes outcomes (European Commission, 2019; Shneiderman, 2020). International consensus recognizes three distinct levels of human involvement; each adapted to different risk profiles and operational needs. The strictest level, Human-in-the-Loop (HITL), requires a human to review, validate, and formally approve every significant decision before it is executed. This level is considered essential for high-risk applications such as recruitment tools, credit scoring, and medical diagnostics, where human judgment remains the final authority (Chen et al., 2023). In contrast, Human-on-the-Loop (HOTL) allows AI systems to operate autonomously in real time while a human supervisor continuously monitors performance and retains the ability to intervene or override decisions when necessary. This model is particularly suitable for dynamic environments such as logistics, autonomous warehousing, and real-time routing.

Finally, Human-in-Command (HIC) represents the lightest form of oversight, in which humans set the overall objectives, ethical boundaries, and rules, while granting the AI significant operational autonomy within those parameters. This level is appropriate for lower-risk applications such as content

recommendation engines and personalization tools (European Commission, 2019). Proper calibration of these three levels of human oversight is fundamental for preserving ethical standards, legal accountability, and organizational trustworthiness (Enqvist, 2023; Shneiderman, 2020).

RESULTS AND DISCUSSION

The study results confirmed that artificial intelligence (AI) is a significant driver of competitiveness in modern global business. However, the long-term success of AI mostly depends on governing it ethically. Artificial Intelligence benefits the core operations of a business. According to Hu (2023), in management, companies like Unilever have cut recruitment costs and time while enhancing diversity with AI-powered tools. In marketing, hyper-personalization systems increase user engagement and retention significantly. For instance, Netflix recommendation algorithms (Gomez-Uribe & Hunt, 2016). The use of solutions like those used by Amazon Robotics and DHL in logistics and supply chains has been estimated to lead to efficiency gains of 20–50%, reduced errors, and lower costs (Wurman et al., 2021; DHL, 2023–2024). These examples showcase the significant potential of AI to improve efficiency and competitive advantage. Nevertheless, there are substantial ethical and practical risks as well. AI may create big advantages in the economy but catastrophic backlashes from it being poorly governed can rapidly escalate as evident from the following: algorithmic bias in recruitment, loss of consumer trust due to inauthentic AI-generated content (as in the Mango case). AI-generated content as happened with Mango, privacy surfacing as well as accelerating the vulnerability of supply chains to cyber-attacks (Raghavan et al., 2022). The five major global frameworks (OECD AI Principles, UNESCO Recommendation, EU AI Act, NIST AI RMF and ISO/IEC 42001) form a complementary and layered ecosystem for ethical governance. While the OECD and UNESCO lay out general ethical principles, the EU AI Act establishes legally binding requirements with global applicability, and NIST and ISO/IEC 42001 offer tools for risk management and certification. Moreover, human oversight is achieved at three levels namely, Human-in-the-Loop (HITL) and Human-on-the-Loop (HOTL) and Human-in-Command (HIC). They help companies optimally balance technology efficiency and human judgement.

CONCLUSION

This paper analyzed the application of artificial intelligence in global business with particular attention to competitiveness, ethical risks and regulatory frameworks. Regarding RQ1, AI increases efficiency, reduces costs, and improves competitiveness in management, marketing, and logistics. These potential benefits notwithstanding serious ethical risks such as algorithmic bias, lack of transparency, and erosion of consumer trust. Referring to the second question (RQ2), the five main frameworks form a strong and complementary governance system. The OECD and UNESCO provide a broad ethical framework, while the EU AI Act offers binding legal rules with extraterritorial effects, and the NIST and ISO/IEC 42001 offer practical implementation and certification tools. As for RQ3, three levels of human oversight (HITL, HOTL, HIC) are crucial to ensure responsible management of AI in organizations. They are meant to place human judgment at the centre where it is most needed and allowing efficiencies to occur in lower risk settings (European Commission, 2019; Shneiderman, 2020; Chen et al., 2023). In coming years, more effective responsible AI adoption is expected to be facilitated by greater regulatory convergence, explainable AI advancements, and improved auditing mechanisms.

REFERENCES

Andrieux, A., et al. (2024). Algorithmic bias in AI recruitment tools: A systematic review. *Journal of Business Ethics, 185*(2), 345–367.

Cavusgil, S. T., Knight, G., & Riesenberger, J. R. (2020). *International business: The new realities* (5th ed.). Pearson.

Chatterjee, S., et al. (2023). AI-driven personalization in marketing: Opportunities and ethical challenges. *Journal of Business Research, 158*, Article 113456.

Chen, X., Wang, X., & Qu, Y. (2023). Constructing ethical AI based on the "Human-in-the-Loop" system. *Systems, 11*(11), Article 548.

Davenport, T. H., & Ronanki, R. (2022). *Artificial intelligence: The insights you need from Harvard Business Review*. Harvard Business Review Press.

DHL. (2023–2024). *Logistics trend radar 2023–2024*. DHL Group.

Ebers, M. (2024). The EU Artificial Intelligence Act: A critical analysis. *European Journal of Risk Regulation, 15*(1), 1–28.

Enqvist, L. (2023). Human oversight in the EU Artificial Intelligence Act. *European Journal of Law and Technology, 14*(2).

European Commission. (2019). *Ethics guidelines for trustworthy artificial intelligence*. European Commission.

European Commission. (2024). *Artificial Intelligence Act: Regulation (EU) 2024/1689*. *Official Journal of the European Union*.

Gomez-Uribe, C. A., & Hunt, N. (2016). The Netflix recommender system: Algorithms, business value, and innovation. *ACM Transactions on Management Information Systems, 6*(4), 1–19.

Hill, C. W. L., & Hult, G. T. M. (2022). *International business: Competing in the global marketplace* (14th ed.). McGraw-Hill Education.

Hu, L. (2023). Unilever's practice on AI-based recruitment. *Highlights in Business, Economics and Management, 16*, 256–263. https://doi.org/10.54097/hbem.v16i.10565

Ismail, O., & Ahmad, N. (2025). Ethical and governance frameworks for artificial intelligence: A systematic literature review. *International Journal of Interactive Mobile Technologies (iJIM), 19*(14), 121–136.

Jobin, A., Ienca, M., & Vayena, E. (2019). The global landscape of AI ethics guidelines. *Nature Machine Intelligence, 1*(9), 389–399.

NIST. (2023). *Artificial intelligence risk management framework (AI RMF 1.0)*. National Institute of Standards and Technology.

OECD. (2024). *OECD AI principles: Update 2024*. Organisation for Economic Co-operation and Development.

Raghavan, M., et al. (2022). Mitigating bias in algorithmic hiring: Transparency and accountability. *Proceedings of the ACM Conference on Fairness, Accountability, and Transparency*, 45–67.

Shneiderman, B. (2020). Human-centered artificial intelligence: Reliable, safe & trustworthy. *International Journal of Human–Computer Interaction, 36*(6), 495–504.

Sidiropoulou, G., Vestlin, M., & Heath, M. (2025). *From trust to skepticism: Consumers' views of AI-generated marketing in fashion* (Bachelor's thesis). Jönköping University.

The Coca-Cola Company. (2023). *Create Real Magic campaign report*. The Coca-Cola Company.

UNESCO. (2021). *Recommendation on the ethics of artificial intelligence*. United Nations Educational, Scientific and Cultural Organization.

Unilever. (2023–2025). *AI in recruitment: Annual sustainability and innovation report*. Unilever.

Veale, M., & Zuiderveen Borgesius, F. (2024). Demystifying the EU Artificial Intelligence Act. *Computer Law Review International, 25*(3), 67–82.

Wurman, P. R., et al. (2021). Outracing champion Gran Turismo drivers with deep reinforcement learning. *Nature, 602*, 223–228.

Xia, H., Chen, H., Zhang, J. Z., & Kamal, M. M. (2026). Exploring the impact of responsible AI governance on corporate performance: A quasi-natural experiment. *Technological Forecasting and Social Change, 223*, Article 124425.

HUMAN RESOURCES MANAGEMENT IN INSURANCE COMPANIES: CASE STUDY WIENER STADTISCHE

DOI: 10.5937/EMC26157P

Marko Pavlović
Academy of Applied Studies – Polytechnic, Belgrade, Republic of Serbia
Dragana Đurić
Higher School of Business Studies, Novi Sad, Republic of Serbia
Marija Perić
Academy of Applied Studies – Polytechnic, Belgrade, Republic of Serbia
Mirjana Dunić
Technical Faculty "Mihajlo Pupin", University of Novi Sad, Zrenjanin, Republic of Serbia
Miodrag Simić
Institute of Social Sciences, Belgrade, Republic of Serbia

ABSTRACT

The research conducted in the company *Wiener Städtische* aimed to analyze the policies and practices of human resource management, with special emphasis on organizational climate, motivation, training programs, and employees' professional development. The sample included 150 employees, and the collected data were processed using the survey research method. The results indicate that most employees perceive the organizational climate and team collaboration positively, while 97% of respondents emphasized that human resource management is of exceptional importance for the company's success. Furthermore, more than 80% of employees have participated in training and education programs, while nearly 70% believe that the company invests sufficiently in employee development. Half of the respondents perceive the HRM model as contemporary, while the rest recognize elements of a traditional approach. The obtained results confirm the crucial role of human resources in ensuring long-term competitive advantage and point to the need for further improvement of communication and employee development policies.

Key words: Human Resource Management, Organizational Climate, Motivation, Training, Insurance Companies.

INTRODUCTION

Interest in this topic arises from the fact that the insurance sector in Serbia has recorded noticeable growth and increased market presence in recent years. Several internationally recognized insurance companies operate on the domestic market, while human resource management has become an important determinant of business performance. Human resources represent the main factor of success in every insurance company. On this basis, the following research hypothesis has been formulated: the integration of training outcomes into work efficiency and professional task performance contributes to employee satisfaction within the organization (Ahmad et al., 2025). The hypothesis may be confirmed, rejected, or partially confirmed depending on the characteristics of the research sample.The subject of this paper is the analysis of human resource management in an insurance company, with Wiener Städtische selected as the case study due to its successful business operations in Serbia for more than a decade. The main objective of the paper is a detailed analysis of human resource management policies within this company, with particular attention given to the HR sector as the central point of analysis. Wiener Städtische was established as a greenfield investment of Vienna Insurance Group Wiener Städtische Versicherung AG, the leading Austrian insurance company with a tradition spanning 190 years and a strong presence in Central and Eastern Europe (Carannante, 2025).The paper consists of three sections. The first section presents the theoretical framework and explains the main concepts of human resource management, including staffing, HR administrative procedures, training, and career development. The second section provides an overview of insurance operations, including the main types of insurance, such as life and non-life insurance, together

with the risks related to these activities. The third section contains empirical research and presents a practical review of HR management in Wiener Städtische through an analysis of the company's mission, vision, and HR policies that support business growth and development. Wiener Städtische gives considerable attention to investments in human resources because employees are regarded as the company's most valuable asset. The employment policy is clearly defined and includes workforce planning, external and internal recruitment, and transparent procedures related to employee selection and documentation. Professional development opportunities for employees include postgraduate education at the master's level, doctoral studies, training programs, seminars, workshops, mentoring, and coaching. Nearly half of the employees hold higher education degrees, most of which were obtained at state universities. The company also allocates a significant share of its budget to professional development. In recent years, these investments have exceeded 3% of total company revenues.

There are numerous definitions of management, which represents one of the most accepted professional concepts and the central category of this research. The most frequently cited definition states that management is the process of planning, organizing, leading, coordinating, and controlling human, material, financial, informational, and other resources in order to achieve organizational goals under the most favorable conditions. This definition appears in many textbooks and in different languages because of its broad and comprehensive character. Special attention is given to human resources as the primary organizational resource (Fedorovych, 2025). Philosophical analyses by Karl Marx identified human labor and human potential as the main factors of social development. In the modern organizational context, people remain at the center of production, finance, public services, and other organizational systems. Human resources may be defined as the total potential of a society, region, or company. This includes physical, psychological, and intellectual capacities, together with culture, knowledge, skills, habits, and civilizational achievements (Cosma, 2024). The objective of management is efficient human resource utilization through better employee performance, higher productivity and work quality, employee satisfaction, and long-term organizational commitment (Fung, 2025). Human resources are distinguished by their ability to learn and adapt. This characteristic makes them the basis of innovation, organizational change, and competitive advantage.

Human Resource Management (HRM) is a separate field of management that examines all aspects of employees and employment within an organization. Unlike other management disciplines, HRM does not rely on one unified theoretical framework. Instead, it applies multidisciplinary approaches. One accepted definition states that HRM includes workforce planning, job analysis, recruitment, employee selection and socialization, training and development, motivation, health protection, and compliance with labor legislation. This definition reflects the broad scope of HRM, which includes activities from recruitment to employee development and reward systems. Current literature also defines HRM as a strategic and coherent approach to managing an organization and its most valuable resource, namely people who contribute individually and collectively to organizational goals. This definition points to the connection between HRM and organizational strategy.

Effective human resource management has become more demanding because of changes in the business environment. The most important factors include globalization, technological change, demographic shifts, and economic crises. Globalization has increased competition among companies and employees, while labor mobility and job insecurity have become more common. Technological development, digitalization, and automation have increased demand for highly skilled labor. Demographic changes, especially population aging and a shortage of younger workers, have created additional pressure on organizations. Economic crises, unemployment, bankruptcies, and offshoring have also affected labor market structures. Despite these challenges, organizations continue to build competitive advantage through human potential. This process requires coordination of employee knowledge, motivation, and interests toward common organizational objectives. As a result, the strategic importance of HRM has become more pronounced than before.

One of the central HRM functions is the implementation of personnel and administrative tasks after recruitment and employee selection. These activities are conducted by the relevant organizational department and include procedures connected with employment relations and employee engagement. Personnel and administrative activities are usually divided into three phases. The first phase includes procedures related to hiring employees or engaging individuals through contracts outside standard

employment. The second phase includes activities carried out during employment or engagement. The third phase includes procedures related to employment termination. In the legal sense, an employment relationship is established through an employment contract regulated by labor legislation. The contract becomes valid after signatures from both the employee and the authorized employer representative. Employment contracts may be concluded for a fixed period or an indefinite duration. If the duration is not specified, the contract is considered indefinite. Practice also includes forms of engagement outside standard employment contracts. A contract for services allows a legal entity or entrepreneur to engage an individual for activities outside the employer's primary business operations. A contract on professional training and development is concluded with individuals completing internships for professional examinations or acquisition of specific knowledge and skills. This form is often described as voluntary because it does not include salary compensation and is based on practical experience. A contract for temporary and occasional work allows employee engagement for tasks of a temporary nature, with a maximum duration of 120 working days within one calendar year. Employers are required to provide social insurance coverage for such employees, including pension, health, and unemployment insurance. Another form is the internship decision, which represents an internal organizational document requiring confirmation from an educational institution regarding the necessity of internship implementation. During employment, organizations conduct various personnel and administrative procedures, such as work-hour records, amendments to employment contracts, reassignment and promotion decisions, and administration of absences, sick leave, and other employment rights. Employment termination procedures are also regulated internally in accordance with legal requirements and include dismissal, mutual termination, retirement, and other forms of ending employment (Zhang, 2023).

The traditional model of human resource planning focused mainly on determining the required number of employees, their qualifications, and competency levels necessary for organizational functioning. The main purpose of this model was balancing labor supply and demand in order to secure the right employees in the right positions at the appropriate time (Gong et al., 2024). Labor demand was influenced by organizational strategy, business objectives, environmental conditions, and methods of human resource utilization. External labor market conditions also had an important influence on planning activities. Current business conditions have shown that the traditional model has become outdated. Modern human resource planning requires a broader and more integrated approach (Jabbour, 2024). Current models include all aspects of planning and attempt to answer three questions: where the organization intends to be, where it is currently positioned, and which activities are necessary for transition. In this context, the environment becomes a determining factor because it shapes both organizational structure and human resource strategy. External environment analysis includes market trends, technological development, competition intensity, political conditions, demographic characteristics, and other relevant influences (Quan et al., 2024). One common practical method is the development of environmental maps in which the organizational goal is placed at the center, while surrounding elements represent external factors such as employees, competitors, customers, and government institutions. Unlike the traditional approach, current HRM models place greater attention on humanistic values, employee motivation, satisfaction, and professional development. Economic indicators remain important, but they are no longer the only priority. Greater focus is now directed toward employee well-being and participation in continuous improvement processes. Results from empirical research conducted in the insurance company Wiener Städtische confirm this tendency. An anonymous survey showed that employees considered motivation the most important factor of organizational success, while 61% of respondents reported insufficient information regarding training and professional development policies. These findings indicate the need for organizations to adjust their strategies and increase attention to transparent communication, continuous education, and systematic employee development. Organizations are increasingly structured as information, process, and development systems characterized by constant change (Zhang, 2023). Such conditions require new organizational structures, different approaches to management, and HRM models adapted to global, digital, and competitive business conditions (Valdez et al., 2024).

RESEARCH RESULTS

The subject of this research is the analysis of human resource management in the insurance company Wiener Städtische, with particular attention directed toward employee motivation practices, training and career development programs, and employee perceptions of organizational climate and the HRM model applied within the company. The primary objective of the research is the examination of employee attitudes

regarding the importance, role, and effects of human resource management in Wiener Städtische. The secondary objectives include the analysis of employee motivation through material and non-material rewards, assessment of employee familiarity with training and development policies, examination of employee satisfaction with organizational climate and teamwork, and identification of employee perceptions regarding the application of a traditional or contemporary HRM model. Several hypotheses were established for the purpose of the research. The first hypothesis assumes that investments in training and professional development positively affect employee satisfaction and motivation. The second hypothesis states that human resource management is perceived as a key factor in the company's success. The third hypothesis assumes that material rewards represent the main source of employee motivation. The final hypothesis suggests that the majority of employees recognize the application of a contemporary HRM model within the company.

An anonymous survey was conducted among randomly selected employees in order to examine employee job satisfaction and attitudes toward human resource management. The research included 150 employees of the company. Considering the size of the sample, the findings cannot be considered fully representative. The survey was conducted between May 5 and May 30, 2025, through random sampling across all company sectors. Respondents completed the questionnaire either directly at the workplace or electronically through e-mail communication. The collected data were processed using Microsoft Excel. The research instrument consisted of a structured questionnaire with closed-ended questions and predefined response options. One survey question examined whether employees believed they occupied the appropriate position within the company. All 150 respondents answered this question, resulting in a response rate of 100%, which gives this result additional analytical importance. The findings indicate that almost 70% of employees are satisfied with their current position. This percentage suggests that most employees consider their knowledge, abilities, and competencies to be aligned with the requirements of their jobs. The result also points to satisfactory HRM practices related to employee placement and task allocation. Approximately 30% of respondents expressed a certain level of dissatisfaction with their position. This finding indicates the existence of employees who may require additional support, opportunities for advancement, or better alignment between competencies and job requirements. Overall, most employees expressed positive attitudes toward their current position, which contributes to organizational stability, work motivation, and long-term job satisfaction. At the same time, the percentage of dissatisfied employees indicates the need for additional HR measures directed toward increasing employee satisfaction and organizational commitment.

Another survey question examined employee satisfaction with organizational climate and teamwork. A total of 77% of respondents answered this question. The fact that nearly one-quarter of employees chose not to respond may indicate a degree of reservation regarding the evaluation of interpersonal relations and team atmosphere. It is possible that some employees avoided answering because of concerns related to workplace relationships or potential negative consequences. Among those who responded, most employees stated that they were satisfied with the organizational climate and the team environment in which they worked. These findings indicate positive interpersonal relations, cooperation, and cohesion within work groups. Such conditions contribute to work motivation, operational efficiency, and overall employee satisfaction. At the same time, the relatively high percentage of unanswered responses suggests the need for stronger organizational trust and more open communication practices within the company.

The research also examined employee perceptions regarding the importance of human resource management in Wiener Städtische. Respondents evaluated the significance of HRM on a scale from 1 to 5. A total of 94% of employees answered this question, which indicates a strong level of interest in the topic. The results show that 97% of respondents consider human resource management highly significant for organizational performance and company success. These findings indicate that employees recognize the contribution of the HR department to professional development, workplace stability, and employee support. The results also reflect confidence in HR management and the perception that HRM has an important strategic position within the organization. From a practical perspective, the findings confirm current tendencies in which HRM extends beyond administrative activities and becomes integrated into strategic organizational processes. In the case of Wiener Städtische, HRM may therefore be regarded as an important factor of organizational growth, development, and competitive position.

The survey further examined employee familiarity with training and professional development policies implemented by the HR department. Employees were asked whether they were familiar with the company's training and development policy. The results indicate that 80% of respondents answered this question, showing a relatively high level of participation. Most employees stated that they were familiar with the company's professional development policy, which confirms that such policies are documented and accessible within the organization. However, a certain number of employees reported insufficient familiarity with these policies. The findings suggest that the issue is related less to the absence of information and more to insufficient employee interest or engagement with available materials. These results point to the importance of stronger communication regarding development opportunities and greater encouragement of employee participation in HR initiatives.

Employee perceptions regarding company investments in training and development programs were also examined. Respondents were asked whether the company invested sufficiently in employee training and development. A total of 93% of respondents answered this question. Nearly 70% expressed satisfaction with the company's investments in training and development activities. These findings indicate that most employees recognize organizational efforts directed toward professional development and competency improvement. Such investments contribute not only to individual development but also to organizational efficiency, innovation, and long-term competitiveness. Nevertheless, the remaining percentage of dissatisfied respondents indicates the possibility for additional improvement regarding the availability, frequency, or scope of training programs. These results highlight the importance of aligning development strategies with employee expectations and organizational objectives.

Another part of the research focused on employee participation in education and training programs. Employees were asked whether they had participated or were currently participating in any education or training activity. Out of 150 respondents, 121 employees answered positively, which represents more than 80% of the sample. This result represents a positive indicator of both organizational commitment to employee development and employee readiness to improve their professional competencies. High participation rates suggest that training and development activities are integrated into organizational culture and recognized as important elements of career advancement and work performance improvement. The findings also indicate that existing training policies produce positive results and should continue to be developed further. The final survey question examined employee perceptions regarding the HRM model applied within Wiener Städtische. Employees were asked whether they considered the company's HRM model traditional or contemporary. The results show that approximately half of the respondents perceived the company as applying a contemporary HRM model characterized by strategic planning, continuous training, employee involvement, and alignment with international standards. The remaining respondents either perceived the organization as operating under a more traditional model or were unable to clearly identify the prevailing approach. These findings suggest that contemporary and traditional HRM practices may coexist within different organizational sectors or management levels. The results also indicate the need for more consistent implementation and stronger visibility of modern HR practices throughout the organization. Improved communication and broader application of contemporary HR strategies may strengthen organizational reputation, employee trust, and long-term competitiveness.

CONCLUSION

The research conducted in Wiener Städtische confirms the importance of human resource management in the operations of modern insurance companies. The findings indicate that most employees hold positive attitudes toward organizational climate and teamwork, which represents an important condition for maintaining a stable and motivating work environment. A particularly important result is that 97% of respondents perceive human resource management as a significant factor of company success, which reflects a high level of employee confidence in this organizational function. The analysis also shows that training and education programs are widely accepted among employees. More than 80% of respondents stated that they had participated in some form of educational activity. These findings confirm that the company recognizes continuous employee development as an important source of knowledge improvement, innovation, and organizational competitiveness. However, approximately 30% of employees expressed dissatisfaction with investments in training and development, which indicates the possibility for further improvement, especially through programs adjusted to individual employee needs and expectations. From the perspective of employee motivation, the research indicates that material rewards remain the

dominant motivating factor within the company. This result is common in organizations operating in competitive sectors. At the same time, long-term employee satisfaction and organizational commitment also require the development of non-material forms of motivation, including professional recognition, opportunities for career advancement, and activities related to work-life balance. The findings regarding employee perceptions of HRM models reveal the coexistence of traditional and contemporary approaches. Half of the respondents recognized the application of a contemporary HRM model, while the remaining respondents identified elements of a traditional approach. This result suggests that the complete transformation of HRM toward a modern organizational model requires additional improvement in communication, procedure standardization, and consistent implementation of HR practices throughout the company. The research confirms that investments in human resources should not be observed only as organizational costs, but also as long-term investments in organizational development and stability. Future research may include comparative analyses with other companies in the insurance sector, longitudinal studies examining the influence of HR policies on employee performance, and qualitative analyses focused on motivation and organizational culture. Such approaches may contribute to the development of management strategies directed toward organizational efficiency and sustainable competitive advantage based on human capital.

The verification of hypotheses produced several important findings. The hypothesis stating that investments in training and professional development positively affect employee satisfaction and motivation was confirmed, since 70% of respondents expressed satisfaction with such investments and more than 80% participated in training activities. The hypothesis that human resource management is perceived as a key factor of company success was also confirmed because 97% of respondents evaluated HRM as highly significant. The hypothesis that material rewards represent the primary source of employee motivation was confirmed as well, given that 85% of respondents identified financial incentives as the main motivator. The final hypothesis, which assumed that the majority of employees recognize the application of a contemporary HRM model, was partially confirmed. Half of the respondents perceived the company as modern in terms of HRM practices, while the remaining respondents identified traditional organizational elements.

REFERENCES

Ahmad, S., Karim, R., Sultana, N., & Pervin Lima, R. (2025). InsurTech: Digital transformation of the insurance industry. In *Financial landscape transformation: Technological disruptions* (pp. 287–299). Emerald Publishing Limited. https://doi.org/10.1108/978-1-83753-750-120251016

Carannante, M. (2025). An analytical review of cyber risk management by insurance companies: Quantitative models for underwriting and pricing. *Risks, 13*(8), Article 144. https://doi.org/10.3390/risks13080144

Cosma, S. (2024). Redefining insurance through technology: Achievements and perspectives of InsurTech. *Journal of Financial Services Research*. Advance online publication. https://doi.org/10.1016/j.jfs.2024.100094

Fedorovych, I. (2025). The impact of digital transformation on the insurance business model and innovative opportunities. *Financial Engineering and Risk Management, 6*, 121–126. https://doi.org/10.23977/ferm.2023.061117

Fung, D. W. H. (2025). Evaluating the role of enterprise risk management in enhancing insurer resilience during COVID-19. *Safety Science*. Advance online publication. https://doi.org/10.1016/j.ssci.2025.113075

Gong, Y., Stanley, J., Wang, B., & Alharithi, M. (2024). Examining strategies developed by insurance companies for addressing carbon emissions in the automotive supply chain in the UK. *Sustainability, 16*(22), Article 9895. https://doi.org/10.3390/su16229895

Jabbour, M. (2024). Enterprise risk management: An institutional work perspective. *Journal of Risk Research*. https://doi.org/10.1080/01559982.2024.2439640

Quan, Z., Hu, C., Dong, P., & Valdez, E. A. (2024). Improving business insurance loss models by leveraging InsurTech innovation. *arXiv*. https://doi.org/10.48550/arXiv.2401.16723

Zhang, S. (2023). The impact of digital transformation on the insurance business model and innovative opportunities. *Financial Engineering and Risk Management, 6*, 121–126. https://doi.org/10.23977/ferm.2023.061117

THE IMPACT OF DIGITAL COMPETENCIES ON HUMAN RESOURCE MANAGEMENT PRACTICES

DOI: 10.5937/EMC26163V

Ana-Marija Vukić
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Dragana Sajfert
ITS Information Tehnology School, Zemun-Belgrade, Republic of Serbia
E-mail: dragana.sajfert@its.edu.rs
Marko Kihler
Union University Law School, Belgrade, Republic of Serbia

ABSTRACT

This study explores the relationship between digital human resource management (HRM) practices and employees' digital competencies in Serbian organizations, from the perspective of students. Although digitalization has become a central priority in human resource management (HRM), there is still a limited understanding of the effectiveness of digital HRM practices. Data were collected through an online questionnaire from 158 students. A survey was conducted among student managers enrolled in programs at the University of Novi Sad and the ITS – Information Technology School in Belgrade. The results indicate that digital HRM practices have a positive, but modest, impact on employees' digital skills. The results highlight the need for organizations to adapt digital HRM strategies to their specific cultural context and not rely solely on technological solutions. This study contributes to the growing body of literature by demonstrating the interaction between technology and the development of employees' digital capabilities, and suggests that a balanced focus on both is necessary for successful digital transformation.

Keywords: Digital competencies, Human resource management, Digital skills, Digital tools, Integration of digital technologies

INTRODUCTION

The rapid digitalization of workplaces, particularly in the Western Balkans and the Serbian labor market, has created new challenges and opportunities for both employees and organizations. In Serbia, the adoption of digital tools for human resource management is progressing, but organizations still face significant obstacles, such as limited digital infrastructure and varying levels of digital competence among employees. These characteristics make the Serbian context an important case for studying the interaction between digital transformation and human resource management practices.

From a practical perspective, the findings provide useful insights for professionals and CAD designers, highlighting the need to tailor digital HRM strategies to each organization in order to maximize the development of digital skills (Vukić, Berković & Sajfert, 2026). The aim of this study is to examine the adoption and use of digital technologies in HRM, understand the benefits and challenges organizations face in implementing digital HRM practices, and provide insights and recommendations for the effective use of technology in workforce management and organizational success (Abdifatah & Abdifatah Ali, 2023).

LITERATURE REVIEW

The literature in this field is extensive and often complex, reflecting the major changes that digitalization brings to human resource management. This study examines the evolution of human resource management (HRM) strategies in the digital age, focusing on the integration of technology,

data-driven decision-making, and employee experience and engagement (Husen, Wahidah & Mustajab, 2023). The aim of this section is to clarify the theoretical background and identify key research gaps, highlighting the necessity of this study. Digital HR competencies refer to the integration of modern digital technologies into HR processes, building on basic digitalization and their application within organizations. E-learning enables continuous training and flexibility in digital HR management, contributing to the development of digital competencies. Digital performance management systems and HR portals further support employee engagement, satisfaction, and internal communication (Husen, Wahidah & Mustajab, 2023). Digital competence is defined as the ability to use digital technologies effectively and critically in various professional and personal contexts (Zervas & Triantari, 2025). This goes beyond basic technical skills and includes problem-solving, effective communication, creativity, collaboration, and critical thinking—dimensions highlighted in frameworks such as "21st-century digital skills" and DigComp (Van Laar et al., 2017). Innovation begins with people, making human capital within the workforce crucial. In a rapidly changing knowledge economy, 21st-century digital skills drive organizational competitiveness and innovation capacity. Although such skills are considered essential, the digital dimension integrated with 21st-century skills is still not sufficiently defined (Van Laar et al., 2017).

Following earlier studies aimed at gaining a deeper understanding of digital competence through a review of the literature and existing digital competence frameworks, this paper focuses on experts' views on digital competence (Janssen et al., 2013). The study presents the results of a Delphi study that explored experts' perspectives on what it means to be digitally competent today. The study included two online consultation rounds: one focused on gathering individual ideas, and the other on validating the aggregated mapping of digital competence, established through various stages of qualitative and quantitative data analysis (Janssen et al., 2013). The paper describes and discusses the final results of the Delphi study, which involved 95 experts from across Europe and beyond.aThe results indicate that digital competence is composed of knowledge, skills, and attitudes related to twelve different areas (Janssen et al., 2013). In addition, the findings reveal that several issues for debate can be identified when it comes to defining the boundaries of digital competence (Janssen et al., 2013).

In the digital domain, digital literacy is the broadest concept, as originally defined by Gilster (1997). It highlights the key thinking skills and competencies needed to navigate this new medium effectively, emphasizing the rapid changes and democratization brought by web technologies (Gilster, 1997). Digital literacy entails more than merely the ability to use software or operate a digital device; it encompasses a wide range of complex cognitive, motor, sociological, and emotional skills that users need to function effectively in digital environments (Eshet-Alkalai, 2004).

METHODOLOGICAL CONCEPT OF THE STUDY

To determine the extent to which Serbian managers are aware of the beneficial effects of digitalization and which competencies they develop, the authors conducted a survey from September to December 2025 among student managers enrolled in programs at the University of Novi Sad and the Information Technology School (ITS) in Belgrade, Serbia. The study employed a survey method targeting management students studying programs in IT, strategic management, strategic marketing, and human resource management (HRM).

Research Problem and Subject

The primary aim of this research was to gain insight into the potential influential relationships between factors affecting human resource management (HRM), business performance, and the competitiveness of domestic firms in the area of computer competencies. The study presented in this paper is based on evidence derived from the analysis of the latest theoretical insights and practical achievements in the field of computer competencies applied to HRM practices.

Research Objectives

The main objective of this research is to enable human resource managers to use the obtained results in assessing creative capabilities—specifically, to determine whether employees possess the necessary qualities to meet the requirements of a position within a company seeking to hire them. This research also pursues a societal goal: to provide scientific insights that support social measures aimed at enhancing and improving computer competencies.

Expected Results and Hypotheses

The research aims to determine the extent to which digital competencies influence human resource management practices and their impact on the functional characteristics of new digital competencies.

- **Null Hypothesis (H0):** There are assumed to be connections between the impact of digital competencies and human resource management practices.
- **Alternative Hypothesis (H1):** There are significant relationships between the correlation of digital competency dimensions and human resource management practices.

Research Methods

The research framework was established using methodological pluralism, which includes content analysis of relevant literature and documents, as well as a survey method conducted through a structured questionnaire. Empirical data were processed using IBM SPSS Statistics 23, employing statistical procedures that ensure a high level of reliability and validity of the obtained scientific findings.

RESEARCH RESULTS

Information technology is characterized by extremely dynamic development. Entire concepts change every few years, and increasingly, this period is becoming shorter. Therefore, institutions involved in educating IT professionals are expected to continuously improve and align their training programs with the advancement of information technologies and provide a concise overview of IT developments. In designing IT curricula, globally recognized standards in computer science education have been adopted, the highest-quality programs have been implemented, and the founders' own experiences from years of work in the field of IT education have been incorporated.

Based on the results obtained through Google Forms, the surveyed student population consisted of 158 respondents, with female students accounting for 44.5% of the sample and male students for 55.5%. Among the surveyed students, 17.7% were younger than 20 years, 63.3% belonged to the 20–25 age group, and 19.0% were between 26 and 30 years old.

Figure 1. illustrates the number of students by study programs – undergraduate studies: A total of 28.4% of respondents enrolled in Information Technology, 22.2% enrolled in IT – Software Engineering, 12.6% enrolled in Management of Information Technologies, 18.9% enrolled in IT – Data Science and Artificial Intelligence, 17.7% enrolled in IT – Digital Multimedia, and 5% of students enrolled in IT – Digital Business.

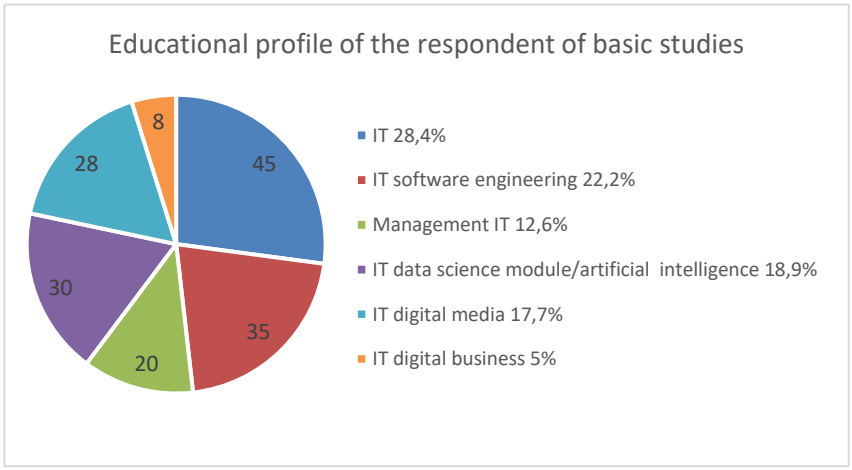


Figure 1: Enrolled educational profile of respondents for digital competencies of basic studies

Figure 2. illustrates the number of students by study programs – master's studies: A total of 50.4% enrolled in Information Technology, 18.4% enrolled in Informatics, Engineering, and Technology in Education, 22.2% enrolled in Information Technology Management, and 9% enrolled in IT – Digital Multimedia.

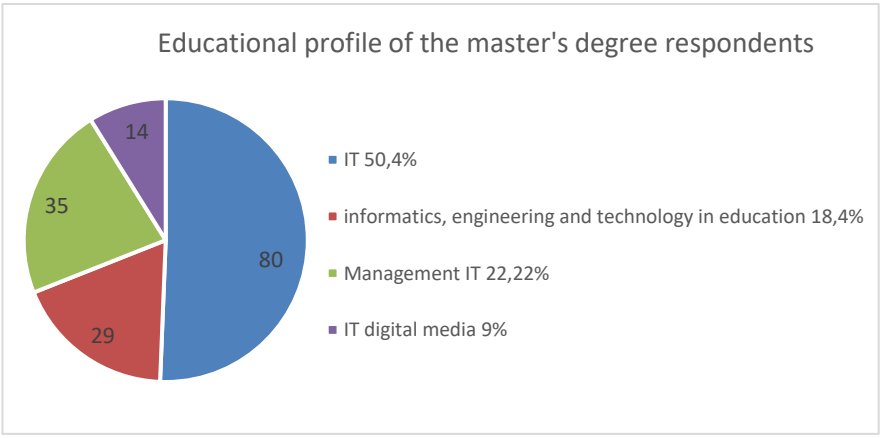


Figure 2: Enrolled educational profile of respondents for digital competencies – master's studies

Figure 3. It should be noted that only 6% perceive the situation as excellent, while 38% consider it good. Meanwhile, 28% believe that the actual use of digital technologies in their companies is satisfactory or even unsatisfactory (28%).

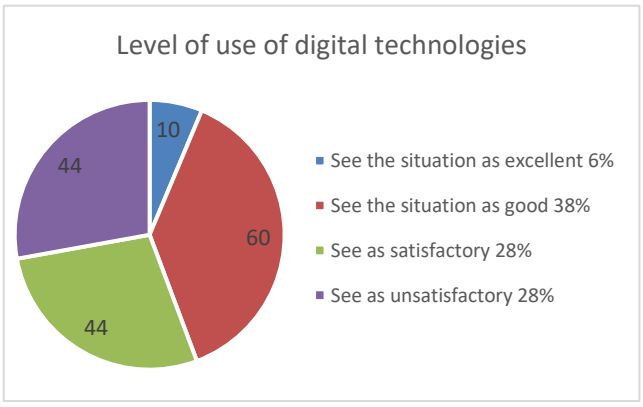


Figure 3: Assessment of the level of digital technology usage by organizational managers

Websites (37%) and CRM systems used for customer relationship management (31%) represent the most commonly adopted digital tools among the surveyed organizations. Lower levels of usage were reported for applications supporting internal processes (14%) and logistics management (18%). The distribution of responses is presented in Figure 4.

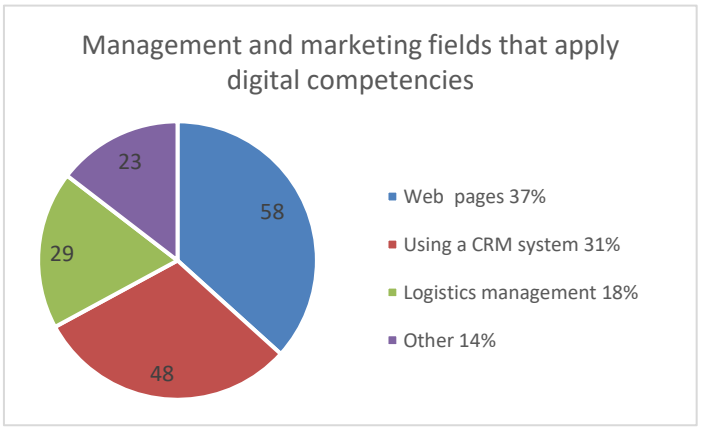


Figure 4: In which areas of management and marketing has your organization implemented digital technologies in the past three years?

The findings indicate that the majority of respondents believe that the implementation of digital technologies in management and marketing has met organizational expectations (57%). At the same time, a considerable proportion of respondents remain uncertain about the achieved effects (20%), while only a relatively small share reported results that exceeded expectations (7%). A detailed distribution of responses is presented in Figure 5.

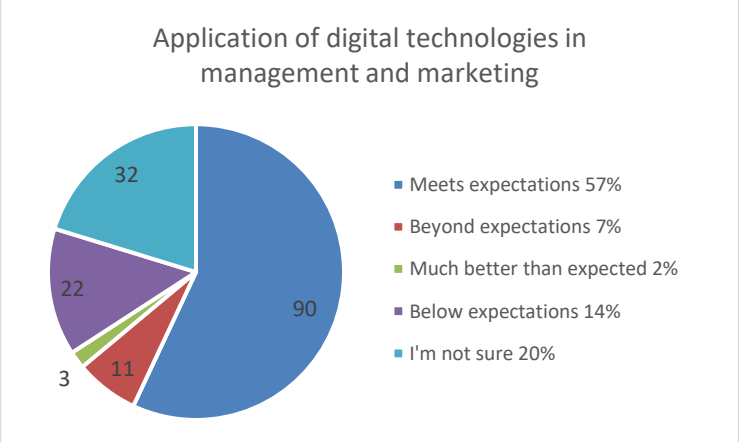


Figure 5: Application of digital technologies in management and marketing: efficiency assessment

DISCUSSION

This research has highlighted certain challenges associated with introducing digital technologies into human resource management practices. This concern is not limited to the previously mentioned process of integrating and combining information and knowledge, but also extends to resistance to change within human resource management practices. The existence of such resistance is confirmed by many global business experts.

CONCLUSION

The study aims to identify, select, and analyze current frameworks for developing digital competence. Its goal is to understand how digital competence is currently perceived and applied in educational

programs, to initiate implementation efforts, and to contribute to the writing of new academic works. It also develops a proposal for a shared understanding of digital competence and identifies human resource management practices.

It is recommended that future research include a larger number of respondents and organizations. Additionally, studies should investigate the barriers that hinder collaboration among individuals, teams, and organizations. The limitations of this research are related to the types of organizations studied and their human resources.

REFERENCES:

Abdifatah Mohamed, & Abdifatah Ali Mohamed. (2023). HRM in the digital era: Exploring the impact of technology and digital transformation on HRM practices and strategies in Somalia. *European Journal of Business and Management, 15*(15), 50–62. https://doi.org/10.7176/EJBM/15-15-06

Eshet-Alkalai, Y. (2004). Digital literacy: A conceptual framework for survival skills in the digital era. *Journal of Educational Multimedia and Hypermedia, 13*(1), 93–106.

Gilster, P. (1997). *Digital literacy*. John Wiley & Sons.

Husen, S., Wahidah, R. N., & Mustajab, D. (2023). Evolution of HRM strategies in the digital age: A comprehensive review. *AMAR (Amkop Management Accounting Review), 4*(1), 42–58. https://doi.org/10.37531/amar.v4i1.1535

Janssen, J., Stoyanov, S., Ferrari, A., Punie, Y., Pannekeet, K., & Sloep, P. (2013). Experts' views on digital competence: Commonalities and differences. *Computers & Education, 68*, 473–481. https://doi.org/10.1016/j.compedu.2013.06.008

Van Laar, E., Van Deursen, A. J. A. M., Van Dijk, J. A. G. M., & De Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior, 72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Vukić, A.-M., Berković, I., & Sajfert, D. (2026). The influence of a CAD designer's creativity on enhancing the quality of a new innovative product. *MEST Journal, 14*(1), 233–246. https://doi.org/10.12709/mest.14.14.01.17

Zervas, I., & Triantari, S. (2025). Digital HRM practices and perceived digital competence: An analysis of organizational culture's role. *Digital, 5*(3), Article 34. https://doi.org/10.3390/digital5030034

Session C: MARKETING MANAGEMENT

Papers (pp. 171-226):

Nurdan Akiner
THE ALGORITHMIC EMPIRE: ALPHABET INC. AND THE INFRASTRUCTURAL HEGEMONY OF PLATFORM CAPITALISM ...171

Marija Bugarski
IMPORTANCE OF BRAND DEVELOPMENT IN THE FASHION INDUSTRY ...179

Nenad Djokic, Nikola Milicevic, Ines Djokic, Branimir Kalas
THE IMPLEMENTATION OF A/B TESTING TECHNIQUE ...185

Dijana Vašaš Kuručev, Aneta Guteša
DIGITAL TOOLS AS DRIVERS OF MICRO-INNOVATIONS IN SME BUSINESS MODELS IN THE CONTEXT OF ENTREPRENEURSHIP 5.0 ...191

Peko Lakatuš, Mihalj Bakator, Miloš Vorkapić
OPTIMIZATION OF MARKETING MANAGEMENT IN INDUSTRIAL (B2B) COMPANIES: A LITERATURE REVIEW AND MODEL PROPOSAL ...197

Peko Lakatuš, Uroš Šarenac
INTEGRATED MARKETING MANAGEMENT MODEL FOR IMPROVING BUSINESS AND MARKET PERFORMANCE OF CONTEMPORARY ENTERPRISES ...202

Ljiljana Stošić Mihajlović, Marija Mihajlović
ORGANIZATIONAL AND FINANCIAL CONSTRAINTS OF MARKETING MANAGEMENT IN SMALL AND MEDIUM ENTERPRISES ...208

Ljiljana Stošić Mihajlović, Marija Mihajlović
DETERMINANTS OF EFFECTIVE MARKETING MANAGEMENT ...214

Bruno Završnik
OMNICHANNEL RETAILING STRATEGY ...220

THE ALGORITHMIC EMPIRE: ALPHABET INC. AND THE INFRASTRUCTURAL HEGEMONY OF PLATFORM CAPITALISM

DOI: 10.5937/EMC26171A

Nurdan Akiner
Akdeniz University, Faculty of Communication, Department of Radio-Television & Cinema, Antalya, Türkiye
E-mail: nurdanakiner@gmail.com

ABSTRACT

The research investigates how digital colonialism operates through the technological authority that platform capitalism provides. It analyzes how power operates through digital systems, moving away from media imperialism models that focused on ownership and content control. Using Alphabet Inc. as a case study, the research examines how integrated platform ecosystems create and capture data-driven value through a critical political economy framework. It investigates how Google, YouTube, and Android work together to transform user data into commercial products that feed algorithmic control systems. The study asserts that platform capitalism functions as an advanced form of digital colonialism, using infrastructural systems to maintain control over access, visibility, and user engagement. The framework shows how Global South countries generate data that Global North corporations force into their centralized systems, creating ongoing extractive relationships. The platform operates as "infrastructural hegemony" in that it establishes itself as a financial intermediary while controlling users' political agency and knowledge production. It introduces the concept of the "algorithmic empire" to describe power embedded in code, data flows, and platform architectures. The research connects digital colonialism with platform capitalism to create a theoretical framework that presents digital infrastructures as imperial outposts while showing how global inequalities continue to expand.

Keywords: Digital Colonialism, Algorithmic Empire, Infrastructural Hegemony, Global South, Alphabet Inc.

INTRODUCTION

Oliver Boyd-Barrett (2014) presents the concept of "media imperialism" as a more focused analytical framework for discussions of cultural imperialism. This approach considers media systems as an extension of Western-centered power relations, evaluating the media not only as a content carrier but as an ideological and economic device that reproduces global inequalities. However, the media imperialism approach limits its analysis to content flows and nation-state-centered power relations. In today's digital landscape, power is rebuilt through data collection, algorithmic sequencing, and platform infrastructures. This transformation narrows the existing frameworks and highlights new conceptualization. The "global village" narrative of digital technologies serves as an ideological veil that hides the unequal nature of digitalization. While global inequalities in internet access and digital literacy persist, even users with access are not equal within these systems. Especially as US-based technology companies have risen to a decisive position in the system through their orchestrating role in global data flows. In this context, Alphabet Inc. dominates core digital infrastructures through search engines, mobile operating systems, cloud services, and video-sharing platforms. The companies in question are not only commercial subjects competing in the market. They are structural power centers that regulate access to information, determine visibility, and govern digital circulation. Postcolonial theory highlights the digital divide and cultural representation (Jandrić & Kuzmanić, 2015) but focuses too heavily on representation, marginalizing the infrastructural and economic dimensions of digital systems. Based on these theoretical limitations, this study proposes the concept of "algorithmic empire" to explain power relations in the digital age. It is established directly but through data infrastructures, algorithmic management, and platform architectures. Algorithmic empire defines a sovereignty regime that collects all kinds of user interactions in digital environments as data and processes them in centralized systems, deriving economic, political, and cultural value. Alphabet Inc. provides a revealing case for analyzing platform capitalism. Data produced especially in the Global South

is collected and processed by Global North-based platforms and converted into economic value. Alphabet's search algorithms, recommendation systems, and mobile ecosystems dominate access to information, establishing not only economic but also cognitive and cultural hegemony.

THEORETICAL FRAMEWORK

This study brings together three main theoretical lines to analyze: (1) the literature on imperialism and media imperialism; (2) discussions of platform capitalism, attention economy, and digital labor; (3) data colonialism and digital colonialism. At the intersection of these three axes, the "algorithmic empire" serves as the study's original conceptual contribution.

Digital Continuity of Imperial Power Relations

The cultural imperialism literature reveals that this relationship is also reproduced on symbolic and ideological planes (Schiller, 1976; Mirrlees, 2020). According to Boyd-Barrett (2015), media systems are not only information-carrying tools, but also structural mechanisms that reproduce global power relations. Today, these imperial power relations increasingly operate through infrastructural and algorithmic forms of control.

Platform Capitalism, Attention Economy, and Digital Labor

Platform capitalism is a new accumulation regime in the digital economy, in which production and circulation processes are organized around platforms. According to Srnicek (2017), platforms are digital infrastructures that bring together different user groups and derive large-scale data from these interactions. Goldhaber (1997) argues that attention has become the scarce resource in an age of information abundance. In the age of information abundance, the scarce resource is attention itself. Platforms blur the distinction between consumption and labor. According to Smythe (2009), the main commodity in mass communication systems is not the content but the audience's attention. Fuchs (2014) explains this process through the concept of "prosumer": Users both consume content and produce unpaid labor, which feeds into the capital accumulation processes of platforms. In this structure, which Zuboff (2019) calls "surveillance capitalism", user behaviors are systematically monitored, analyzed, and linked to predictable behavior models. As a result, digital platforms operate as structures that establish a new capitalist accumulation regime rising on the trivet of attention, data, and labor.

Data Colonialism and Infrastructural Hegemony

The global spread of platform capitalism has given rise to a new form of accumulation: data colonialism. Thatcher, O'Sullivan, and Mahmoudi (2016) emphasize that this new form of exploitation functions through the commodification of everyday life. Couldry and Mejias (2019) define data colonialism as a new phase of capitalism: while classical colonialism appropriates land, resources, and labor, today life itself is confiscated in the form of data. While the countries of the Global South remain largely raw data suppliers, the authority to process and transform it into final value lies with companies based in the Global North (Bolaño & Zanghelini, 2025). Digital colonialism is not solely economic; it also operates through infrastructural and epistemological dimensions. Large technology companies dominate software, hardware, and network infrastructures, thereby shaping the fundamental rules of the digital ecosystem and centralizing information flows (Kwet, 2019). Lessig's (2000) "code is law" approach demonstrates that software architectures regulate user behavior in digital environments. Building on these discussions, algorithmic empire operates through three primary mechanisms: Data extraction, algorithmic management, and infrastructural dependency. Infrastructural hegemony is not only about platforms directing user behavior; it refers to the determination of the conditions of possibility of digital life. On this plane, Gramsci's concept of hegemony takes on a digital form: while consent is produced through user participation, enforcement is enacted through algorithmic visibility and access control. Alphabet Inc. represents one of the clearest examples of this structure.

RESEARCH METHOD

This qualitative case study analyzes Alphabet Inc.'s corporate structure, platform integration strategies, data collection mechanisms, and algorithmic management practices through a critical political economy lens.

Alphabet's integration across search engines, video-sharing platforms, mobile operating systems, and cloud computing was a decisive factor in selecting the case. During the data collection process, Alphabet's annual reports from 2020 to 2025, publicly available API documentation, and texts on the company's platform policies were analyzed. This study does not claim to be a quantitative generalization; instead, it aims to provide a deep interpretation of the workings of platform power from a critical political economy perspective.

DISCUSSION OF FINDINGS

Alphabet Inc. originated from the Google search engine, developed by Larry Page and Sergey Brin at Stanford University in 1998, based on the PageRank algorithm. In its 2004 IPO, the company adopted a dual class share structure, establishing a corporate governance model that grants founders disproportionate voting rights. In 2015, it was restructured as a holding company with core platforms like Google, YouTube, and Android positioned as subsidiaries (The Verge, 2015). This institutional differentiation reflects a layered power architecture between infrastructural governance (Alphabet) and operational platform control (Google). Alphabet's growth strategy is based on expanding its ecosystem by acquiring critical data repositories (Srnicek, 2017) reinforcing the company's "winner-takes-all" dynamic. Table 1 summarizes Alphabet's strategic acquisitions and their contributions to the data ecosystem.

Table 1: Alphabet's Strategic Acquisitions and Data Ecosystem Expansion

Year	Company	Approximate Value	Strategic Data Contribution
2005	Android	~$50 million	Uninterrupted data flow via the mobile operating system
2006	YouTube	$1.65 billion	Control of the video attention economy
2007	DoubleClick	$3.1 billion	Internet-wide advertising traffic and cookie infrastructure
2013	Waze	~$1 billion	Real-time location and traffic data
2014	Nest Labs	$3.2 billion	Domestic life data (thermostats, cameras)
2021	Fitbit	$2.1 billion	Biometric health data (heart rate, sleep patterns)

Note: Compiled by the author based on Vise and Malseed (2017), Lunden (2013), Nancu and Barzecu (2024), and Lee (2019).

Alphabet's revenue composition reflects the scale of its platform-based business model. The company's annual revenues have reached hundreds of billions of dollars, with the primary revenue derived from linking users' digital traces to "predictable consumption patterns" for advertisers (Alphabet Inc., 2025a; 2025b).

Data Colonialism and Infrastructural Dependency

In this process, platforms have evolved into modern colonial apparatuses that transfer value to the Global North by harvesting and processing the raw data of the Global South. As shown in Table 2, platform infrastructures transform heterogeneous data types into different forms of economic and algorithmic value.

Table 2: Typology of Data Extraction and Transformation Mechanisms in Platform Capitalism

Data Type	Platform / Method	Transformation Mechanism
Search queries	Google Search	Intent extraction (user profiling and behavioral prediction) → targeted advertising systems
Viewing history	YouTube	Attention optimization (algorithmic curation and watch-time maximization) → recommendation loops
Location data	Google Maps / Android	Mobility profiling (spatial tracking and behavioral mapping) → predictive modeling systems
Health data	Fitbit / Google Health	Biometric extraction (physiological monitoring and datafication) → integration into data markets
Domestic data	Nest	Routine modeling (household behavior analysis and automation) → security and energy optimization systems
Emotional data	YouTube engagement	Affect analysis (sentiment tracking and emotional inference) → user segmentation and content targeting

Note: This table presents the author's analytical classification based on the literature on platform capitalism and digital colonialism (Fuchs, 2014; Srnicek, 2017; Zuboff, 2019).

All this data is processed on Alphabet's U.S. based servers and used to train artificial intelligence models (Naidu, 2026). The time users spend on the platform, along with their comments and likes, represents a

cost-free source of value for Alphabet (Mileros, 2025). The company has established infrastructure hegemony by controlling the infrastructure of digital life. This is a digital adaptation of Gramsci's theory, where sovereignty is constructed through consent and infrastructure dependency rather than direct force.

Alphabet's infrastructural hegemony is embodied in three key dimensions:

(1) Compulsory Use of Digital Infrastructures. Services such as Google Drive, Google Cloud, and Gmail are not only for individual users; they have also become a de facto digital platform for companies, public institutions, and non-governmental organizations in the Global South. Having a Google account, even without using an external cloud storage tool, creates a private "usage-history cloud.

(2) Dominance over Physical Infrastructure. Alphabet's control extends beyond the software layer to the internet's physical backbone. Nwankwo (2025) argues that big tech companies are redefining the industry and the digital economy with their investments in submarine cables, thus transforming Google into a telecommunications and media company. The company operates one of the world's largest private fiber optic cable networks to carry global data traffic. Gjesvik (2023) reveals that "hyperscalers" like Google have risen to become the new dominators of the submarine cable market and that this special infrastructure control has narrowed states' sovereignty. As of 2022, content providers like Alphabet own or lease 71% of global undersea bandwidth capacity; this rate was below 10% in 2012 (Nwankwo, 2025).

(3) Algorithmic Governance and Visibility Regime. YouTube's recommendation algorithms operate to maximize user attention, establishing a distribution regime that determines which content is likely to gain visibility. As Goldhaber (1997) points out, in the information age, the scarce resource is not information but attention, and content that does not gain visibility is marginalized economically and culturally. Foucault (2007) shows that power is not only exercised through the means of oppression; it becomes functional through knowledge production, visibility regimes, and the determination of norms. Algorithms become micro-power devices that shape individuals' perception of the universe by ruling over what counts as "information", "importance," and "remarkability" (Cheney-Lippold, 2017). Platforms do not force users; they elicit consent in a discourse that presents participation as a "natural" and "free" choice. However, this consent is preconfigured by the infrastructural dependency created by the platforms (Fuchs, 2021). Algorithmic systems assume a double function: disciplinary visibility and hegemonic consent

Digital Poverty: The Intersection of Access, Cost, and Data Appropriateness

Lack of internet connection is only one aspect of digital poverty; other factors include vulnerability to data ownership, a lack of digital literacy, and access charges.

(1) Access and Cost Barrier. The digital divide varies sharply across regions. Falowo and Falowo (2026) report that Sub-Saharan Africa (SSA) has the lowest mobile internet penetration globally: as of 2024, only 29% of the population has access, compared to the global average of 58%. Reasons include limited internet infrastructure, low affordability of mobile devices and data services, insufficient digital capabilities, government regulations, and lack of physical network facilities. These factors exacerbate the spiral of digital poverty in the Global South, making it challenging for users to establish a sustainable and meaningful connection, even when they breach the barrier. This cost pressure shapes the nature of users' interaction with platforms. Low-income users avoid video content to save data, turn to text-based media, or are forced to use services touted as "free" but that exposes them to much more data-intensive extraction. This creates a vicious circle where cost pressure deepens data appropriation.

(2) Actual Price of a Free Service: Data Appropriation. Alphabet's "Next Billion Users" strategy uses a scalable expansion model to enhance digital inclusion in markets with limited internet access. Within this approach, services such as Google, YouTube, and Android are offered free to users, thereby integrating audiences in low-income areas into the platform ecosystem. However, the free access model corresponds to an accumulation regime in which user behavior is tied to data production without interruption which Zuboff (2019) calls "surveillance capitalism." Thus, the "Next Billion Users" strategy is not just digital inclusion policy but an extension of data-driven capitalism. Couldry and Mejias (2019) call this process "data colonialism" and emphasize that the Global South has become a structural reservoir of digital labor and data production. Srnicek (2017), however, argues that platform capitalism generates increasing returns as

user numbers grow through network effects and economies of scale, thereby reinforcing market dominance. Data extraction in the global platform economy presents asymmetrical patterns in different social contexts. Data from users in the Global South is collected and processed at much lower cost due to disparities in digital literacy levels and gaps in privacy awareness (van Deursen & van Dijk, 2019). Moreover, since access to the platforms is mostly granted through contractual "acceptance" mechanisms, user consent is effectively coerced consent. The fact that platforms such as Google and YouTube have become de facto infrastructure suppliers in many Global South countries restricts users' access to alternative digital ecosystems and establishes a structural dependency relationship (Srnicek, 2017; Couldry & Mejias, 2019; Plantin et al., 2018). From this perspective, platform capitalism is not just a data-based accumulation regime. It is a global power structure that rises on the three pillars of unequal access, coercive consent, and infrastructural monopolization.

(3) Digital Literacy and Power Asymmetry. For billions of digitally illiterate people, access to the internet or a smartphone is not inherently meaningful (Boyd-Barrett, 2014). More critically, a lack of digital literacy leaves users completely unprotected against data appropriation. If a user cannot understand where their data flows, how it is processed, and which algorithms are used, this does not constitute informed consent, even if declared. Jandrić and Kuzmanić (2015) read this through a postcolonial lens: Colonial powers appropriating indigenous peoples while educating them under the pretext of "civilizing". Today, Alphabet creates new markets and fresh data sources behind the rhetoric of "increasing digital literacy" and "bringing the internet to everyone". Yet digital literacy projects mostly teach the use of Google's own tools (Gmail, Google Drive, YouTube), which further reinforces the existing dependency relationship.

(4) Digital Poverty Spiral and Infrastructural Domination. Digital poverty is a clear embodiment of infrastructural hegemony. As poor users become dependent on platforms, the cost of switching out of these ecosystems rises exponentially (Valente & Grohmann, 2024). If a user's entire email archive is in Gmail, all their photos are in Google Photos, and their job applications are handled through Google Drive, it becomes virtually impossible for that user to leave the Alphabet ecosystem. This creates infrastructural dependency (Whelan, 2021). Alphabet's "next billion users" strategy leverages this poverty to collect data from the most vulnerable at minimal cost and use this data to train US-based AI models (Nothias, 2025). This process is the clearest example of data colonialism: The data of the poor becomes the lifeblood of the algorithm of the rich (Couldry & Mejias, 2019).

Platform Labor Regimes and Precariousness

At the heart of Alphabet's business model is a surveillance regime that monitors user behavior. All interaction users have within the Google ecosystem (including search queries, YouTube viewing habits, and location information) contribute to data generation. These data are converted into prediction products and constitute the main economic input of platform capitalism. Recommendation algorithms are the front end of platform capitalism’s surveillance regime. Fuchs (2014) argues, this modeling is not just surveillance control. It has simultaneously become the main means of surplus-value production. While users' participation on platforms seems voluntary, it entails consenting to data generation and algorithmic rules. Consent is built into the platform’s architecture; not using the platform risks social and economic exclusion.

Free Digital Labor: From Prosumer to Data Mining

Fuchs’s prosumer clarifies this dual role: each time a user consumes information on the platform, they also produce data that aids in the company's capital accumulation process. There is no cash equivalent for user labor on the platform. However, behind the scenes of this "free" interaction, as Srnicek (2017) emphasizes, lies the marketing of the user's attention and data to advertisers. This is Marx’s surplus-value in digital form that users cannot capture what they create; the platform confiscates it.

Algorithmic Management and the Precariousness of Content Creators. Alphabet's workforce structure is multi-layered, ranging from traditional corporate employment models to fragmented and precarious forms of labor created by digital platform capitalism. While the most visible component of this structure is content producers (YouTubers and influencers), the least visible segment consists of data labelers and

microtask workers. Content producers must not only create content but also perform for algorithmic visibility. Lee et al. (2015) show that algorithmic governance determines visibility and income. Rosenblat and Stark (2016) note that platforms create structural precariousness with non-transparent rules. Precariousness is also emotional. Hochschild's (2012) emotional labor becomes, on platforms, a requirement to bond with viewers. Baym (2018) calls this "relational labor," transforming audience loyalty into a measurable metric. Influencers build community, but platforms commodify this emotional labor and sell it to advertisers. Hochschild's (2012) concept of emotional labor gains a new dimension on digital platforms, turning audience relationships into economic value. Influencers foster community through constant interaction, but platforms commodify this emotional labor and market it to advertisers as loyal audiences. Duffy (2017) notes that although this process appears voluntary and creative, it is in fact a labor regime defined by deep precariousness and uncertainty.

Invisible Workforce and Global Labor Hierarchies. The training of Alphabet's algorithmic systems relies heavily on labeled data sets. Data labelers contribute to the learning processes of algorithmic systems through microtasks such as image classification, object recognition, audio transcription, and content moderation. This labor regime, which Gray and Suri (2019) call "ghost work", is invisible and fragmented. These workers mostly work for low hourly wages (approximately 1-3 dollars) and are deprived of job security, social rights, and long-term contracts. These workers are not the end users of the platforms, but workers who are directly integrated into the production process. Viewed in Marx's (1867/1990) concept of the "industrial reserve army", this regime is a flexible, temporary and constantly mobilized reservoir of labor on a global scale. For big tech companies, the Global South is not only a data production ground but also a reservoir of low-cost labor. This structure includes not only data labelers but also call center workers, content auditors, and other workers who prepare data for AI systems. These forms of labor reproduce global inequalities and maintain historical power relations by transforming them (Akıner, 2024). However, this relationship does not resemble classical colonialism; instead, it represents an asymmetrical dependency relationship re-established through digital production chains. Data production and labor processes construct not only an economic but also a political and epistemological regime of inequality. Digitalization does not change the nature of labor; it transforms how labor is exploited. Marx's labor-capital contradiction persists on digital platforms, but exploitation has become more covert, fragmented, and precarious (Rani et al., 2025). Chen (2026) argues that platform capital uses algorithmic technologies as "digital supervisors" to control labor more efficiently. Platforms confine labor to a task-based framework. The worker is not dependent on an employer, but this "freedom" means being unprotected (Büyükyavuz Deniz, 2024). Algorithmic governance poses new risks to workers' well-being, especially in emerging economies (Rani, Srivastava, Valodia, & Castel-Branco, 2025). Worldwide, 150–430 million data workers report poor conditions, exploitation, and psychological disorders (Du & Okolo, 2025). Alphabet's workforce strategy minimizes costs and maximizes profits by atomizing labor, making it precarious and invisible (a systemic feature of platform capitalism). The Global South pays the heaviest price (Table 3). Data workers toil in "digital sweatshops" (Du & Okolo, 2025); in Africa, labeling and moderation workers are rendered completely invisible to users while working under extremely precarious conditions (Pidoux et al., 2025).

Table 3: Labor Stratification and Forms of Precarity in Platform Capitalism

Labor Layer	Worker Group	Precarity Form
Core labor	Service and infrastructure workers (e.g., campus service workers, logistics staff)	Outsourcing (subcontracting structures), low wages, and limited labor protections
Platform-dependent labor	Content creators and digital producers	Algorithmic dependency (platform visibility and monetization control) and income volatility
Invisible data labor	Micro-task workers and crowd workers	Task fragmentation, labor invisibility, and extremely low compensation

CONCLUSION

This study analyzes Alphabet Inc. as a case of platform capitalism's infrastructural hegemony in the Global South. The findings show that digital capitalism is far beyond a mere economic model; it reveals a new form of sovereignty that operates through data, infrastructure, and algorithms. Alphabet's monopolization strategies have elevated the company to the position of an essential infrastructure for global digital life. Alphabet's business model is based on the principle of continuously collecting, processing, and capitalizing on user data. When this process is conceptualized as data colonialism, a structural value transfer becomes evident, in which data collected from the Global South is transferred to artificial intelligence and advertising economies centered around the Global North. Meanwhile, the digital labor regime is atomized

and precarious. The study proposes the concepts of "algorithmic empire" and "infrastructural hegemony". An algorithmic empire refers to a new regime of power in which sovereignty is exercised through data flows, algorithms, and digital infrastructures rather than direct territorial control. Infrastructural hegemony describes the transformation of platforms into building blocks that determine the conditions of possibility of social reality, going beyond being mere content distribution channels.

On this plane, the Gramscian concept of hegemony gains a digital identity: while consent is produced through user participation, it becomes operational through routing, algorithmic visibility, and infrastructural dependency. For the Global South, this structure entails three key risks: economic concentration and digital exclusion, the erosion of data sovereignty, and the ossification of technological dependence. These risks are not limited to the market level but also have structural consequences for sovereignty and development capacity. In the age of algorithmic empire, imperial power relations underwent a radical transformation. Sovereignty is no longer over physical geography; it rules data, infrastructure, and algorithms. But this structure is not static, increasing regulatory interventions and alternative digital infrastructure initiatives are constantly testing the limits of this new form of empire. The future of digital sovereignty is not based solely on analyzing existing structures, but also on the construction of alternative, public digital infrastructures.

REFERENCES

Akıner, N. (2024). A theoretical approach to digital colonialism in the context of media imperialism. In *International Conference on Social Science Research (ICONSR 2024): Abstracts & Proceedings Book* (pp. 131–141). Association of Kutbilge Academicians.

Alphabet Inc. (2025a). *Form 10-K annual report*. https://abc.xyz/investor/

Alphabet Inc. (2025b). *Form 10-Q quarterly report*. https://abc.xyz/investor/

Baym, N. K. (2018). *Playing to the crowd: Musicians, audiences, and the intimate work of connection*. NYU Press.

Bolaño, C., & Zanghelini, F. (2025). Data economy: A discussion on value, fictitious valorisation, and national sovereignty. *Big Data & Society, 12*(4). https://doi.org/10.1177/20539517251396101

Boyd-Barrett, O. (2014). *Media imperialism*. Sage.

Büyükyavuz Deniz, A. N. (2024). Digital labour and platform capitalism: Labour platform review. *Avrasya Sosyal ve Ekonomi Araştırmaları Dergisi, 11*(1), 113–127.

Chen, T. (2026). The political economy critique of the gig economy: Algorithmic exploitation and labor alienation. *Critical Humanistic Social Theory, 3*(1). https://doi.org/10.62177/chst.v3i1.1152

Cheney-Lippold, J. (2017). *We are data: Algorithms and the making of our digital selves*. New York University Press.

Couldry, N., & Mejias, U. A. (2019). *The costs of connection: How data is colonizing human life and appropriating it for capitalism*. Stanford University Press.

Du, M., & Okolo, C. T. (2025, October 7). *Reimagining the future of data and AI labor in the Global South*. Brookings Institution. https://www.brookings.edu/articles/reimagining-the-future-of-data-and-ai-labor-in-the-global-south/

Duffy, B. E. (2017). *(Not) getting paid to do what you love: Gender, social media, and aspirational work*. Yale University Press.

Falowo, O., & Falowo, S. (2026). Low internet penetration in Sub-Saharan Africa and the role of LEO satellites in addressing the issue. *Telecom, 7*(1), Article 7. https://doi.org/10.3390/telecom7010007

Foucault, M. (2007). *Security, territory, population: Lectures at the Collège de France, 1977–1978*. Springer.

Fuchs, C. (2014). *Digital labour and Karl Marx*. Routledge.

Fuchs, C. (2021). *Social media: A critical introduction* (3rd ed.). Sage.

Gjesvik, L. (2023). Private infrastructure in weaponized interdependence. *Review of International Political Economy, 30*(2), 722–746. https://doi.org/10.1080/09692290.2022.2069145

Goldhaber, M. H. (1997). The attention economy and the net. *First Monday, 2*(4). https://doi.org/10.5210/fm.v2i4.519

Gray, M. L., & Suri, S. (2019). *Ghost work: How to stop Silicon Valley from building a new global underclass*. Harper Business.

Hochschild, A. R. (2012). *The managed heart: Commercialization of human feeling* (3rd ed.). University of California Press.

Jandrić, P., & Kuzmanić, A. (2015). Digital postcolonialism. *IADIS International Journal on WWW/Internet, 13*(2).

Kwet, M. (2019). Digital colonialism: US empire and the new imperialism in the Global South. *Race & Class, 60*(4), 3–26. https://doi.org/10.1177/0306396818823172

Lee, M. (2019). *Alphabet: The becoming of Google*. Routledge.

Lee, M. K., Kusbit, D., Metsky, E., & Dabbish, L. (2015). Working with machines: The impact of algorithmic and data-driven management on human workers. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 1603–1612). ACM. https://doi.org/10.1145/2702123.2702548

Lessig, L. (2000). *Code and other laws of cyberspace*. Basic Books.

Lunden, I. (2013, June 11). Google bought Waze for $1.1B, giving a social data boost to its mapping business. *TechCrunch*. https://techcrunch.com/2013/06/11/google-bought-waze-for-1-1b-giving-a-social-data-boost-to-its-mapping-business/

Marx, K. (1990). *Capital: A critique of political economy* (B. Fowkes, Trans.; Vol. 1). Penguin Classics. (Original work published 1867)

Mileros, M. D. (2025). *Users like you and me: Understanding the user-driven data economy from a human-centric perspective* (Vol. 2432). Linköping University Electronic Press.

Mirrlees, T. (2020). US empire and cultural imperialism: A reconceptualization and twentieth-century retrospective. In O. Boyd-Barrett & T. Mirrlees (Eds.), *Media imperialism: Continuity and change* (pp. 45–59). Rowman & Littlefield.

Naidu, S. (2026, January 16). *Trends in AI data collection by Big Tech and regulatory responses across jurisdictions*. Open Terms Archive. https://opentermsarchive.org/en/publications/trends-in-ai-data-collection-by-big-tech-and-regulatory-responses-across-jurisdictions/

Nancu, D., & Barzecu, A. M. (2024). Economic and financial performance of the company Alphabet Inc. (Google): Company with a global footprint in the development of the knowledge-based economy. *Ovidius University Annals, Economic Sciences Series, 24*(1), 275–280.

Nothias, T. (2025). An intellectual history of digital colonialism. *Journal of Communication, 75*(5), 385–397. https://doi.org/10.1093/joc/jqaf003

Nwankwo, J. E. (2025). Redefining competition and submarine cable ownership: Equiano, MainOne, and the making of middlemen. *The Information Society, 41*(5), 279–289. https://doi.org/10.1080/01972243.2025.2547676

Pidoux, J., Kypraiou, S., Kgomo, S., Malgwi, K. I., Mathenge, R. M., Okinyi, M., Oyange, J., & Tighanimine, M. (2025). Mapping data labour supply chain in Africa in an era of digital apartheid: A struggle for recognition. *arXiv*. https://doi.org/10.48550/arXiv.2512.04269

Plantin, J. C., Lagoze, C., Edwards, P. N., & Sandvig, C. (2018). Infrastructure studies meet platform studies in the age of Google and Facebook. *New Media & Society, 20*(1), 293–310. https://doi.org/10.1177/1461444816661553

Rani, U., Srivastava, R., Valodia, I., & Castel-Branco, R. (2025). New technologies, transformation of labour process, and future of work in the Global South: An overview. *Indian Journal of Labour Economics, 68*, 339–347. https://doi.org/10.1007/s41027-025-00569-x

Rosenblat, A., & Stark, L. (2016). Algorithmic labor and information asymmetries: A case study of Uber's drivers. *International Journal of Communication, 10*, 3758–3784.

Smythe, D. W. (2009). On the audience commodity and its work. In M. G. Durham & D. M. Kellner (Eds.), *Media and cultural studies: Keyworks* (pp. 230–256). Wiley-Blackwell.

Srnicek, N. (2017). *Platform capitalism*. Polity Press.

Thatcher, J., O'Sullivan, D., & Mahmoudi, D. (2016). Data colonialism through accumulation by dispossession: New metaphors for daily data. *Environment and Planning D: Society and Space, 34*(6), 990–1006. https://doi.org/10.1177/0263775816633195

The Verge. (2015, August 10). *Google is reorganizing and Sundar Pichai will become new CEO*. https://on.theverge.com/2015/8/10/9128083/sundar-pichai-ceo-google-larry-page-sergey-brin

Valente, J. C., & Grohmann, R. (2024). Critical data studies with Latin America: Theorizing beyond data colonialism. *Big Data & Society, 11*(1), Article 20539517241227875. https://doi.org/10.1177/20539517241227875

Van Deursen, A. J. A. M., & Van Dijk, J. A. G. M. (2019). The first-level digital divide shifts from inequalities in physical access to inequalities in material access. *New Media & Society, 21*(2), 354–375. https://doi.org/10.1177/1461444818797082

Vise, D. A., & Malseed, M. (2017). *The Google story* (Updated ed.). Pan Books.

Whelan, G. (2021). Alphabet. In *Megacorporation: The infinite times of Alphabet* (pp. 43–68). Cambridge University Press. https://doi.org/10.1017/9781108626095.003

Zuboff, S. (2019). *The age of surveillance capitalism: The fight for a human future at the new frontier of power*. PublicAffairs.

IMPORTANCE OF BRAND DEVELOPMENT IN THE FASHION INDUSTRY

DOI: 10.5937/EMC26179B

Marija Bugarski
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: marija.bugarski@tfzr.rs

ABSTRACT

This study examines brand development in the fashion industry, focusing on the relationship between brand identity, differentiation, consumer perception, and digital engagement. Strong foundations, including visual style, heritage, and values, support consistent communication and positioning. Differentiation strategies allow a label to stand out through unique design, quality, and lifestyle associations. These factors influence how consumers perceive and evaluate products. Management processes, such as marketing communication, product design consistency, digital engagement, and channel management, translate internal definitions into external experiences. These experiences shape perception and loyalty. Digital media has introduced new conditions for interaction. This technology allows for continuous engagement and feedback that affect consumer attitudes and the image of the entity. Consumer outcomes, including perception, image, loyalty, and emotional connection, show the effectiveness of marketing strategies and lead to long term preference. A theoretical model shows the connections between foundational elements, processes, and outcomes. It shows how adjustments in identity, values, and communication influence overall performance. Practical strategies for governments, enterprises, and individuals include maintaining consistency, using market knowledge, and integrating digital engagement to strengthen recognition and stay relevant in competitive fashion markets.

Key words: Fashion industry, Brand development, Identity, Consumer perception, Digital media.

INTRODUCTION

Brand evolution in the fashion industry is examined as a structured process that connects identity, communication, and consumer response. Fashion markets have intense competition, short product life cycles, and a strong symbolic dimension attached to products. In such conditions, marketing strategies provide a way to distinguish items that may otherwise appear similar in functional terms. A clearly defined identity supports recognition and leads to consistent expectations among consumers. The concept of equity explains how value is created through awareness, associations, and perceived quality. These factors together influence purchasing decisions and long term preference (Aaker, 2009; Keller, 1993). In the fashion context, these elements are closely linked with visual presentation, storytelling, and lifestyle positioning.

The main goal of this paper is to examine the importance of brand development in the fashion industry through the relationship between identity, differentiation, consumer perception, and digital engagement. The study also aims to propose a theoretical model that explains how foundational elements, management processes, and consumer outcomes interact within fashion markets.

The importance of this topic comes from the increasing complexity of the fashion industry, where companies operate in highly competitive and digitally connected environments. Strong brand development supports recognition, market positioning, consumer loyalty, and long term competitiveness. The paper contributes to the existing literature by integrating concepts from brand management, consumer behavior, and digital communication into a unified theoretical framework applicable to contemporary fashion markets.

LITERATURE BACKGROUND

Academic literature provides several perspectives on how companies are developed and managed. Research in consumer culture shows that consumption is not limited to functional use. It includes symbolic meanings and identity construction (Arnould & Thompson, 2005). Fashion products are often used to express social identity, group belonging, and personal style. This makes marketing a main element in shaping consumer interpretation. Cultural branding further explains how labels gain relevance through shared meanings and narratives that connect with broader social contexts (Holt, 2004). Marketing research specific to fashion shows the importance of aligning product design, communication, and distribution with market positioning to maintain coherence (Barnes, 2013).

The role of brand identity and brand differentiation in the fashion industry

Identity represents the internal definition of a company, including its visual elements, values, and overall direction. In the fashion industry, identity is expressed through design consistency, logos, color schemes, and communication style. Together, visual and symbolic elements form a recognizable system that allows consumers to identify the label across different touchpoints. Differentiation refers to the process of distinguishing a company from competitors through unique attributes and positioning strategies. Strong identity and clear differentiation lead to a more stable market position, especially in environments where trends change frequently. Research shows that entities with well defined identities are more likely to achieve recognition and maintain consistency in consumer perception (Aaker, 2012; Kapferer, 2008). In fashion, differentiation is often linked to aesthetic direction, price level, and associations with certain lifestyles or social groups.

Influence of branding on consumer perception and loyalty

Consumer perception is shaped through interactions with a company, including product experience, communication, and external influences. Image reflects the set of associations that consumers hold, which can include quality, style, and emotional meaning. A consistent image leads to more predictable consumer responses and supports repeat purchasing behavior (Keller, 1993; Zhang, 2015). Loyalty in the fashion industry extends beyond satisfaction with product performance. It includes emotional attachment and identification with the label, which are influenced by symbolic meaning and personal relevance. Personality is one of the constructs used to explain how consumers relate to a company in human like terms, which can strengthen attachment and preference over time (Aaker, 1997). These relationships are relevant in fashion, where personal expression is tied to consumption.

Impact of digital media on fashion brand development

Digital media introduces new forms of interaction between companies and consumers. Social media platforms allow direct communication and a continuous presence in daily lives. Fashion labels use these tools to present collections and share values in real time. Influencer marketing is a common approach where individuals with many followers affect attitudes toward products (De Veirman et al., 2017). Success in digital communication depends on consistency with the identity of the company. Inconsistencies in communication may create confusion among consumers. Luxury labels must balance exclusivity and accessibility online (Chevalier & Mazzalovo, 2021). The framework integrates identity and market knowledge with communication strategies to influence outcomes such as perception and loyalty (Aaker, 2009; Keller, 1993).

Identity and differentiation define how a label is created and recognized. Identity includes visual elements and symbolic aspects like heritage and values. A consistent identity helps consumers recognize the company across channels and over time (Aaker, 2012). Differentiation distinguishes the company from competitors through unique attributes. Fashion companies differentiate through design innovation, quality, or lifestyle associations. Luxury labels rely on craftsmanship, while fast fashion companies focus on speed and trend response. Clear differentiation leads to stronger recognition and

reduces confusion (Kapferer, 2008). A well defined identity allows for consistent messages that strengthen market position.

Consumer perception and loyalty connect to marketing activities. Perception comes from experience, communication, and social influence. A coherent image leads to predictable responses and reduces uncertainty (Keller, 1993). Loyalty involves emotional attachment and identification with the label. Personality concepts assign human characteristics to companies to strengthen attachment (Aaker, 1997). Consistent messages across touchpoints make consumer understanding stable. Positive associations link with long term preference (Zhang, 2015). Companies must respond to trends while maintaining their core identity. This process involves monitoring feedback and adjusting strategies to stay aligned with consumer expectations.

Digital media creates new conditions for communication and visibility. Online platforms allow companies to present content continuously, replacing seasonal campaigns. Social media channels function as tools for showcasing collections and narratives. This form of communication relies on visual consistency. Content must align with the identity to maintain clarity. The shift toward digital interaction has changed how audiences connect with fashion entities.

MODEL DEVELOPMENT

Development of the model provides a structured way to connect the main components of an identity into a framework. This structure is based on the integration of inputs, processes, and outputs. These parts explain how marketing activities influence consumer outcomes. Inputs include identity, architecture, and market knowledge. These define the initial conditions for fashion sector growth.

The theoretical model for development in the fashion industry has three main elements. Together, the three elements represent the progression from internal definition to external consumer response and illustrate the relationship between strategic inputs, operational processes, and market outcomes (Aaker, 2009; Keller, 1993). The structure and connection between these components are shown in Figure 1.

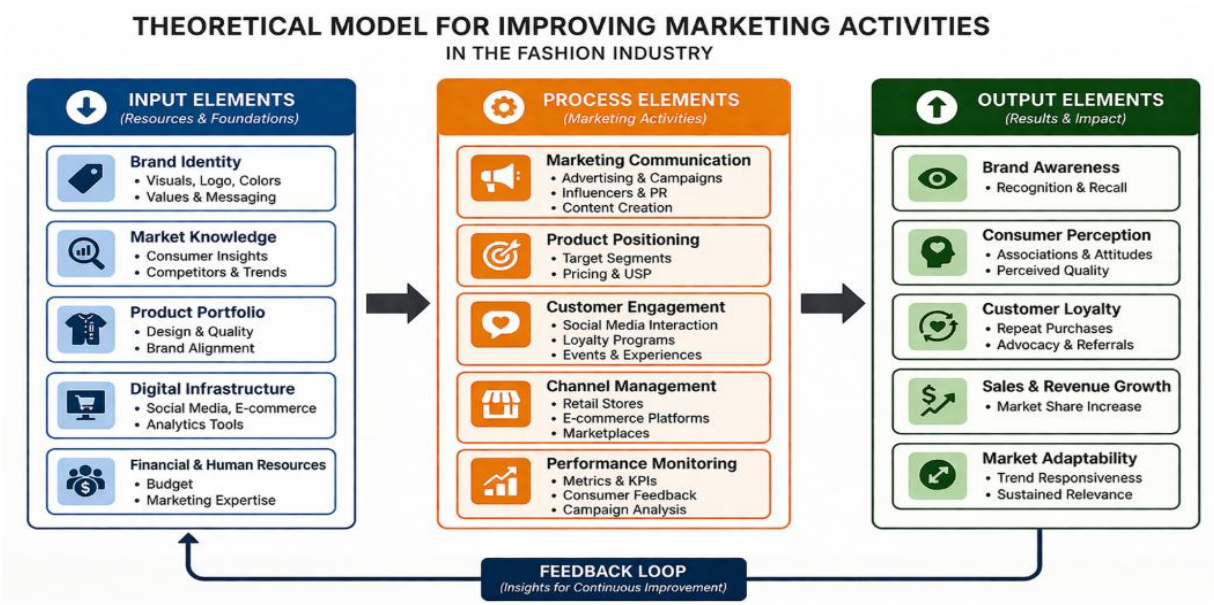


Figure 1: Theoretical model of fashion brand development

The first main element refers to foundations. These define the internal structure and direction of the company. Sub-elements include identity, which consists of visual and symbolic characteristics; heritage, which reflects the historical background and continuity; values, which guide communication and positioning; architecture, which organizes product lines; and market knowledge, which includes

understanding of consumer preferences and competitors. These sub-elements provide the basis for consistent strategic decision making (Kapferer, 2008).

The second main element focuses on processes. These translate internal definitions into visible and actionable strategies. Sub-elements include marketing communication, which covers the channels used to present the label; product design consistency, which ensures alignment between collections and identity; positioning strategy, which defines how the company is placed in relation to competitors; digital engagement, which involves interaction through social media; and channel management, which coordinates distribution. All processes determine how the entity is experienced by consumers and influence the clarity of messages (Barnes, 2013; De Veirman et al., 2017).

The third main element relates to consumer outcomes. These represent the results of marketing activities. Sub-elements include perception, which reflects how consumers interpret messages; image, which consists of accumulated associations; perceived quality, which influences the evaluation of products; loyalty, which refers to repeated purchasing; and emotional connection, which describes personal attachment. These outcomes are shaped through continuous interaction and determine the overall effectiveness of strategic positioning (Keller, 1993; Zhang, 2015).

Relationships within the proposed model are based on the interaction between foundations, processes, and outcomes. Identity serves as the starting point. It defines the visual and conceptual characteristics that guide all further activities. A clearly defined identity influences marketing communication, product design consistency, and positioning strategy. These processes rely on a stable reference for how the company is presented. Heritage leads to authenticity and continuity. This affects how communication messages are framed and how consumers interpret the label over time. Heritage also supports emotional connection, as consumers associate the company with tradition and credibility (Kapferer, 2008).

Values function as a guiding structure for both internal decisions and external communication. These values shape marketing messages, tone of voice, and the selection of communication channels. When values are reflected in processes, they lead to a clearer image and stronger consumer perception. Inconsistencies between stated values and actual communication lead to confusion or reduced trust. Architecture influences how different product lines are organized. This affects positioning strategy and channel management. A well structured architecture allows consumers to understand relationships between products. Market knowledge provides information about consumer preferences, competitor strategies, and industry trends. This element affects decisions related to product design, communication, and digital engagement. It ensures that strategies stay relevant to current market conditions (Aaker, 2009).

Processes act as a link between internal definition and external consumer response. Marketing communication translates identity, values, and positioning into messages. The effectiveness of communication depends on consistency with foundations. Alignment supports recognition and clarity in perception. Product design consistency ensures that each collection reflects the established identity. This reinforces the image over time. In fashion, where trends change frequently, maintaining consistency in design elements helps preserve coherence. Positioning strategy determines how the company is placed relative to competitors. This influences consumer interpretation and evaluation.

SUGGESTIONS AND GUIDELINES

- Public institutions can support the fashion sector through policies that protect intellectual property and encourage creative industries. These programs provide funding and education to improve understanding of marketing, positioning, and digital communication.
- Public investment in digital infrastructure and training programs helps companies and individuals use online platforms. This support allows for better digital engagement and adaptation to changing consumer behavior (De Veirman et al., 2017).

- Organizations can develop clear identity systems that include visual elements, values, and consistent communication guidelines. These systems should apply to all channels to maintain recognition and coherent perception (Aaker, 2012).
- Fashion labels can align product design with their core identity to ensure consistency across collections. This alignment helps reinforce the image and supports long term positioning in competitive markets (Kapferer, 2008).
- Businesses can use market research and data analysis to understand consumer preferences and industry trends. Insights from market knowledge guide decisions related to positioning, communication, and product development (Aaker, 2009).
- Commercial entities can integrate digital strategies into marketing processes through social media and influencer collaborations. Digital activities should remain aligned with the established identity to avoid confusion and maintain clarity in perception (Chevalier & Mazzalovo, 2021).
- Individuals can develop personal labels or small companies through consistent visual identity and targeted communication. Clear presentation across digital platforms supports recognition and audience engagement.
- Individuals also can engage with consumers through interactive content and feedback on social media. This interaction strengthens perception and leads to the development of loyalty over time.
- Management teams and individuals can monitor consumer perception and image through reviews and engagement metrics. This information helps adjust strategies and improve alignment with consumer expectations (Zhang, 2015).
- Education in marketing, design, and digital communication supports adaptation to market changes. Continuous learning leads to more structured development for all participants in the industry.

CONCLUSION

Evolution in the fashion industry requires the integration of identity, differentiation, consumer perception, and digital engagement. Strong foundations, including a clearly defined identity, heritage, and values, provide the basis for consistent communication and positioning. Differentiation supports market positioning and helps a company stand apart from competitors through unique design, quality, and lifestyle associations (Aaker, 2012; Kapferer, 2008). Marketing processes translate internal definitions into visible strategies through communication, product design consistency, digital engagement, and channel management. The alignment of these processes with foundational elements leads to coherent perception and stronger consumer recognition (Barnes, 2013; De Veirman et al., 2017). Consumer outcomes, including perception, image, loyalty, and emotional connection, show the effectiveness of these strategies. These results show how well a company maintains relevance over time (Keller, 1993; Zhang, 2015).

Digital media introduces additional dynamics, allowing for continuous interaction with consumers and providing feedback. This feedback informs adjustments in marketing strategies. This environment increases the need for consistency across online and offline channels to preserve coherence (Chevalier & Mazzalovo, 2021). The theoretical model shows the relationships between foundational elements, processes, and outcomes. It shows how adjustments in one area influence others and how market knowledge guides strategic decisions. Effective development in fashion integrates these elements to maintain recognition, influence consumer behavior, and keep long term performance stable.

The proposed theoretical model functions as a continuous cycle where the outcomes directly inform future strategies. This process occurs through the feedback loop which connects the output elements back to the initial input resources. Data from consumer perception and market adaptability provide necessary information for adjusting identity and market knowledge. This connection ensures that the marketing activities stay aligned with changing consumer attitudes and sales performance. The model

remains effective because it uses these insights to update the product portfolio and financial allocations based on real world results.

REFERENCES

Aaker, D. A. (2009). *Managing brand equity*. Simon & Schuster.

Aaker, D. A. (2012). *Building strong brands*. Simon & Schuster.

Aaker, J. L. (1997). Dimensions of brand personality. *Journal of Marketing Research, 34*(3), 347–356. https://doi.org/10.1177/002224379703400304

Arnould, E. J., & Thompson, C. J. (2005). Consumer culture theory (CCT): Twenty years of research. *Journal of Consumer Research, 31*(4), 868–882. https://doi.org/10.1086/426626

Barnes, L. (2013). Fashion marketing. *Textile Progress, 45*(2–3), 182–207. https://doi.org/10.1080/00405167.2013.868677

Chevalier, M., & Mazzalovo, G. (2021). *Luxury brand management in digital and sustainable times*. John Wiley & Sons.

De Veirman, M., Cauberghe, V., & Hudders, L. (2017). Marketing through Instagram influencers: The impact of number of followers and product divergence on brand attitude. *International Journal of Advertising, 36*(5), 798–828. https://doi.org/10.1080/02650487.2017.1348035

Holt, D. B. (2004). *How brands become icons: The principles of cultural branding*. Harvard Business School Press.

Kapferer, J.-N. (2008). *The new strategic brand management: Creating and sustaining brand equity long term* (4th ed.). Kogan Page.

Keller, K. L. (1993). Conceptualizing, measuring, and managing customer-based brand equity. *Journal of Marketing, 57*(1), 1–22. https://doi.org/10.1177/002224299305700101

Zhang, Y. (2015). The impact of brand image on consumer behavior: A literature review. *Open Journal of Business and Management, 3*(1), 58–62. https://doi.org/10.4236/ojbm.2015.31006

THE IMPLEMENTATION OF A/B TESTING TECHNIQUE

DOI: 10.5937/EMC26185D

Nenad Djokic
University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia
Nikola Milicevic
University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia
Ines Djokic
University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia
Branimir Kalas
University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia
E-mail: branimir.kalas@ef.uns.ac.rs

ABSTRACT

In the digital environment, companies face intense competition, where even minor mistakes may lead to significant revenue losses. This is particularly important given increasingly demanding consumers who expect efficient and seamless online experiences. Consequently, companies need to carefully analyze consumer behavior and systematically test their content elements. A/B testing represents an effective approach for this purpose. By comparing different versions of content elements, it enables the identification of the variant that performs better among users. As a result, organizations may achieve benefits such as higher conversion rates and increased user engagement. However, to obtain reliable results, A/B testing should be conducted through clearly defined phases and supported by appropriate statistical methods. Furthermore, a variety of specialized software tools are available to facilitate the implementation and management of A/B testing processes.

Key words: A/B testing, digital marketing, statistical approach

INTRODUCTION

In digital marketing, as well as in offline environments, one of the primary tasks involves analyzing consumer behavior and understanding their decision-making processes. Consumers' needs and wants represent the foundation of most marketing activities. Although traditional analytical methods can also be applied in the online context, they may face limitations in generating the detailed insights required for optimizing modern marketing strategies. The rapid expansion and continuous evolution of digital platforms, including the introduction of new aesthetic and functional elements, have increased the need for effective marketing tactics thus leading to the application of contemporary evaluation tools, such as A/B testing (Kumar, 2021).

A/B testing is widely used when evaluating the effects of website changes on users, particularly in relation to personalization features (Esteller-Cucala et al., 2020). Considering that well-designed websites tend to attract and retain visitors, consequently leading to increased engagement, improved conversion rates, and ultimately higher revenue (Sharma and Tripathi, 2023), they should be continuously adjusted and improved. A/B testing represents a key tool for validating proposed website modifications before full-scale implementation. Accordingly, this paper presents an explanation of this technique, along with its main phases.

A/B TESTING TECHNIQUE

The technique of A/B testing, in the literature also known as split testing, refers to "comparing two versions of a marketing element such as an email campaign, website layout, or advertisement by exposing different segments of the audience to each version" (Kumar, 2021, p. 323). Quin et al. (2024) define it as a form of online controlled experimentation and hypothesis testing aimed at evaluating and comparing two variants under real-world conditions. The main goal is to identify which variant performs better in attaining predefined objectives (Kumar, 2021).

Mulla (2020) discusses the evolution of the A/B testing method. Its earliest applications were recorded in clinical trials, after which it became widely adopted in digital marketing. Within this domain, A/B testing evolved from a relatively simple procedure into an essential instrument for data-driven decision-making. With the expansion of digital platforms, the method developed into an effective tool for isolating and analyzing specific variables, thereby providing valuable insights into user behavior.

The application of A/B testing offers several advantages. Puri et al. (2022) highlight the following benefits:

- Improved user engagement – testing alternative versions of content enables the identification of the variant preferred by the majority of users; modifying content based on empirical results can enhance the target audience's experience and increase campaign effectiveness; for example, A/B testing may be applied to evaluate multiple versions of a call-to-action element within the same advertisement in order to select the most effective option.
- Increased conversion rates – A/B testing represents one of the simplest and most effective approaches for identifying which content element prompts the highest proportion of users to perform a desired action, in digital marketing known as a "conversion"; by distinguishing effective from ineffective variants, organizations can optimize content and improve conversion rates for actions such as click-throughs, sign-ups, or video views;
- Ease of analysis and quick results – the evaluation of variants in an A/B test is methodologically straightforward, as performance is assessed using predefined metrics aligned with specific objectives; the variant that demonstrates superior performance relative to alternatives should be selected; even with smaller sample sizes, A/B testing can generate valuable insights, including participant feedback regarding their preferences.

In addition to its benefits, Puri et al. (2022) identify certain limitations of A/B testing. These include:

- High resource consumption – A/B testing is most appropriate when a single element is evaluated at a time; if multiple elements are tested simultaneously, the process may become time-consuming and require greater resources.
- Suitability for specific goals – A/B testing is particularly effective when the objective is to assess the impact of one specific element (e.g., a call-to-action button, video content, or color) on a desired outcome (e.g., clicks, sign-ups, or shares); however, when multiple elements or entirely different content versions are to be compared, alternative approaches, such as offline testing or focus group discussions, may provide more cost-effective results.

A/B testing is widely adopted across various organizations in digital environments. According to Quin et al. (2024), it is extensively implemented by major technology companies, including Google, Meta, LinkedIn, and Microsoft.

In addition to A/B testing, it is important to mention the A/A test, sometimes referred to as a null test, in which users are assigned to two groups but exposed to exactly the same experience. This approach can be used for collecting data and assessing its variability for power calculations, as well as for testing the experimentation system (Kohavi et al., 2009).

A/B TESTING PROCESS

The A/B testing process is typically structured into several phases. Following Quin et al. (2024), three main phases can be distinguished:

- design phase – this phase focuses on designing the A/B test, during which key parameters are defined, including the research hypothesis, the target population and sample selection, the duration of the experiment, and the performance metrics (e.g., number of clicks or click-through rate);
- execution phase – this phase involves implementing the A/B test within the operational software system; after splitting the sample population, both variants are released into a live environment, and relevant data are collected for experimental evaluation.
- evaluation phase – this phase concerns the analysis of experimental outcomes; upon completion of the test, the initial hypothesis is examined using appropriate statistical methods; based on the results, follow-up actions may be taken, such as deploying the winning variation or designing new variants for subsequent testing.

A structured and well-planned A/B testing process can enhance marketing profitability by identifying key areas that require optimization (VWO, n.d.). In this regard, VWO (n.d.) presents five main steps:

- research – prior to designing an A/B testing plan, thorough research on current website performance should be conducted;
- observation and hypothesis formulation – documenting research observations and developing data-driven hypotheses contribute to achieving business objectives;
- variation creation – this step involves creating an alternative version of existing content based on the previously defined hypothesis, with specific modifications subject to testing.
- testing – this phase includes implementing the selected testing method; particular attention should be paid to the choice of statistical approach – Frequentist or Bayesian (Table 1); additionally, timing and experiment duration must be carefully determined; the duration of the test should be calculated based on factors such as average traffic volume, current conversion rate, expected improvement in conversion rate, and the number of variations;
- analyzing results and deploying winning variation – the analysis relies on various performance metrics, including percentage change, confidence levels, and potential effects on related indicators; if the results are statistically and practically significant, the winning variation should be implemented.

Table 1: Statistical approach (VWO, n.d., p. 12)

Frequentist Approach	Bayesian Approach
Frequentist statistics follow the "Probability as Long-Term Frequency" definition of probability.	Bayesian statistics follow the notions of "Probability as Degree of Belief" and "Logical Probability."
In this approach, only data from the current experiment are used. The Frequentist solution is to conduct tests and draw conclusions.	In this approach, prior knowledge from previous experiments is incorporated into the current data. The Bayesian solution is to combine prior information with observed data to draw conclusions.
Provides an estimated mean (and standard deviation) of samples where A beats B but ignores cases where B beats A.	Takes into account the probability of A beating B and calculates the expected range of improvement.
Requires the test to run for a fixed period to obtain sufficient data, but does not indicate how close or far apart A and B actually are. It does not provide the probability of A beating B.	Provides greater control over testing. It allows better planning, a more accurate basis for ending tests, and clearer insight into how close or far apart A and B are.

HubSpot (n.d.) outlines six core principles for conducting effective A/B testing, particularly in relation to accurately measuring results and identifying the better-performing variant. These principles include: testing one variable at a time, implementing small modifications to the tested content, considering larger variables such as an entire landing page, evaluating both conversion rates and long-term business outcomes, ensuring comparable audiences of similar size and background, and controlling for timing effects. HubSpot (n.d.) also proposes the following steps for carrying out an A/B test:

- selection of the test variable,
- defining the objective,
- hypothesis formulation,
- identification of testable elements,
- determination of sample size and experiment duration.

Based on a systematic literature review, Quin et al. (2024) report that A/B testing is most frequently used to test algorithms, visual elements, and workflow or process modifications, with web, search engine, and e-commerce contexts representing the predominant application domains. Furthermore, equality-based hypothesis testing is commonly employed to analyze experimental outcomes, while bootstrapping methods are also discussed in several primary studies.

A/B TESTING TOOLS

There are several software tools that provide A/B testing services. Following CRO experts' recommendations, Massey (2024) listed tools for running A/B tests as well as tools supporting data collection processes. Among the presented A/B testing tools, Optimizely was described as a leading platform, offering benefits such as ease of use, retroactive filtering, intuitive data display and goal comparison, saved audiences, and strong third-party integrations. However, it has limitations in advanced targeting, slow updates for saved changes to the content delivery network (CDN), a less intuitive test setup compared to competitors, and issues with carrying query parameters or cookies within certain tests. The second tool on the list was VWO, described as particularly popular within the marketing domain and suitable for businesses with smaller budgets. Its advantages include faster updates, easier goal setup, simplified data export, responsive customer support, and an intuitive color-coded interface. Reported limitations include the inability to view all goal reports simultaneously, lack of saved targeting options, and the absence of a cumulative conversion rate graph under low-traffic conditions (Massey, 2024). The Table 2. presents selected A/B testing tools reviewed by Solomon (2026).

It should be noted that some companies develop and use internal A/B testing tools tailored to their specific needs. To the best of the authors' knowledge, based on publicly available information and online research, no widely recognized A/B testing platforms originating from Serbia were identified.

CONCLUSION

One of the primary tasks of any market-oriented company is to analyze consumer behavior. Before undertaking important activities, consumer preferences and responses should be carefully examined. In digital marketing, A/B testing represents an approach that can serve this purpose. It involves the comparison of two content versions, allowing the target audience's responses to determine which version performs better. This technique offers several advantages, including improved user engagement, increased conversion rates, and ease of analysis with relatively quick results. However, certain challenges related to its implementation should also be considered, particularly resource requirements and its suitability primarily for specific goals. To ensure accurate and reliable outcomes, A/B testing should be conducted through several structured

phases, beginning with research on current website performance. After documenting research observations and formulating hypotheses, variations are created and tested using appropriate statistical methods. The results are then analyzed, and the better-performing variation is selected for implementation. In addition to internal A/B testing solutions developed by individual companies, numerous publicly available software tools can support the design and execution of A/B tests.

Table 2: A/B testing tools (Solomon, 2026)

Tool	Best for	Trial info	Price
Zoho Pagesense	Best for conversion optimization	Free trial available	From $15/month (billed annually)
Omniconvert	Best for data-driven A/B testing	Free demo available	From $167/month (billed annually)
LaunchDarkly	Best for customizable feature flagging options	14-day free trial	From $12/service connection/month
Instapage	Best for AI-driven A/B testing	Free demo + 14-day free trial available	From $79/month (billed annually)
VWO	Best for website behavioral analytics	Free demo + 30-day free trial available	Pricing upon request
Crazy Egg	Best for Shopify ecommerce stores	30-day free trial	From $29/month (billed annually)
Optimizely	Best for targeted product rollouts	Free demo available	Pricing upon request
Leanplum	Best for A/B testing of mobile notifications	14 day free trial	From $330/month
Convertize	Best for code-free webpage edits	Free trial available	Pricing upon request
Adobe Target	Best for personalized audience experiences	Free demo available	Pricing upon request

ACKNOWLEDGEMENT

This research was funded by the Provincial Secretariat for Higher Education and Scientific Research of the Autonomous Province of Vojvodina, the Republic of Serbia, during the project “Development of a Web Content Testing Process through a Bayesian Approach”, grant number: 003797303 202509418 003 000 000 001/2.

REFERENCES

Esteller-Cucala, M., Fernandez, V., & Villuendas, D. (2020). Evaluating Personalization: The AB Testing Pitfalls Companies Might Not Be Aware of – A Spotlight on the Automotive Sector Websites. *Frontiers in artificial intelligence*, 3, 20, 1-8.

HubSpot. (n.d.). *An Introduction to A/B Testing*. Hubspot. Retrived from https://www.hubspot.com/hubfs/Introduction%20to%20A_B%20Testing.pdf

Kohavi, R., Longbotham, R., Sommerfield, D., & Henne, R.M. (2009). Controlled experiments on the web: survey and practical guide. *Data mining and knowledge discovery*, 18(1), 140-181.

Kumar, S. (2021). The role of A/B testing in advancing marketing analytics: a systematic approach. *The Journal of Scientific and Engineering Research*, 8(12), 323-330.

Massey, B. (2024). *The 20 Most Recommended AB Testing Tools By Leading CRO Experts* (2024 Update). Retrived from https://conversionsciences.com/ab-testing-tools/

Mulla, F.M. (2020). The Critical Role of A/B Testing in Digital Campaign Optimization and Performance Enhancement. *International Journal for Multidisciplinary Research*, 2(1), 1-6.

Puri, P., Mangwani, F., Svenson, D., Majija, L., Negi, N.S. & Maharjan, M. (2022). *Using A/B Testing for Campaigns on Digital Media. A useful tool to refine and improve creative materials on digital media platforms*. Mountain View: Vital Strategies.

Quin, F., Weyns, D., Galster, M., & Silva, C.C. (2024). A/B testing: A systematic literature review. *Journal of Systems and Software*, 211, 112011, 1-28.

Sharma, H. & Tripathi, K. (2023). The importance of website usability in digital marketing: a review. *International Journal of Innovative Research in Computer Science & Technology*, 11(3), 27-31.

Solomon, J. (2026). *19 Best A/B Testing Software Reviewed in 2026*. Retrived from https://cpoclub.com/tools/best-ab-testing-software/#:~:text=Table_title:%20The%20Best%20A/B%20Testing%20Software%20Comparison,For:%20Best%20for%20AI%2Ddriven%20A/B%20testing%20%7C

VWO. (n.d.). *The Complete Guide to A/B Testing*. Retrived from https://research.vwo.com/rs/007-HHD-895/images/eBook_The_Complete_Guide_AB%20Testing.pdf

DIGITAL TOOLS AS DRIVERS OF MICRO-INNOVATIONS IN SME BUSINESS MODELS IN THE CONTEXT OF ENTREPRENEURSHIP 5.0

DOI: 10.5937/EMC26191V

Dijana Vašaš Kuručev
University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia
Aneta Guteša
University of Ljubljana, Faculty od Arts, Ljubljana, Slovenia
E-mail: anetagutesa@yahoo.com

ABSTRACT

This study examines how digital tools support micro-innovations in SME business models within the context of Entrepreneurship 5.0. The research focuses on the interaction between digital technological infrastructure, organizational integration of digital tools, and business model outcomes. Digital technologies such as cloud systems, CRM platforms, data analytics tools, e-commerce platforms, and digital communication systems allow SMEs to introduce small operational and strategic adjustments. These technologies influence internal workflow organization, digital marketing activities, data-driven decision-making, and collaboration with customers and partners. A theoretical model is proposed that connects three main elements: digital technological infrastructure, organizational integration processes, and micro-innovation outcomes in SME business models. The model explains how digital tools support adjustments in value creation activities, value delivery mechanisms, revenue structures, and customer interaction practices. Incremental changes supported through digital technologies contribute to improved operational flexibility and stronger responsiveness to market conditions. The framework provides a structured basis for examining how SMEs integrate digital technologies and gradually adjust their business models within the Entrepreneurship 5.0 context.

Key words: Entrepreneurship 5.0, SMEs, Digital tools, Micro-innovation, Business models

INTRODUCTION

Small and medium-sized enterprises operate in business environments characterized by strong competition, technological change, and shifting customer expectations. Digital technologies have become increasingly present in everyday business activities, influencing how organizations communicate with customers, manage internal processes, and develop new forms of value creation. Within this context, the concept of Entrepreneurship 5.0 has emerged as an approach that combines technological development with human-centered, sustainable, and socially aware entrepreneurial practices. This perspective considers digital technologies not only as technical tools but also as instruments that support new ways of organizing business activities and interacting with stakeholders. Digital transformation in SMEs often begins with the adoption of relatively simple digital solutions such as cloud services, communication platforms, digital marketing tools, and data management systems. This combination of technological capabilities enables SMEs to explore new methods of delivering value without the need for large-scale structural changes. The development of Entrepreneurship 5.0 highlights the importance of combining digital capabilities with responsible and human-centered business practices, where technological solutions support collaboration, transparency, and long-term sustainability.

Incremental innovation represents a common strategy for SMEs due to the relatively low level of risk compared to large transformation initiatives. Micro-innovations refer to small modifications in business activities that lead to measurable improvements in efficiency, customer satisfaction, or revenue generation. Digital tools provide practical support for such changes because they allow companies to experiment with new solutions in a controlled manner. Customer relationship

management systems, digital marketing platforms, and e-commerce applications enable organizations to test new approaches to communication and service delivery. Data collected through these tools can be analyzed to identify patterns and opportunities for improvement. Continuous adjustments supported by digital technologies therefore create an environment in which business models evolve through a series of smaller innovations rather than through major structural changes.

Business models consist of several interconnected elements that define how an organization creates, delivers, and captures value. Digital tools influence each of these elements in different ways. Value creation activities may change through the use of digital production systems, collaborative platforms, and information management tools. Understanding how digital tools influence micro-innovations in SME business models represents an important step in examining the broader transformation of entrepreneurial activity under the Entrepreneurship 5.0 concept.

The paper is guided by the following research questions:

- How do digital tools support the development of micro-innovations in SME business models within the context of Entrepreneurship 5.0?
- How does the integration of digital tools into organizational processes influence value creation, value delivery, and revenue structures in SME business models?

LITERATURE ANALYSIS

Small and medium-sized enterprises operate in environments shaped by technological development and digital connectivity. Digital technologies are integrated into organizational structures, communication practices, and decision-making processes (Melo et al., 2023; Santini et al., 2023). Entrepreneurship 5.0 connects technological progress with human-centered values, sustainability, and responsible business behavior (Rajagopal, 2026). SMEs rely on flexibility and adaptability due to limited resources. Digital tools allow adjustments in processes, communication, and service delivery without large investments (Kahveci, 2025; Vrontis et al., 2022). This situation has increased interest in how digital technologies influence entrepreneurial activities and support gradual changes in business models. Digital transformation in SMEs develops through gradual adoption rather than sudden structural change (Wang & Esperança, 2023). Organizations integrate tools such as cloud platforms, communication systems, and data applications into existing workflows. These technologies improve information organization, coordination, and interaction with customers and partners (Mkhize et al., 2025). They enable data collection related to customer preferences and operational performance. Access to such information supports more informed decisions and adjustment of strategies according to market conditions (Vo Van et al., 2026).

Entrepreneurship 5.0 introduces a broader perspective in which digital tools are used for collaboration, transparency, and sustainability (Rajagopal, 2026). SMEs adjust internal responsibilities and external relationships during digital adoption. Online platforms enable direct customer interaction and strengthen connections with partners and networks (Martín-Peña et al., 2024). This connectivity supports knowledge exchange and organizational learning (Trabert et al., 2022). Digital adoption becomes linked with gradual adjustment of business practices. Micro-innovations emerge as incremental changes within this process. These changes affect communication methods, pricing, distribution channels, and internal coordination without major structural transformation (Curado et al., 2022; Yusof et al., 2023). Digital marketing platforms, online services, and customer relationship systems support experimentation and refinement of business practices (Binsaeed et al., 2023). Feedback collected through digital channels guides further adjustments. Digital tools support continuous experimentation in SME environments. Organizations test communication strategies, service formats, and product offerings through digital platforms. Customer responses can be observed in short periods. E-commerce systems and analytics tools provide insights into customer behavior and preferences (Eisape, 2022). These insights support gradual adjustments in business models and alignment with market expectations. Digital platforms also contribute to the development of interconnected business ecosystems, where SMEs interact with multiple stakeholders and co-create value (Martín-Peña et al., 2024). Internal organizational processes are also affected by digital

technologies. Project management platforms, communication tools, and shared data systems improve coordination and access to information (Santini et al., 2023). Improved coordination leads to adjustments in workflows, responsibilities, and time management. Small improvements accumulate over time and contribute to better performance (Heredia et al., 2022). Digital technologies therefore support micro-innovations within internal operations. Digital technologies influence relationships with external stakeholders. Online platforms enable direct communication with customers through social media, feedback systems, and service interfaces. Organizations collect information about customer satisfaction and expectations (Binsaeed et al., 2023). This information supports adjustments in product design, service delivery, and pricing. Continuous interaction with customers becomes a source of incremental change.

Access to digital technologies lowers barriers for experimentation. Many tools are available through subscription or cloud-based models with modest costs (Mkhize et al., 2025). SMEs can test solutions without large resource commitments. This supports ongoing learning. Employees gain experience with digital tools, while managers observe effects on performance. Organizations gradually develop capabilities related to digital practices (Atobishi et al., 2024). Business models in SMEs evolve through incremental adjustments supported by digital tools. Digital technologies influence value creation, delivery, and revenue structures (Costa Melo et al., 2023). Internal processes improve through better coordination and data access. Online channels extend market reach and change distribution practices (Haini, 2026). Digital payment systems and service platforms enable new revenue approaches. Continuous adjustments supported by data allow SMEs to remain aligned with market conditions and customer expectations (Yuwono et al., 2025).

Based on the analyzed model, a model for driving micro-innovations in SME business models in the context of Entrepreneurship 5.0.

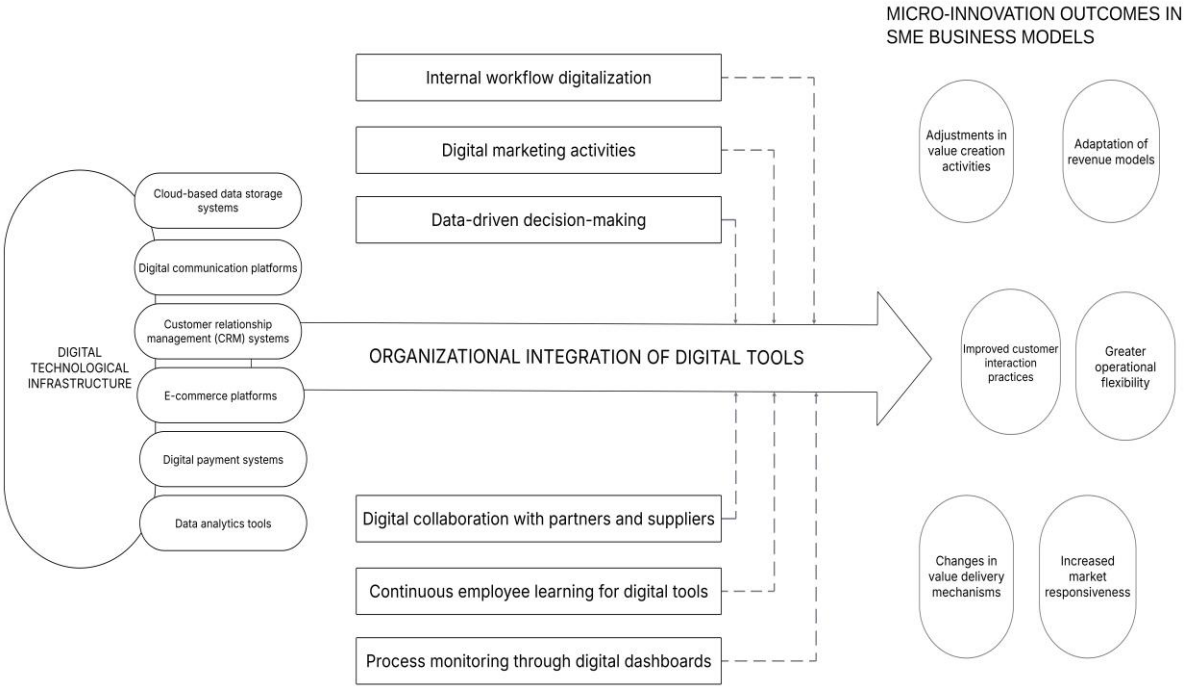


Figure 1: Model for driving micro-innovations in SME business models in the context of Entrepreneurship 5.0.

Digital technological infrastructure provides the technological environment through which SMEs introduce incremental changes in their business models. Cloud-based data storage systems allow centralized access to operational and customer information, which supports internal workflow digitalization and coordination among employees. Digital communication platforms influence internal collaboration and interaction with customers and partners. These platforms support digital marketing

activities and generate feedback that informs data-driven decision-making. Customer relationship management systems collect and organize customer data, which helps companies adjust marketing strategies and improve customer interaction practices. Data analytics tools process information from sales, marketing campaigns, and customer behavior, allowing managers to interpret market patterns and modify operational decisions. E-commerce platforms influence value delivery mechanisms because products and services can be distributed through online channels. Digital payment systems support electronic transactions and provide data about purchasing patterns, which may lead to adjustments in revenue models. Organizational integration processes translate these technological resources into everyday business practices. Internal workflow digitalization organizes operational activities, while digital marketing activities support communication with targeted customer segments. Digital collaboration with partners improves coordination across supply networks, and continuous employee learning improves the effective use of digital tools. Process monitoring through digital dashboards provides information about performance indicators, which supports incremental adjustments. These interactions contribute to micro-innovation outcomes such as adjustments in value creation activities, modified revenue structures, improved customer interaction practices, greater operational flexibility, and increased market responsiveness.

SUGGESTION AND GUIDELINES

Based on the developed model and analyzed literature, the following strategies and actions for for driving micro-innovations in SME business models in the context of Entrepreneurship 5.0. are noted:

- Enterprises can implement cloud-based data storage systems in everyday operations. Centralized data access improves coordination and information sharing.
- Enterprises can introduce customer relationship management systems. These systems organize customer data and support adjustments in marketing and service activities.
- Enterprises can adopt digital marketing tools such as social media platforms and online advertising systems. These tools allow companies to test communication strategies and observe customer reactions.
- Enterprises can introduce e-commerce platforms for digital sales. Online channels expand market reach and generate data about customer demand.
- Enterprises can apply data-driven decision-making practices. Managers can review digital performance indicators before adjusting strategies.
- Enterprises can organize training for employees related to digital tools. Continuous learning improves the effective use of digital technologies.
- Enterprises can monitor performance through digital dashboards. Operational indicators support identification of opportunities for small adjustments.

CONCLUSION

The study examined how digital tools support micro-innovations in SME business models within the context of Entrepreneurship 5.0. The analysis focused on the relationship between digital technological infrastructure, organizational integration of digital tools, and the outcomes that appear through incremental business adjustments. Digital systems such as cloud platforms, customer relationship management systems, analytics tools, e-commerce platforms, and digital communication technologies provide SMEs with accessible resources that allow gradual changes in operational and market activities. These technologies allow organizations to introduce small modifications in internal processes, communication practices, and service delivery methods without major structural transformation.

The first research question addressed how digital tools support the development of micro-innovations in SME business models. The findings indicate that digital technologies provide the technological environment that allows companies to test new operational practices, adjust marketing communication, and reorganize internal workflows. Cloud systems improve access to information, while CRM platforms organize customer data that supports adjustments in service and marketing

activities. Digital analytics tools allow managers to interpret operational indicators and customer feedback, which leads to incremental improvements in organizational decisions and business practices.

The second research question examined how the integration of digital tools into organizational processes influences value creation, value delivery, and revenue structures in SME business models. The analysis shows that digital tools influence several components of the business model through their integration into everyday business activities. Internal workflow digitalization reorganizes value creation activities through improved coordination and information exchange. Digital marketing platforms and communication channels influence value delivery through new forms of customer interaction and online service distribution. E-commerce platforms and digital payment systems allow modifications in revenue structures through digital transactions and alternative pricing formats.

The proposed framework provides a structured understanding of how digital technological infrastructure and organizational integration processes interact to produce micro-innovations in SME business models. The framework can support further research that examines the relationship between digital tool adoption, incremental innovation, and SME competitiveness within the broader Entrepreneurship 5.0 context.

REFERENCES

Atobishi, T., Moh'd Abu Bakir, S., & Nosratabadi, S. (2024). How do digital capabilities affect organizational performance in the public sector? The mediating role of organizational agility. *Administrative Sciences, 14*(2), Article 37. https://doi.org/10.3390/admsci14020037

Binsaeed, R. H., Yousaf, Z., Grigorescu, A., Chitescu, R. I., Nassani, A. A., & Samoila, A. (2023). Customer engagement and customer relationship management capabilities' effects on innovation performance and customer distrust's moderating role. *Sustainability, 15*(12), Article 9475. https://doi.org/10.3390/su15129475

Costa Melo, I., Alves Junior, P. N., Queiroz, G. A., Yushimito, W., & Pereira, J. (2023). Do we consider sustainability when we measure small and medium enterprises' (SMEs') performance passing through digital transformation? *Sustainability, 15*(6), Article 4917. https://doi.org/10.3390/su15064917

Curado, C., Gonçalves, T., & Brito, J. C. (2022). Understanding the HRM systems double contribution to radical and incremental innovation in SMEs: A configurational approach. *Journal of Economics and Management, 44*, 315–343.

Eisape, D. A. (2022). Transforming pipelines into digital platforms: An illustrative case study transforming a traditional pipeline business model in the standardization industry into a digital platform. *Journal of Open Innovation: Technology, Market, and Complexity, 8*(4), Article 183. https://doi.org/10.3390/joitmc8040183

Haini, H. (2026). ICT, innovation and SME export likelihood: Evidence from SMEs in the ASEAN economies. *The Singapore Economic Review, 71*(1), 107–126. https://doi.org/10.1142/S0217590821500478

Heredia, J., Castillo-Vergara, M., Geldes, C., Gamarra, F. M. C., Flores, A., & Heredia, W. (2022). How do digital capabilities affect firm performance? The mediating role of technological capabilities in the new normal. *Journal of Innovation & Knowledge, 7*(2), Article 100171. https://doi.org/10.1016/j.jik.2022.100171

Kahveci, E. (2025). Digital transformation in SMEs: Enablers, interconnections, and a framework for sustainable competitive advantage. *Administrative Sciences, 15*(3), Article 107. https://doi.org/10.3390/admsci15030107

Martín-Peña, M. L., Lorenzo, P. C., & Meyer, N. (2024). Digital platforms and business ecosystems: A multidisciplinary approach for new and sustainable business models. *Review of Managerial Science, 18*, 2465–2482. https://doi.org/10.1007/s11846-024-00772-y

Melo, I. C., Queiroz, G. A., Alves Junior, P. N., de Sousa, T. B., Yushimito, W. F., & Pereira, J. (2023). Sustainable digital transformation in small and medium enterprises (SMEs): A review on performance. *Heliyon, 9*(3), Article e13908. https://doi.org/10.1016/j.heliyon.2023.e13908

Mkhize, A., Mokhothu, K. D., Tshikhotho, M., & Thango, B. A. (2025). Evaluating the impact of cloud computing on SME performance: A systematic review. *Businesses, 5*(2), Article 23. https://doi.org/10.3390/businesses5020023

Rajagopal. (2026). Entrepreneurship 5.0: Synchronizing technology and human factor. In *Next Generation Entrepreneurship: Convergence of Innovation, Technology, and Society* (pp. 535–557). Springer Nature Switzerland.

Santini, F. D. O., Matos, C. A. D., Ladeira, W. J., Jardim, W. C., & Perin, M. G. (2023). Information technology adoption by small and medium enterprises: A meta-analysis. *Journal of Small Business & Entrepreneurship, 35*(4), 632–655. https://doi.org/10.1080/08276331.2022.2145787

Trabert, T., Beiner, S., Lehmann, C., & Kinkel, S. (2022). Digital value creation in sociotechnical systems: Identification of challenges and recommendations for human work in manufacturing SMEs. *Procedia Computer Science, 200*, 471–481. https://doi.org/10.1016/j.procs.2022.01.245

Vo Van, H., Abu Afifa, M., & Saleh, I. (2026). Accounting information systems and organizational performance in the cloud computing era: Evidence from SMEs. *Sustainability Accounting, Management and Policy Journal, 17*(1), 267–299. https://doi.org/10.1108/SAMPJ-01-2024-0044

Vrontis, D., Chaudhuri, R., & Chatterjee, S. (2022). Adoption of digital technologies by SMEs for sustainability and value creation: Moderating role of entrepreneurial orientation. *Sustainability, 14*(13), Article 7949. https://doi.org/10.3390/su14137949

Wang, S., & Esperança, J. P. (2023). Can digital transformation improve market and ESG performance? Evidence from Chinese SMEs. *Journal of Cleaner Production, 419*, Article 137980. https://doi.org/10.1016/j.jclepro.2023.137980

Yusof, N. A., Kamal, E. M., Lou, E. C., & Kamaruddeen, A. M. (2023). Effects of innovation capability on radical and incremental innovations and business performance relationships. *Journal of Engineering and Technology Management, 67*, Article 101726. https://doi.org/10.1016/j.jengtecman.2022.101726

Yuwono, T., Novandari, W., Suroso, A., & Setyanto, R. P. (2025). The importance of ICT adoption on MSMEs performance: The mediating role of distinctive competencies. *Journal of Enterprising Communities: People and Places in the Global Economy, 19*(3), 610–630. https://doi.org/10.1108/JEC-06-2024-0113

OPTIMIZATION OF MARKETING MANAGEMENT IN INDUSTRIAL (B2B) COMPANIES: A LITERATURE REVIEW AND MODEL PROPOSAL

DOI: 10.5937/EMC26197L

Peko Lakatuš
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Mihalj Bakator
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: mihalj.bakator@tfzr.rs
Miloš Vorkapić
University of Belgrade, Institute of Chemistry, Technology and Metallurgy, Belgrade, Republic of Serbia

ABSTRACT

Marketing management in industrial B2B companies faces growing complexity due to digital transformation, long-term customer relationships, and sustainability demands. This paper identifies key factors affecting marketing management effectiveness through a structured review of literature published between 2015 and 2021. Findings show that existing studies focus on individual aspects—such as CRM, digitalization, value creation, or sustainability—without providing an integrated framework. To address this gap, a conceptual optimization model is proposed, combining strategic marketing alignment, digital tools and CRM, value proposition development, sustainability principles, and performance monitoring. The model offers both theoretical and practical contributions, providing a foundation for future empirical validation and managerial application in industrial B2B contexts.

Keywords: Marketing management, B2B marketing, Digitalization, CRM, Value proposition, Sustainability.

INTRODUCTION

Marketing management in B2B industrial enterprises has evolved into a strategic function that goes beyond traditional support for sales. Contemporary challenges include complex customer decision-making, long-term business relationships, and the need to integrate marketing with production, logistics, and service functions. In this context, digitalization, CRM systems, and sustainability are recognized as key factors for achieving competitive advantage (Homburg et al., 2015; Webster et al., 2015; Morgan et al., 2019). The aim of this paper is to identify, through an analysis of relevant scientific literature, the key factors shaping marketing management effectiveness in B2B industrial enterprises, and to propose an optimization model that integrates digitalization, CRM systems, value proposition, and sustainability. The study is based on a systematic review of literature published between 2015 and 2021.

The research question addressed in this study is: How does the integration of digitalization, CRM systems, value proposition, and sustainability affect marketing management effectiveness in B2B industrial enterprises, and how can these factors be systematically combined through an optimization model? The original contribution of this paper lies in the proposal of an integrated marketing management model, developed based on identified gaps in existing research.

METHODOLOGY

This study employs a qualitative literature analysis of relevant scientific publications from 2015 to 2021. The analysis follows approaches that emphasize the specific characteristics of B2B marketing and the need for systematic examination (Lilien, 2016; Brennan et al., 2018).
Literature selection was based on thematic relevance to B2B industrial marketing management, a clearly defined theoretical or empirical contribution, and availability in reputable scientific journals and databases. The research methodology comprised three main phases:

1. Identification and selection of publications – systematic searches in scientific databases and relevant journals.
2. Literature analysis and comparison – identification of key trends, challenges, and research gaps in existing studies.
3. Synthesis of findings and model development – formulation of a conceptual framework integrating digitalization, CRM systems, value proposition, and sustainability. The selected time frame covers a period of intensive development of digital tools and CRM systems in B2B contexts, providing insight into contemporary trends and the need for integrated marketing management approaches (Ritter & Pedersen, 2024).

LITERATURE REVIEW

Table 1. presents a thematic overview of key scientific contributions in the field of marketing management in B2B industrial enterprises published between 2015 and 2021. The literature is grouped into four dominant dimensions: digitalization, CRM systems and customer relationships, value proposition, and sustainability/marketing strategy. This thematic approach allows the inclusion of all relevant studies while maintaining a compact conference-friendly format and enables a clear identification of research gaps related to the absence of integrated marketing management models.

Table 1: Review of the literature on marketing management in B2B enterprises (2015–2021)

Dimension	Included authors (2015–2021)	Main focus	Identified research gap
Digitalization	Järvinen & Taiminen (2016); Leeflang et al. (2019); Ritter & Pedersen (2020); Homburg et al. (2017)	Marketing automation, digital tools, customer experience management, and digital capabilities in B2B markets.	Digitalization is mainly analyzed independently, with limited integration with CRM systems, value proposition, and sustainability in a unified model.
CRM systems and customer relationships	Sheth (2017); Kumar & Reinartz (2018); Bakator et al. (2020); Bakator et al. (2021); Homburg et al. (2015); Webster et al. (2015)	Strategic role of marketing, customer relationship management, and long-term B2B relationships.	Lack of holistic and operational frameworks linking CRM systems with digital tools, value creation, and sustainability.
Value proposition and value creation	Kindström et al. (2019); Keränen & Jalkala (2019); Eggert et al. (2020); Lilien (2016)	Value-in-use, service-oriented business models, and B2B-specific value creation processes.	Insufficient empirical models connecting value creation with CRM systems and digitalization.
Sustainability and marketing strategy	Lindgreen et al. (2019); Morgan et al. (2019); Cortez & Johnston (2017); Brennan et al. (2018)	Strategic marketing, sustainability, and future directions of B2B marketing theory.	Sustainability and strategy are rarely integrated with operational marketing management tools in B2B industrial enterprises.

Although prior research has significantly advanced the understanding of individual dimensions of marketing management in B2B industrial enterprises, the reviewed studies predominantly address these dimensions in isolation. Digitalization, CRM systems, value proposition development, and sustainability are most often examined as separate research streams (Homburg et al., 2015; Lilien, 2016; Kumar & Reinartz, 2018; Lindgreen et al., 2019).

The absence of an integrated and practically applicable marketing management model that systematically combines these dimensions represents a key research gap. This gap serves as the foundation for the development of the proposed integrated marketing management optimization model, presented in the following section of the paper.

B2B MARKETING MANAGEMENT IN INDUSTRIAL COMPANIES

Marketing management in B2B industrial enterprises has specific characteristics distinguishing it from the B2C sector, mainly due to complex decision-making processes, long-term customer relationships, and a limited number of strategically important clients. In this context, marketing assumes a strategic role, encompassing market and customer needs analysis, management of product and service portfolios, development of communication strategies, and coordination with production, logistics, and after-sales service. Lack of such functional integration often leads to misaligned activities, weaker value propositions, and reduced effectiveness. Digitalization and automation enable more accurate monitoring of customer behavior, improved segmentation, and personalized offerings, while sustainability principles contribute to trust, corporate reputation, and long-term competitive advantage (Homburg et al., 2015; Webster et al., 2015; Morgan et al., 2019).

Literature Analysis

Analysis of relevant literature highlights three dominant trends. First, strategic integration of marketing with production, logistics, and after-sales service ensures synergy between market demands and operational efficiency. Fragmented marketing reduces responsiveness to customer needs, while customer experience management reinforces the need for integration with digital tools and CRM systems (Homburg et al., 2017). Second, digitalization of marketing and adoption of CRM systems improve monitoring, segmentation, and personalization, but few integrated solutions link CRM with value proposition and overall strategy (Järvinen & Taiminen, 2016; Leeflang et al., 2019; Ritter & Pedersen, 2020; Bakator et al., 2021). Third, value proposition and sustainability are recognized as key competitive factors, yet empirically grounded models connecting these dimensions with marketing performance are scarce (Kindström et al., 2019; Eggert et al., 2020; Lindgreen et al., 2019; Keränen & Jalkala, 2019). The key research gap is the absence of an integrated, empirically tested model combining strategic integration, digitalization and CRM, value proposition, sustainability, and performance monitoring.

Proposed Marketing Management Optimization Model

Based on the identified trends, this study proposes an integrated marketing management model with four interconnected components. The first component ensures strategic integration of marketing with production, logistics, and after-sales service. The second component focuses on digitalization and CRM systems for performance monitoring, customer relationship management, segmentation, and personalization. The third component addresses value proposition development and sustainability through innovative, high-quality, and responsible practices. The fourth component involves continuous monitoring and adaptation of marketing strategies to market changes and customer needs. The model is illustrated in Figure 1, emphasizing the interconnected and integrated nature of these components.

Opportunities for Empirical Testing of the Proposed Model

The model provides a foundation for future empirical research in B2B industrial enterprises. Strategic integration can be operationalized through collaboration between marketing, production, logistics, and after-sales service and marketing involvement in strategic decisions (Homburg et al., 2015; Webster et al., 2015). Digitalization and CRM adoption can be measured through marketing automation, CRM use in managing relationships, and application of data analytics (Bakator et al., 2020; Järvinen & Taiminen, 2016; Kumar & Reinartz, 2018; Bakator et al., 2021). Value proposition and sustainability can be examined via industrial customers' perception of value, innovativeness, and sustainable practices (Kindström et al., 2019; Eggert et al., 2020; Lindgreen et al., 2019). Quantitative methods such as surveys and SEM, or qualitative case studies, could empirically validate the model and assess its impact on marketing performance and overall business outcomes (Sheth, 2017; Ritter & Pedersen, 2020; Cortez & Johnston, 2017; Brennan et al., 2018; Morgan et al., 2019).



Figure 1: Proposed B2B Marketing Management Optimization Model

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

This study has certain limitations that should be considered when interpreting its results. The research is based on a qualitative analysis and systematization of existing literature, without conducting empirical studies in specific industrial enterprises. While this approach allows for the identification of key trends and research gaps, it does not provide direct empirical validation of the proposed model. The literature review is limited to the period from 2015 to 2021 and to articles published in selected international journals, which may affect the scope of theoretical and practical approaches analyzed. Furthermore, the study focuses primarily on B2B industrial enterprises, so the results and conclusions cannot be directly generalized to other sectors, such as B2C or service industries.

Future research could focus on empirical validation of the proposed model through quantitative studies across different industrial sectors, as well as comparative analyses of enterprises of varying sizes and levels of digital maturity. In particular, examining the impact of individual model components on key performance indicators, such as productivity, market competitiveness, and long-term business sustainability, would be valuable. Additionally, a longitudinal approach is recommended to monitor the effects of model implementation over time, along with the integration of additional variables such as organizational culture, innovation capacity, and knowledge management. This would allow the proposed model to be further refined and adapted to the complex requirements of modern B2B industrial environments.

CONCLUSION

The analysis of relevant literature shows that marketing management in B2B industrial enterprises is a multidimensional and highly strategic function, whose effectiveness depends on the coordinated integration of multiple interconnected factors. The digitalization of marketing processes, the implementation of CRM systems, systematic development of the value proposition, and the inclusion of sustainability principles have been identified as key sources of long-term competitive advantage in modern industrial environments. The conducted literature review enabled the identification of a clear research gap, reflected in the lack of integrated and empirically grounded marketing management models tailored to the specificities of B2B industrial enterprises. In response to this gap, the study proposes an integrated marketing management optimization model that combines strategic integration

of the marketing function, digitalization and CRM systems, value proposition, sustainability, and continuous performance monitoring into a single, logically connected framework.

The contribution of this study lies primarily in the development of a conceptual model with potential for practical application in industrial enterprises, as well as for empirical validation in future research. The proposed model provides a foundation for future empirical studies and practical implementation in B2B industrial enterprises.

REFERENCES

Bakator, M., Đorđević, D., Ćoćkalo, D., & Bogetić, S. (2020). The impact of consumer–company relationships on brand loyalty. *Management: Journal of Sustainable Business and Management Solutions in Emerging Economies*, 25(1), 1–12.

Bakator, M., Đorđević, D., Ćoćkalo, D., Ćeha, M., & Bogetić, S. (2021). CRM and customer data: Challenges of conducting business in digital economy. *Journal of Engineering Management and Competitiveness (JEMC)*, *11*(2), 85-95.

Brennan, R., Canning, L., & McDowell, R. (2018). Business-to-business marketing: Origins, development and future directions. *Industrial Marketing Management*, 69, 1–11.

Cortez, R. M., & Johnston, W. J. (2017). The future of B2B marketing theory: A historical and prospective analysis. *Industrial Marketing Management*, 66, 1–10.

Eggert, A., Ulaga, W., Frow, P., & Payne, A. (2020). Conceptualizing and communicating value in business markets: From value in exchange to value in use. *Industrial Marketing Management*, 87, 80–90.

Homburg, C., Jozić, D., & Kuehnl, C. (2017). Customer experience management in business-to-business markets: Conceptual foundations and research agenda. *Journal of the Academy of Marketing Science*, 45(3), 377–401.

Homburg, C., Vomberg, A., Enke, M., & Grimm, P. (2015). The loss of the marketing department's influence: Is it really happening? And why worry? *Journal of the Academy of Marketing Science*, 43(1), 1–13.

Järvinen, J., & Taiminen, H. (2016). Harnessing marketing automation for B2B content marketing. *Industrial Marketing Management*, 54, 164–175.

Keränen, J., & Jalkala, A. (2019). Customer value assessment in business markets: Methods and implications. *Industrial Marketing Management*, 79, 130–140.

Kindström, D., Kowalkowski, C., & Sandberg, E. (2019). Service-driven business models in the industrial context. *Industrial Marketing Management*, 82, 96–107.

Kumar, V., & Reinartz, W. (2018). Customer relationship management in B2B markets. *Journal of Marketing*, 82(2), 80–97.

Leeflang, P. S. H., Verhoef, P. C., Dahlström, P., & Freundt, T. (2019). Challenges and solutions for marketing in a digital era. *European Management Journal*, 37(1), 1–12.

Lilien, G. L. (2016). The B2B knowledge gap. *International Journal of Research in Marketing*, 33(3), 543–556.

Lindgreen, A., Maon, F., Vanhamme, J., & Sen, S. (2019). Business sustainability in business-to-business markets: Concepts, challenges, and opportunities. *Industrial Marketing Management*, 82, 11–22.

Morgan, N. A., Whitler, K. A., Feng, H., & Chari, S. (2019). Research in marketing strategy. *Journal of the Academy of Marketing Science*, 47(1), 4–29.

Ritter, T., & Pedersen, C. L. (2020). Digitization capability and the digitalization of business models in business-to-business firms: Past, present, and future. *Industrial Marketing Management*, 86, 180–190.

Ritter, T., & Pedersen, C. L. (2024). Is segmentation a theory? Improving the theoretical basis of a foundational concept in business-to-business marketing. *Industrial Marketing Management*, 116, 82–92.

Sheth, J. N. (2017). Revitalizing relationship marketing. *Industrial Marketing Management*, 64, 1–4.

Webster, F. E., Malter, A. J., & Ganesan, S. (2015). The decline and dispersion of marketing competence. *Industrial Marketing Management*, 50, 11–18.

INTEGRATED MARKETING MANAGEMENT MODEL FOR IMPROVING BUSINESS AND MARKET PERFORMANCE OF CONTEMPORARY ENTERPRISES

DOI: 10.5937/EMC26202L

Peko Lakatuš
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Uroš Šarenac
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: uros.sarenac@tfzr.rs

ABSTRACT

Marketing management in contemporary enterprises requires the integration of multiple functions in order to achieve sustainable competitive advantage in a digitally transformed business environment. This paper proposes an integrated marketing management model that combines brand management, content marketing, an omnichannel approach, customer orientation, and a flexible marketing strategy, linking these dimensions with key performance indicators (KPIs). The proposed framework emphasizes the role of digital tools and analytics in optimizing marketing activities and supporting data-driven decision-making. By systematically connecting strategic and operational marketing dimensions with measurable business and market outcomes, the model provides both a theoretically grounded and practically applicable guide for managers. The study contributes to a deeper understanding of integrated marketing management and establishes a foundation for future empirical research, particularly in industrial and B2B contexts.

Key words: Marketing management, Integrated marketing model, Brand management, Content marketing, Omnichannel strategy, Customer orientation, Business and market performance.

INTRODUCTION

Contemporary enterprises operate in an environment characterized by rapid technological change, intensified competition, and increasing customer expectations. Digital transformation has fundamentally reshaped the role of marketing, shifting it from a primarily promotional function toward a strategic, data-driven managerial discipline that directly influences business and market performance. As a result, marketing management has become a significant factor in achieving and sustaining competitive advantage.

Recent research emphasizes the importance of several key marketing dimensions, including brand management, content marketing, omnichannel strategies, customer orientation, and strategic flexibility. These elements enable enterprises to create consistent customer experiences, strengthen market positioning, and respond effectively to dynamic market conditions. However, existing studies often examine these dimensions in isolation, which limits their ability to explain how integrated marketing efforts contribute to measurable performance outcomes.

A significant challenge for contemporary enterprises lies in the lack of comprehensive frameworks that systematically connect strategic and operational marketing activities with key performance indicators (KPIs). Although digital tools and analytics provide unprecedented opportunities for data-driven decision-making, many organizations struggle to integrate these capabilities into a coherent marketing management system.

In response to these challenges, this paper aims to develop an integrated marketing management model that links core marketing dimensions with business and market performance indicators. By synthesizing insights from recent literature and emphasizing the role of digital technologies and analytics, the proposed model offers a structured approach to improving marketing effectiveness and competitiveness. The study contributes to the growing body of research on integrated marketing management and provides a conceptual foundation for future empirical investigations, particularly in industrial and B2B contexts.

LITERATURE REVIEW AND IDENTIFICATION OF THE RESEARCH GAP

Contemporary academic and professional literature in the field of marketing management increasingly emphasizes the need for a systematically integrated approach to managing marketing activities under conditions of digital transformation and growing competitive pressure. Studies published between 2020 and 2025 focus on several interrelated marketing dimensions that have a significant impact on business and market performance. In particular, brand management, content marketing, omnichannel approach, customer orientation, and flexible marketing strategy are identified as key determinants of enterprise competitiveness.

In order to systematize existing knowledge and identify dominant research directions, a thematic analysis of relevant sources was conducted. An overview of key studies, their main contributions, and identified limitations is presented in Table 1, followed by a more detailed interpretation across individual thematic areas.

Table 1: Literature Review by Thematic Areas, Key Contributions, and Identified Research Gaps

Thematic Area	Authors (Year)	Key Contribution	Identified Research Gap
Brand Management	Kumar, Ramachandran, & Kumar (2020); Trainor, Andzulis, Rapp, & Agnihotri (2020); Kabadayi & Gupta (2022)	Brand as a key differentiator; influences value perception, trust, and customer loyalty; strategic role in digital environments and B2B sectors.	Most studies examine brand in isolation; lack of models linking brand strategy with omnichannel approach, content marketing, and measurable indicators.
Content Marketing	Harmeling, Moffett, Arnold, & Carlson (2020); Herhausen, Miočević, Morgan, & Kleijnen (2020)	Promotes customer engagement, brand visibility, and digital interaction; educational and value-oriented content strengthens trust.	Focus on tactical aspects; insufficiently integrated into the strategic framework and measurable business outcomes.
Omnichannel Approach	Cai & Choi (2023); Gao & Su (2020); Thaichon, Quach, Barari, & Nguyen (2024); Rahman, Carlson, Gudergan, Wetzels, & Grewal (2025)	Channel synchronization improves customer satisfaction, retention, and sales outcomes; ensures a consistent customer experience.	Existing studies focus on operational aspects; lack of integration with brand management, content marketing, and flexible strategy.
Customer Orientation	De Keyser, Verleye, Lemon, Keiningham, & Klaus (2020); Lemon & Verhoef (2020)	Collection and use of customer data improves satisfaction and loyalty; personalization and analytics are central to decision-making.	Lack of models integrating customer orientation with other marketing dimensions and measurable KPI indicators.
Flexible Marketing Strategy	Kohtamäki, Parida, Oghazi, Gebauer, & Baines (2020); Trainor, Andzulis, Rapp, & Agnihotri (2020)	Enables adaptation to market changes and resource optimization; agile approaches for more efficient marketing activities.	Lack of empirically validated integrated models linking flexible strategy with brand management, content marketing, and the omnichannel approach.

Literature in the field of marketing management emphasizes the need for an integrated approach to managing marketing activities in the context of digital transformation and increasing competition (Kumar, Ramachandran, & Kumar, 2020; Trainor, Andzulis, Rapp, & Agnihotri, 2020). Research conducted between 2020 and 2025 indicates that the key marketing dimensions that significantly influence business and market outcomes include brand management, content marketing, an omnichannel approach, customer orientation, and a flexible marketing strategy (Cai & Choi, 2023; Gao & Su, 2020; Harmeling, Moffett, Arnold, & Carlson, 2020; Kabadayi & Gupta, 2022; Lemon & Verhoef, 2020; Jia, 2025; Gupta et al., 2025; Abboud et al., 2025).

The literature review presented in Table 1 systematizes the contributions of individual studies and identifies existing gaps. Although these elements are well-researched, most studies examine them in a fragmented manner. For example, brand management studies emphasize its impact on differentiation and customer loyalty but do not link brand strategy with omnichannel and content marketing activities (Kumar, Ramachandran, & Kumar, 2020; Kabadayi & Gupta, 2022). Content marketing is often analyzed from a tactical perspective focusing on customer engagement and digital visibility, while its integration into a broader strategic framework remains underexplored (Harmeling, Moffett, Arnold, & Carlson, 2020; Herhausen, Miočević, Morgan, & Kleijnen, 2020).

The omnichannel approach highlights the importance of channel synchronization for a consistent customer experience and increased sales; however, connections with brand management, content marketing, and flexible strategy are often missing (Cai & Choi, 2023; Gao & Su, 2020; Thaichon, Quach, Barari, & Nguyen, 2024; Rahman, Carlson, Gudergan, Wetzels, & Grewal, 2025). Customer orientation and data collection enable personalization and loyalty improvement but are frequently not integrated with other marketing elements and measurable performance outcomes (De Keyser, Verleye, Lemon, Keiningham, & Klaus, 2020; Lemon & Verhoef, 2020). Finally, a flexible strategy allows agile adaptation to market changes, yet empirically validated models linking it with other factors are lacking (Kohtamäki, Parida, Oghazi, Gebauer, & Baines, 2020; Trainor, Andzulis, Rapp, & Agnihotri, 2020).

These identified limitations point to a research gap in integrated marketing management and provide a foundation for the proposed systematically unified approach, which links key dimensions with measurable business and market performance outcomes.

METHODOLOGICAL RESEARCH APPROACH

The research in this paper is based on a qualitative approach, aiming to develop a conceptual marketing management model for improving business and market performance (Kumar, Ramachandran, & Kumar, 2020; Trainor, Andzulis, Rapp, & Agnihotri, 2020). The methodological framework includes a systematic review and significant analysis of literature from 2020 to 2025, focusing on relevant studies in marketing, digital business, and management (Kohtamäki, Parida, Oghazi, Gebauer, & Baines, 2020).

The research procedure was carried out through three interrelated phases:

1. Identification of key marketing management factors and accompanying variables with direct or indirect impact on marketing and business outcomes.
2. Comparative and significant analysis of the interdependencies among these factors, including linking marketing activities with performance indicators and identifying limitations of existing solutions.
3. Conceptual synthesis of the findings, based on which a proposed integrated approach was developed that connects key elements with KPI indicators and the role of digital tools and analytics.

This approach enables a theoretically grounded and systematic formulation of solutions, providing a foundation for future empirical research and practical application in modern business systems.

PROPOSED INTEGRATED CONCEPTUAL MODEL OF MARKETING MANAGEMENT

Based on the literature review and the identified research gap, a proposed integrated conceptual model of marketing management is suggested for improving business and market performance, linking key marketing elements with measurable performance indicators (Cai & Choi, 2023; Kabadayi & Gupta, 2022; Kohtamäki, Parida, Oghazi, Gebauer, & Baines, 2020).

The proposed approach integrates five dimensions: brand management, content marketing, an omnichannel approach, customer orientation, and a flexible marketing strategy, which function as interrelated components through data exchange and feedback.

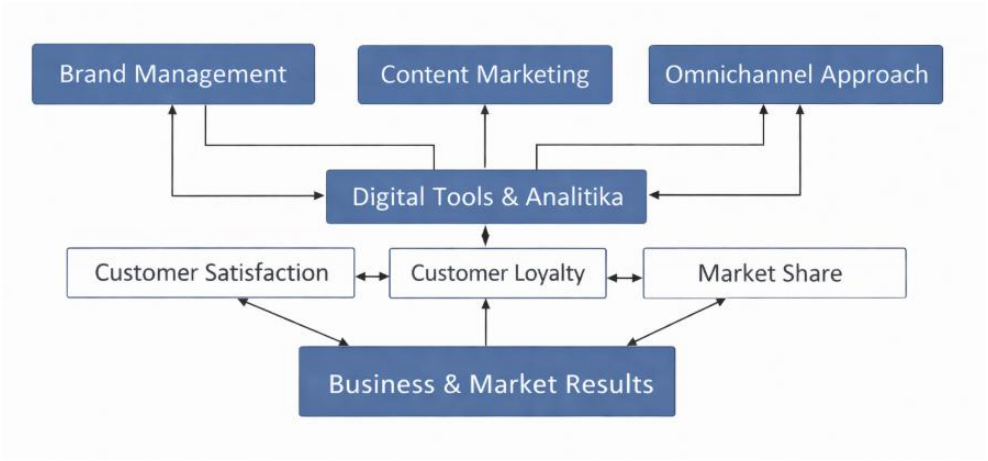


Figure 1: Integrated Conceptual Model of Marketing Management

Brand management and content marketing form the communication foundation of the model, contributing to trust building and brand recognition (Herhausen, Miočević, Morgan, & Kleijnen, 2020; Trainor, Andzulis, Rapp, & Agnihotri, 2020).

The omnichannel approach enables a consistent customer experience across multiple channels and increases the efficiency of marketing activities (Gao & Su, 2020; Cai & Choi, 2023).
Customer orientation coordinates marketing activities based on data regarding customer needs and behavior (De Keyser, Verleye, Lemon, Keiningham, & Klaus, 2020; Harmeling, Moffett, Arnold, & Carlson, 2020).

A flexible strategy allows for rapid adaptation to market changes and optimization of activities (Rahman, Carlson, Gudergan, Wetzels, & Grewal, 2025; Thaichon, Quach, Barari, & Nguyen, 2024).
Digital tools and analytics function as an integration mechanism for monitoring KPI indicators and optimizing marketing decisions (Kumar, Ramachandran, & Kumar, 2020; Lemon & Verhoef, 2020).
The model represents an interconnected system of dimensions that collectively influence marketing and business performance, providing a theoretically grounded and practically applicable framework for improving marketing management.

DISCUSSION

The results of the literature analysis and conceptual synthesis indicate that contemporary marketing management requires an integrated and systematic approach to key dimensions: brand management, content marketing, an omnichannel approach, customer orientation, and a flexible strategy. Previous research most often examines these dimensions in isolation, while their combined impact on firm market performance remains underdeveloped (Cai & Choi, 2023; Kabadayi & Gupta, 2022; Kohtamäki et al., 2020; Jia, 2025; Gupta et al., 2025; Abboud et al., 2025).

The proposed approach addresses the identified research gap by linking strategic and operational marketing elements with measurable indicators (De Keyser et al., 2020; Trainor et al., 2020). Digital tools and analytics function as an integration mechanism, enabling continuous monitoring and optimization of marketing decisions. This concept extends existing approaches to marketing management through multidimensional integration and a clear connection between marketing functions and business performance.

A limitation of this study is that the model is conceptual in nature and based on literature analysis, without empirical validation. Future research should include quantitative testing and the operationalization of the integrated framework in real business systems.

Suggestions and Guidelines for Improving Competitiveness of Enterprises

Based on the proposed integrated marketing management model, several key suggestions can be formulated to improve the competitiveness of contemporary enterprises. These guidelines emphasize the strategic integration of core marketing dimensions and the use of digital tools and performance indicators.

Enterprises should approach brand management as a strategic resource that ensures consistent positioning and differentiation across all marketing channels. Aligning brand identity with content marketing and omnichannel activities strengthens customer trust and market visibility.

Content marketing should be strategically planned and focused on delivering value to customers rather than short-term promotional effects. Integrating content activities with broader marketing objectives and monitoring their performance through analytics enables continuous improvement and stronger customer engagement.

An effective omnichannel approach requires coordination of all communication and distribution channels to provide a consistent customer experience. Enterprises should invest in technologies that enable data integration and support real-time monitoring of customer interactions across channels.

Customer orientation should be strengthened through systematic use of data and analytics to understand customer needs and behaviors. These insights should inform personalization, segmentation, and strategic decision-making, while customer-related metrics should be linked to overall marketing performance indicators.

Finally, enterprises should adopt flexible and adaptive marketing strategies that allow timely responses to market changes. Continuous performance measurement using KPIs supports strategic alignment and improves long-term competitiveness.

CONCLUSION

Contemporary business conditions, characterized by digital transformation, competition, and changing customer behavior, require an integrated and adaptive approach to marketing management. Traditional partial approaches are no longer sufficient for achieving sustainable business and market performance.

Based on the literature review, key dimensions of marketing management have been identified as dominant factors influencing business outcomes. The lack of a comprehensive integrated framework confirms the existence of a research gap. The proposed conceptual model integrates marketing management dimensions with digital tools and analytics, enabling a more systematic connection of activities with measurable results and the improvement of strategic and operational decision-making.

The contribution of this study lies in the conceptual integration of contemporary marketing approaches and in providing a theoretical foundation for further empirical research across different industrial and market contexts.

REFERENCES

Abboud, S., Hanna, E., Jeunen, O., Raheja, V., & Wheeler, S. (2025, September). *Agentic personalisation of cross-channel marketing experiences.* In *Proceedings of the Nineteenth ACM Conference on Recommender Systems* (pp. 907–910). ACM. https://doi.org/10.1145/3705328.3748125

Cai, Y. J., & Choi, T. M. (2023). Omni channel marketing strategy in the digital platform era. *Journal of Business Research, 168*, 114197. https://doi.org/10.1016/j.jbusres.2023.114197

De Keyser, A., Verleye, K., Lemon, K. N., Keiningham, T. L., & Klaus, P. (2020). Moving the customer experience field forward. *Journal of Service Research, 23*(4), 433–455. https://doi.org/10.1177/1094670520941276

Gao, F., & Su, X. (2020). Omnichannel retail operations with buy-online-and-pick-up-in-store. *Management Science, 66*(6), 2474–2492. https://doi.org/10.1287/mnsc.2019.3543

Gupta, M., Ghafoori, A., Kim, E., Merhi, M. I., & Filieri, R. (2025). *Growth hacking capability: Conceptualization, survey instrument development, and empirical study of its impact on firm performance. Journal of Business Research, 196*, 115446. https://doi.org/10.1016/j.jbusres.2025.115446

Harmeling, C. M., Moffett, J. W., Arnold, M. J., & Carlson, B. D. (2020). Toward a theory of customer engagement marketing. *Journal of the Academy of Marketing Science, 48*(2), 312–335. https://doi.org/10.1007/s11747-019-00687-0

Herhausen, D., Miočević, D., Morgan, R. E., & Kleijnen, M. H. P. (2020). The digital marketing capabilities gap. *Industrial Marketing Management, 90*, 276–290. https://doi.org/10.1016/j.indmarman.2020.07.009

Jia, X. (2025). *Digital marketing and brand competitiveness: The mediating role of marketing capability and operational capability. Journal of Retailing and Consumer Services, 87,* 104429. https://doi.org/10.1016/j.jretconser.2025.104429

Kabadayi, S., & Gupta, R. (2022). The value relevance of digital marketing capabilities to firm performance. *Journal of the Academy of Marketing Science, 50*(4), 504–525. https://doi.org/10.1007/s11747-022-00858-7

Kohtamäki, M., Parida, V., Oghazi, P., Gebauer, H., & Baines, T. (2020). Digital servitization business models in ecosystems: A theory of the firm. *Journal of Business Research, 104*, 380–392. https://doi.org/10.1016/j.jbusres.2019.06.027

Kumar, V., Ramachandran, D., & Kumar, B. (2020). Influence of new age technologies on marketing: A research agenda. *Journal of Business Research, 125*, 864–877. https://doi.org/10.1016/j.jbusres.2020.01.007

Lemon, K. N., & Verhoef, P. C. (2020). Understanding customer experience throughout the customer journey. *Journal of Marketing, 84*(2), 69–96. https://doi.org/10.1177/0022242920901746

Rahman, S. M., Carlson, J., Gudergan, S. P., Wetzels, M., & Grewal, D. (2025). How do omnichannel customer experiences affect customer engagement? Theory and empirical validation. *Journal of Business Research, 189*, Article 115196. https://doi.org/10.1016/j.jbusres.2024.115196

Thaichon, P., Quach, S., Barari, M., & Nguyen, M. (2024). Exploring the role of omnichannel retailing technologies: Future research directions. *Australasian Marketing Journal, 32*(2), 162–177. https://doi.org/10.1177/14413582231167664

Trainor, K. J., Andzulis, J. M., Rapp, A., & Agnihotri, R. (2020). Social media technology usage and customer relationship performance: A capabilities-based examination of social CRM. *Journal of Business Research, 116*, 562–573. https://doi.org/10.1016/j.jbusres.2020.05.002

ORGANIZATIONAL AND FINANCIAL CONSTRAINTS OF MARKETING MANAGEMENT IN SMALL AND MEDIUM ENTERPRISES

DOI: 10.5937/EMC26208S

Ljiljana Stošić Mihajlović
Academy of Appiled Technical and Preschool Studies, Nis - Department in Vranje, Republic of Serbia
E-mail: ljiljana.stosic.mihajlovic@akademijanis.edu.rs
Marija Mihajlović
Ministry of Construction, Transport and Infrastructure of the Republic of Serbia

ABSTRACT

This paper focuses on the theoretical analysis of organizational and financial constraints of marketing management in small and medium enterprises (SMEs). SMEs face limited resources, which hinders the implementation of effective marketing strategies and affects competitiveness and sustainability. Financial constraints include a lack of resources for promotion, market research, and digital channel adoption, while organizational constraints involve the absence of formal marketing teams, centralized decision-making, and limited employee competencies. The paper demonstrates how marketing capabilities, including digital skills, innovativeness, and proactivity, allow SMEs to partially overcome these constraints and improve marketing performance. The theoretical integration of financial, organizational, and capability factors provides a framework for strategic planning and efficient resource utilization. The conclusions indicate that SMEs should invest in employee skill development, flexible organizational structures, and creative marketing tactics, enhancing competitiveness and supporting long-term growth. The study is valuable for academics, managers, and practitioners seeking to understand the key success factors of marketing under resource limitations.

Key words: SMEs, Financial constraints, Organizational constraints, Marketing capabilities, Competitiveness.

INTRODUCTION

Marketing management in small and medium enterprises (SMEs) plays a crucial role in achieving competitiveness, growth, and business sustainability. SMEs often operate under conditions of limited resources, which significantly complicates the planning and implementation of marketing activities. A lack of financial resources and limited human capital represent major obstacles to applying modern strategies, including digital marketing, market research, and the promotion of products or services. Financial constraints affect SMEs' capacity to invest in marketing channels, while organizational constraints, such as the absence of formal teams, centralized decision-making, and insufficient employee training, reduce the efficiency of marketing strategy implementation. Empirical evidence shows that the effectiveness of marketing activities in SMEs is closely linked to the choice and combination of marketing instruments, where insufficient use of promotional and distribution tools often limits market reach and competitive positioning (Stošić Mihajlović & Trajković, 2020).

Understanding these constraints is essential for managers and SME owners to develop strategies that optimize resources and enhance market performance. Despite these challenges, SMEs have the potential to develop marketing capabilities, including digital skills, creativity, proactivity, and analytical competencies, which can partially mitigate the negative effects of constraints and improve competitive advantage.

The aim of this paper is to provide a detailed analysis of how financial and organizational constraints impact marketing management in SMEs, and to identify key capabilities and approaches that allow

enterprises to utilize available resources more effectively. The paper also emphasizes the importance of flexible organizational structures, strategic planning, and innovative marketing tactics as tools for improving market performance.

By integrating financial, organizational, and capability factors into a coherent theoretical framework, this study offers a valuable guide for academics, managers, and practitioners seeking to enhance marketing practices in SMEs and strengthen their market position. The insights presented in this work support the development of sustainable and efficient marketing strategies, enabling SMEs to achieve long-term growth even in resource-constrained environments.

THEORETICAL FRAMEWORK

Financial Constraints

Financial constraints represent one of the most significant challenges faced by small and medium-sized enterprises (SMEs) in the context of marketing management. A limited budget directly affects a company's ability to plan, implement, and monitor marketing strategies, which can lead to reduced competitiveness and long-term sustainability. The lack of financial resources often forces SMEs to focus on short-term activities, while investments in long-term strategies and innovations are postponed or neglected (Storey, 2010). This means that companies with limited finances often adopt ad-hoc marketing approaches, without detailed planning or evaluation of return on investment.

In the contemporary digital environment, even strategies considered low-budget, such as social media marketing, require basic investments in tools, software, and employee training (Wani & Palkar, 2023). This implies that financial constraints are not only a matter of available funds but also the capacity of SMEs to allocate resources efficiently. Low financial flexibility can limit the use of advanced digital tools, automated analytics systems, or sophisticated e-commerce platforms, thereby reducing the potential for competitive positioning in the market.

Moreover, research shows that financial constraints can stimulate innovation and creativity in marketing. Companies that cannot invest in expensive channels often develop new, innovative tactics for promotion and customer engagement (Cao & Weerawardena, 2023). This means that a limited budget can act as an incentive for developing unique marketing approaches, which can increase efficiency and provide a competitive advantage. For example, SMEs can leverage viral content, local influencer marketing, partnership campaigns, or creative promotional events with minimal costs. One of the key challenges posed by financial constraints is the lack of resources for market research and data analysis. Without adequate research, SMEs risk making uninformed decisions, which can lead to failed campaigns and resource losses. Therefore, companies must use alternative market research methods, such as online surveys, social media insights, and free analytics tools, to compensate for budget limitations (Hossain, Nguyen & Rahman, 2021). This means that the effective use of available free and low-budget resources becomes a critical success factor.

Financial constraints also affect the ability of SMEs to invest in product development and portfolio diversification. Companies with limited budgets often focus on existing products and markets, while innovations and new initiatives remain underutilized. This means that financial constraints can restrict long-term growth and reduce the adaptability of enterprises to environmental changes.

Further research highlights the importance of integrating financial planning with marketing strategies. Companies that develop detailed budget plans, track ROI for each campaign, and use analytics to optimize costs manage to maximize marketing performance even with limited resources (Belitski & Rejeb, 2022). In this regard, strategic budget planning and the use of low-cost but effective channels represent key tools in overcoming financial constraints. Finally, financial constraints are not only a challenge but also an opportunity to develop capabilities for efficient resource management. SMEs that cultivate internal competencies in planning, digital marketing, and creative strategies can partially compensate for the lack of funds and achieve sustainable growth. This means that even under limited

budget conditions, with a strategic approach and innovation, SMEs can achieve measurable market performance and gain a competitive advantage.

Organizational Constraints

Organizational constraints in small and medium-sized enterprises (SMEs) represent a significant challenge for effective marketing management. They relate to structural, procedural, and human factors that affect a company's ability to plan, implement, and monitor marketing activities. Key aspects include the lack of formal marketing teams, centralized decision-making, poorly defined processes, and limited employee competencies. These characteristics often result in slower decision-making, reduced innovation, and a lower ability to adapt to market changes (Kotler & Keller, 2016). This means that the organizational structure of SMEs directly impacts their flexibility and long-term development.

Flexible and decentralized organizations enable faster decision-making and better coordination among employees, which enhances the ability to implement digital marketing strategies and creative campaigns [Garrido-Moreno et al., 2020]. In this regard, SMEs that invest in clearly defined roles, internal procedures, and competent teams can significantly improve marketing efficiency. This means that even small changes in organizational structure, such as introducing a marketing coordinator or holding regular team meetings for campaign planning, can have a substantial impact on overall marketing performance. One of the challenges of organizational constraints is also the insufficient training and education of employees. Staff who lack the necessary digital and analytical skills often cannot effectively use modern marketing tools, reducing overall productivity and campaign effectiveness (Marolt et al., 2022). This means that competency development is crucial not only for overcoming constraints but also for creating long-term competitive advantage. Continuous employee training in digital marketing, data analytics, and campaign management enables SMEs to better respond to market changes and implement innovative strategies.

Furthermore, hierarchical structures and complex business processes can slow down innovation and flexibility. Companies that rely on centralized decision-making often face slow adaptation and reduced ability to respond to market changes (Marolt et al., 2022). In this context, enterprises that develop agile and horizontal structures can more quickly test new marketing ideas and adjust campaigns in real time. This means that organizational reforms and process optimization are not a luxury but a necessity for SMEs operating in a modern, dynamic market environment. Beyond structural aspects, organizational culture plays a key role in overcoming constraints. A culture that encourages innovation, teamwork, and proactivity enables employees to recognize opportunities and propose solutions independently, significantly improving marketing efficiency (Belitski & Rejeb, 2022). This means that developing an organizational culture that supports learning, experimentation, and collaboration is just as important as formal structure. Finally, integrating organizational and financial resources allows SMEs to optimize marketing activities and maximize performance even under limited resources. Companies that combine a flexible organizational structure, trained employees, and a strategic approach to budgeting can create a competitive advantage and achieve sustainable market growth.

Marketing Capabilities of SMEs

Marketing capabilities represent a key strategic resource for SMEs, enabling companies to overcome the negative effects of financial and organizational constraints. They include skills in market analysis, digital competencies, creativity, proactivity, and innovativeness in the development and implementation of marketing strategies (Barney, 1991). This means that the capabilities of employees and the organization as a whole play a central role in achieving competitive advantage, as they allow for better utilization of available resources and increased efficiency in marketing activities. Digital capabilities are becoming increasingly important, particularly in the context of growing internet use, social media, and e-commerce platforms. SMEs that develop the digital skills of their employees can effectively use online tools for promotion, consumer analytics, and campaign personalization

(Empirical Digital Marketing Study, 2024). This means that digital competencies enable companies to partially compensate for the lack of financial resources, as they allow for more efficient and cost-effective customer targeting and campaign performance tracking.

Employee proactivity in marketing allows SMEs to anticipate changes in consumer behavior and quickly adjust their strategies (Belitski, Rejeb, 2022). This means that companies that actively monitor market trends and use insights from competitive analysis have a greater ability to identify new opportunities, develop innovative products, and improve customer engagement. Innovativeness is reflected in the ability to create new marketing approaches, experiment with campaign formats, and use unconventional channels for promoting products and services. Analytical capabilities are also critical. SMEs that possess skills in collecting and interpreting data on the market, customers, and campaign performance can better plan budgets, optimize campaigns, and increase return on investment (Hossain, Nguyen & Rahman, 2021). This means that developing analytical competencies allows companies to efficiently use limited resources and maximize marketing performance, even under financial or organizational constraints. Furthermore, marketing capabilities include the development of customer relationship management (CRM) skills, which contribute to loyalty and long-term sustainability of SMEs. Companies that effectively manage communication, personalization, and value delivery to customers achieve better results and greater competitiveness (Cao & Weerawardena, 2023). In this regard, the combination of digital, analytical, and innovative capabilities allows SMEs to achieve multiple advantages: better market visibility, higher campaign efficiency, and the ability to adapt to changes.

It is important to note that marketing capabilities are not static. Continuous development of employee competencies, adoption of new technologies, and experimentation with strategies enable SMEs to maintain competitive advantage and achieve long-term growth. This means that capabilities are not merely a compensation for constraints, but a foundation for innovation, flexibility, and sustainable marketing management in SMEs. Finally, integrating marketing capabilities with financial and organizational resources creates synergy that allows SMEs to efficiently utilize limited resources and maximize marketing performance. This means that the capabilities of employees and the organization directly contribute to the enterprise's ability to overcome challenges, innovate, and sustainably develop its market activities.

Integration of Financial and Organizational Constraints

Financial and organizational constraints often act simultaneously and complementarily, shaping the ability of small and medium-sized enterprises (SMEs) to implement effective marketing strategies. Financial constraints, such as limited budgets for promotion, market research, or digital channels, reduce a company's capacity to carry out planned activities. On the other hand, organizational constraints, including centralized decision-making, the absence of formal marketing teams, and insufficient employee training, further hinder the execution of campaigns and innovative initiatives (Kotler & Keller, 2016). This means that SMEs often cannot optimally utilize either financial or human resources without an integrated approach.

The integration of these factors involves the strategic alignment of financial resources and organizational capacities. For example, a company with a limited budget can significantly improve the effectiveness of its campaigns by using a flexible organizational structure, delegating responsibilities, and enabling teams to make decisions independently (Garrido-Moreno et al., 2020). In this regard, the combination of decentralization and budgetary discipline allows SMEs to quickly adapt marketing activities to environmental changes and maximize the use of available resources. Furthermore, the synergy between financial and organizational factors contributes to increased innovation in marketing. SMEs that successfully integrate both aspects can experiment with low-budget but creative campaigns, leverage digital channels with high ROI, and develop strategies that simultaneously reduce costs and increase market visibility (Cao & Weerawardena, 2023). This means that integration enables companies to transform constraints into competitive advantages.

It is important to note that integrating financial and organizational resources also requires the development of employees' marketing capabilities. Digital skills, analytical competencies, and proactivity enable teams to manage campaigns effectively, even when budgets and organizational structure impose limitations (Belitski & Rejeb, 2022). This means that employee and organizational capabilities together create a framework for overcoming challenges. SMEs that combine financial planning, a flexible organizational structure, and competent teams can significantly enhance marketing efficiency and strengthen their long-term competitive position. The integration of financial and organizational factors is key to resource optimization, innovation, and achieving sustainable market performance in a dynamic and challenging business environment.

Marketing Performance and Implications

Marketing performance in small and medium-sized enterprises (SMEs) is measured through campaign results, sales growth, acquisition of new customers, return on investment, and strengthening of market position. Financial and organizational constraints significantly affect these indicators, as they reduce a company's ability to implement comprehensive and long-term marketing strategies (Marolt et al., 2022). This means that SMEs with limited budgets and inflexible organizational structures often cannot fully exploit the potential of their campaigns, which directly impacts competitiveness.

The development of marketing capabilities, including digital skills, analytical competencies, and innovativeness, enables companies to partially overcome the negative effects of constraints and improve marketing performance (Wen Wu, et al., 2024). In this regard, SMEs that invest in employee training, experimentation with digital channels, and the creation of creative campaigns achieve better ROI and greater market visibility, even under resource-limited conditions.

The practical implications are manifold. Companies should focus resources on the most efficient channels, using analytical tools to monitor campaign performance and optimize costs. Additionally, the application of low-budget but innovative strategies, such as influencer marketing, partnership campaigns, and viral content, can significantly increase customer engagement and market impact (Cao & Weerawardena, 2023). This means that even with limited resources, SMEs can achieve measurable and sustainable marketing success. Furthermore, integrating marketing capabilities with financial and organizational resources allows SMEs to develop a competitive advantage and strengthen their long-term market position. Companies that successfully balance budget, flexible structures, and competent teams can better analyze market trends, identify new niches, and respond quickly to changes in consumer behavior (Belitski & Rejeb, 2022). This means that the combination of financial, organizational, and capability factors is key to enhancing marketing performance and ensuring the sustainability of SMEs in the market.

CONCLUSION

Marketing management in small and medium enterprises (SMEs) faces significant challenges due to financial and organizational constraints, which limit the ability to plan, implement, and monitor marketing activities effectively. Financial constraints reduce opportunities for investment in promotion, market research, digital channels, and the development of new products, while organizational constraints, including centralized decision-making, the absence of formal marketing teams, and limited employee competencies, further hinder the implementation of strategies and innovative initiatives. Nevertheless, the development of marketing capabilities, including digital skills, creativity, analytical competencies, and employee proactivity, allows SMEs to partially overcome these constraints and improve market performance. A flexible organizational structure, delegation of responsibilities, and strategic planning contribute to better adaptation to market changes and more efficient use of limited resources. In addition, creative and low-budget marketing tactics help SMEs maintain a competitive advantage and increase visibility in the market.

The conclusions of this paper indicate that SMEs should focus on human resource development, continuous employee training, the application of innovative strategies, and the optimization of

organizational processes. The integration of financial, organizational, and capability factors is essential for achieving long-term growth, sustainability, and competitiveness.

This theoretical framework provides practical guidance for managers and SME owners, helping them identify priority actions, improve marketing efficiency, and strategically plan the use of available resources. By leveraging marketing capabilities alongside careful resource management and organizational flexibility, SMEs can achieve stable market performance and secure a long-term position in a challenging business environment.

REFERENCES

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120. https://doi.org/10.1177/014920639101700108

Belitski, M., & Rejeb, N. (2022). Social media marketing capabilities and firm performance in SMEs. *Journal of Business Research*, 145, 636–648. https://doi.org/10.1016/j.jbusres.2022.03.012

Cao, G., & Weerawardena, J. (2023). Strategic use of social media in marketing and financial performance: The B2B SME context. *Industrial Marketing Management*, 111, 41–54. https://doi.org/10.1016/j.indmarman.2023.03.007

Cartwright, S., Liu, H., & Raddats, C. (2021). Strategic use of social media within business to business (B2B) marketing: A systematic literature review. *Industrial Marketing Management*, 97, 35–58. https://doi.org/10.1016/j.indmarman.2021.06.005

Dwivedi, Y. K., Ismagilova, E., Hughes, D. L., Carlson, J., Filieri, R., Jacobson, J., & Wang, Y. (2021). Setting the future of digital and social media marketing research: Perspectives and research propositions. *International Journal of Information Management*, 59, 102168. https://doi.org/10.1016/j.ijinfomgt.2020.102168

Garrido Moreno, A., García Morales, V., King, S., & Lockett, N. (2020). Social media use and value creation in the digital landscape: A dynamic capabilities perspective. *Journal of Service Management*, 31(3), 313–343. https://doi.org/10.1108/JOSM-09-2018-0286

Hossain, M. I., Nguyen, H., & Rahman, M. (2021). Key drivers of marketing performance in small scale enterprises: Evidence from Bangladesh. *Marketing Intelligence & Planning*, 39(1), 45–60. https://doi.org/10.1108/MIP-03-2020-0123

Kotler, P., & Keller, K. L. (2016). *Marketing Management* (15th ed.). Harlow, UK: Pearson Education.

Marolt, M., Zimmermann, H. D., & Pucihar, A. (2022). Social media use and business performance in SMEs: The mediating roles of relational social commerce capability and competitive advantage. *Sustainability*, 14(22), 15029. https://doi.org/10.3390/su142215029

Smallbone, D., Saridakis, G., Abdullahi Abubakar, Y. (2022) Internationalisation as a stimulus for SME innovation in developing economies: Comparing SMEs in factor-driven and efficiency-driven economies *Journal of Business Research*, 140, 123–136. https://doi.org/10.1016/j.jbusres.2022.01.045

Storey, D. J. (2010). *Managing Growth in Small Firms*. Cheltenham, UK: Edward Elgar Publishing.

Stošić Mihajlović, L., & Trajković, S. (2020). The importance of marketing instruments for market approach and operation of export companies. *Journal of Process Management – New Technologies, International*, 8(1). https://doi.org/10.5937/jouproman8-24859

Suhail. P Fathima Isra Dr. Mubarak Rahman. (2025). Emerging Paradigms; Commerce and Management Researches. *ISBN:* 978-93-341-2548-1 https://zodharesearch.com/media/PDFs/Publications/Regulars/emerging_paradigms_commerce_and_management_researches.pdf

Wani, S. A., & Palkar, S. (2023). Digital marketing strategies in SMEs: Overcoming financial and organizational constraints. *International Journal of Online Engineering*, 19(2), 73–88. https://doi.org/10.3991/ijoe.v19i02.173570

Wen Wu, Botella-Carrubi, D., Bianco-Gonzalez-Tjero, C. (2024). Empirical digital marketing study in SMEs. (2024). *Technological Forecasting & Social Change*, 190, 122479. https://doi.org/10.1016/j.techfore.2024.122479

Zainuddin, M., & Sudarmiatin, S. (2023). Marketing performance of small and medium enterprises: Literature study approach with bibliometrics. Preprint. https://www.researchgate.net/publication/376329602

DETERMINANTS OF EFFECTIVE MARKETING MANAGEMENT

DOI: 10.5937/EMC26214S

Ljiljana Stošić Mihajlović
Academy of Appiled Technical and Preschool Studies, Nis - department in Vranje
E-mail: ljiljana.stosic.mihajlovic@akademijanis.edu.rs
Marija Mihajlović
PhD Student, Ministry of Construction, Transport and Infrastructure of the Republic of Serbia

ABSTRACT

Effective marketing management is a key factor for achieving a competitive advantage in modern enterprises operating within a globalized and digitally integrated business environment. Its efficiency depends on a combination of strategic planning, innovation, digital transformation, customer relationship management (CRM), and the organization's ability to analyze data and make information-based decisions. The aim of this paper is to identify and analyze in detail the key determinants of effective marketing management, with a particular emphasis on contemporary trends, digital tools, empirical examples, and practical implications. The study also explores the importance of creating value through innovative campaigns and the implementation of CRM systems to enhance customer experience and loyalty. Special attention is given to the role of organizational culture, agility, and the capacity for decision-making based on data analytics. A review of literature and case studies shows that organizations implementing an integrated marketing management approach achieve higher profitability, optimize resources, and increase overall brand value. It is concluded that effective marketing management requires continuous adaptation of strategies, the application of digital tools, and innovative methods to ensure that enterprises remain competitive and profitable in the long term within the modern business environment.

Key words: Marketing management, Efficiency, Digital transformation, CRM, Innovation

INTRODUCTION

Marketing management is a central function in organizations as it connects products, services, and customer experiences with market needs, creating value for all stakeholders (Kotler & Keller, 2022). Kotler and Keller emphasize that marketing management is not merely product promotion but a process that integrates planning, implementation, and control of marketing activities. Effective marketing management allows companies to precisely identify customer needs, optimize resources, and achieve long-term business objectives. The efficiency of marketing management depends on the organization’s ability to integrate strategies, technology, data analytics, and creative approaches (Armstrong & Kotler, 2020). Literature highlights that organizations that continuously analyze market trends, apply digital tools, and adopt innovative methods achieve higher customer loyalty and long-term profitability. Modern business environments are characterized by globalization, rapidly changing consumer behaviors, and the growth of digital channels, increasing the complexity of marketing management (Chaffey, 2021). Digital transformation enables precise targeting, offer personalization, and resource optimization. Companies that successfully integrate digital technologies and data-driven strategies gain competitive advantages, increasing both profitability and customer engagement.

The effectiveness of marketing management is significantly influenced by the appropriate selection and integration of marketing instruments, as inadequate use of promotion and distribution mechanisms can limit market performance and competitive positioning (Stošić Mihajlović & Trajković, 2020).

The aim of this paper is to examine the determinants of effective marketing management, including strategic planning, digital transformation, innovation, CRM, organizational capabilities, and data analytics, using empirical examples and key performance indicators (KPIs).

THEORETICAL FRAMEWORK OF MARKETING MANAGEMENT

Marketing management is defined as the process of planning, implementing, and controlling marketing strategies to create value for customers and achieve business objectives (Kotler & Keller, 2022). Effective marketing management is crucial for building long-term customer value, as the integration of digital technologies and personalized strategies increases engagement and customer loyalty (Fitriyani & Tukiran, 2024). That means companies using digital tools better meet customer needs and build stronger relationships. Consumer characteristics and their response to influencer messages directly affect the effectiveness of digital marketing campaigns Therefore, understanding the target audience and how they react makes campaigns more successful. Integrating knowledge management into marketing processes improves decision-making, as organizational readiness and technological infrastructure support better marketing performance (Abbas, 2024). That means companies systematically using data and knowledge make better strategic marketing decisions.

Online presence and digital strategies, such as SEO and targeted promotion, affect consumer reach and engagement (Hermayanto, 2023). Current digital tactics help managers communicate more effectively with the market. Factors directly affecting the effectiveness of digital marketing campaigns include technological changes, consumer preferences, and regulatory challenges (Kumar et al., 2024). Managers must monitor digital environment changes to stay competitive. From a consumer psychology perspective, strategies that consider emotional and cognitive factors can increase marketing effectiveness (Han, 2023). Understanding consumer behavior is a determinant of successful marketing messages. Adoption of digital marketing in SMEs depends on resources, knowledge, and willingness to innovate. That means organizational capabilities directly influence marketing success.

Factors affecting consumer responses to influencer campaigns include their characteristics and message relevance (Azhar, Mohd Yusof & Harun, 2024). The message must be relevant and authentic to have an effect. Organizations that effectively use marketing evaluation metrics have a stronger foundation for strategic planning. That means measuring results helps managers adjust tactics. External changes such as technological advancement and consumer behavior shifts require flexibility in marketing management. Therefore, managers must quickly adapt strategies to these changes. Marketing effectiveness also depends on product quality and positioning, as better market characteristics contribute to greater competitiveness. Marketing must align with overall product quality and competitive advantages.

Digital media platforms have become central to reaching consumers and influence campaign planning (Abdullah et al., 2025). Therefore, online presence is crucial for segmentation and audience reach. Adoption of marketing analytics depends on organizational support, data availability, and IT infrastructure (Gokhale & Saha, 2023). That managers must ensure technology and data support for analytics to function effectively. Cultural factors influence global marketing strategies and must be considered during internationalization. Cultural differences affect how campaigns should be adapted for local markets.

Research shows that consumers' attitudes toward advertising affect perception and acceptance of social media messages (Bakalo & Zewude, 2023). That consumer attitudes shape how successful advertising messages will be. Focusing on creating customer value rather than only sales leads to greater marketing impact (Fitriyani & Tukiran, 2024). Therefore, marketing should build long-term relationships, not just short-term results. Effective sales and market share growth often depend on combining traditional and digital strategies (Hermayanto, 2023). That means combining different channels increases campaign reach and impact. Factors such as customer feedback and preferences allow better adaptation of marketing activities, therefore, feedback is essential for iterative marketing improvement. Marketing managers who understand factors affecting consumer decisions can better

plan targeted campaigns (Azhar et al., 2024). Consumer behavior research supports more effective campaign planning. Digital transformation in marketing affects not only channels but also organizational processes, requiring new skills and adaptable structures (Fitriyani & Tukiran, 2024). In modern conditions, companies must invest in training and technology to remain competitive. Literature emphasizes that successful marketing management requires a strategic approach, application of digital technologies, data analytics, and creativity.

Key Principles of Marketing Management

Marketing management is based on four key principles: customer orientation, integration of activities, value creation, and long-term focus.

Customer orientation - means that organizations continuously analyze the needs, desires, and behavior of their customers (Armstrong & Kotler, 2020). A customer-focused approach enables precise targeting, reduces the risk of campaign failure, and contributes to long-term loyalty. Literature indicates that understanding psychographic, demographic, and cultural factors allows for the creation of personalized strategies and emotional connections with the brand. For instance, Amazon uses customer data to personalize product recommendations, increasing sales and engagement. Understanding customer preferences enables the creation of offers that meet specific needs and enhance the overall customer experience.

Integration of activities - involves coordinating the marketing function with other departments, including sales, IT, finance, and product development (Day, 2019). Synchronized activities allow for more efficient resource utilization and faster campaign implementation. Google's cross-functional teams demonstrate how coordinated efforts enable rapid adaptation to market changes and optimize resources at all stages of the marketing process. Integration includes KPI tracking, channel optimization, and communication coordination between marketing and other departments, improving efficiency and reducing costs.

Value creation - is the central function of marketing management and involves generating perceived value for consumers (Kumar et al., 2021). Value creation encompasses product quality, additional benefits, brand communication, and emotional engagement. Dove's "Real Beauty" campaign shows how socially responsible marketing creates value and positively influences brand perception. Literature highlights that value creation contributes to long-term customer loyalty, strengthens brand image, and enables differentiation. Innovative and socially responsible campaigns increase engagement and enhance corporate reputation.

Long-term focus - involves planning and implementing activities aimed at sustainable outcomes (Rust & Huang, 2020). Investments in digital technologies, CRM, and analytics provide long-term benefits, including cost reduction, increased profitability, and enhanced customer loyalty. Literature demonstrates that companies with long-term strategies successfully respond to market changes and innovate their products and communications. Long-term focus includes continuous KPI monitoring, strategy adjustment, and ongoing improvement.

These principles allow organizations to develop relevant strategies, optimize resources, and continuously enhance customer value, which is essential for long-term profitability and competitive advantage.

DETERMINANTS OF EFFECTIVE MARKETING MANAGEMENT

Effective marketing management depends on the alignment of organizational capabilities, financial resources, and a firm's strategic market orientation. Managerial competencies, availability of information, and the ability to adapt marketing activities to changing market conditions play a particularly important role.

Strategic Planning - Strategic planning involves defining long-term objectives, market segmentation, brand positioning, and developing the marketing mix (Aaker, 2020). A clearly defined strategy enables precise targeting, resource optimization, and achievement of competitive advantage.

Table 1: Sample KPIs for Strategic Planning

KPI	Description	Target
Campaign ROI	Percentage of revenue relative to marketing costs	≥20%
Market Share Growth	Percentage growth relative to competitors	≥5% per year
CSAT (Customer Satisfaction)	Customer satisfaction score	≥85%
Number of New Segments	Number of newly targeted segments	≥3 per year

Digital Transformation and Technology - Digital transformation allows marketing process automation, data analysis, and precise targeting (Chaffey, 2021; Wamba et al., 2020). CRM systems and big data analytics enable predictions of customer behavior and cost optimization.

Table 2: Sample KPIs for Digital Transformation

KPI	Description	Target
Online Campaign Conversion	Percentage of visitors who make a purchase	≥3%
Engagement Rate	User activity on digital channels	≥15%
Cost per Acquisition (CPA)	Cost to acquire a new customer	≤€50

Innovation and Creativity - Innovative campaigns and creative marketing approaches enable brand differentiation and increase customer engagement (Hutter et al., 2013; Kotler et al., 2021). Interactive campaigns, social responsibility, and omnichannel marketing strengthen emotional connections with the brand.

Table 3: Sample KPIs for Innovation

KPI	Description	Target
Number of Innovative Campaigns	New campaigns implemented per year	≥5
Reach and Impressions	Total campaign reach	≥100,000
Engagement Rate	User activities (like, share, comment)	≥10%

Customer Relationship Management (CRM) - CRM systems enable the collection, analysis, and use of customer data to personalize experiences and increase loyalty (Payne & Frow, 2017). Organizations implementing CRM improve customer satisfaction, reduce churn, and enhance sales.

Organizational Capabilities and Culture - Organizational capability includes agility, flexibility, and the ability to implement marketing strategies (Day, 2019). Organizations with a strong culture of innovation and collaboration adapt faster to market changes and digital transformation.

Application of Analytics and Decision-Making Data analytics enables information-based decision-making, campaign optimization, and KPI tracking (Wamba et al., 2020). Big data and AI tools allow prediction of customer behavior, personalization, and improved ROI of marketing activities.

CONTEMPORARY TRENDS IN MARKETING MANAGEMENT

Contemporary marketing management is constantly evolving due to globalization, digital transformation, and changing consumer expectations. Organizations must monitor the latest trends to remain competitive and relevant in the market. The most significant trends include omnichannel marketing, data-driven marketing, corporate social responsibility (CSR) marketing, personalization and customer experience, and digital automation with artificial intelligence (AI).

Omnichannel Marketing - Omnichannel marketing involves integrating all sales and communication channels both digital and physical - into a seamless customer experience (Verhoef et al., 2015). The goal is to allow customers to move between online and offline channels without losing continuity or quality of experience. Literature shows that companies implementing omnichannel approaches achieve

higher engagement, increased loyalty, and higher average revenue per customer. For example, retailers such as Sephora and Nike integrate online stores, mobile apps, and physical stores to enable personalized shopping, product reservations, and multi-platform brand interaction. Omnichannel marketing requires departmental coordination, data synchronization, and performance monitoring across all channels.

Data-Driven Marketing - Data-driven marketing enables organizations to use large volumes of data (big data) and analytical tools to make informed decisions (Wamba et al., 2020). By analyzing customer behavior, demographics, and brand interactions, companies can optimize campaigns, personalize communication, and improve ROI. Literature emphasizes that analytics reduces campaign failure risk and allows timely strategy adjustments. For instance, Netflix uses viewing and preference data to recommend content, increasing engagement and reducing subscriber churn. The benefits include better market understanding, precise targeting, and enhanced customer experiences through personalized offers.

Corporate Social Responsibility (CSR) Marketing - CSR marketing integrates ethical, environmental, and social values into marketing strategies (Kotler et al., 2021). Companies promote not only products but also socially beneficial goals, strengthening emotional connections with consumers. Literature indicates that consumers increasingly prefer brands demonstrating responsible and sustainable behavior. Dove's "Real Beauty" campaign illustrates how socially responsible marketing positively impacts brand image, enhances loyalty, and generates viral effects on social media. CSR marketing requires careful planning, authenticity, and consistency, as inauthentic campaigns may lead to negative publicity.

Personalization and Customer Experience - Personalization involves tailoring products, services, and communications to the individual needs and preferences of customers (Kumar et al., 2021). Modern consumers expect personalized offers, recommendations, and brand interactions aligned with their interests. Literature shows that highly personalized campaigns increase engagement, conversion, and loyalty. Examples include Amazon's product recommendations, Spotify's personalized playlists, and Coca-Cola's named bottles campaigns. Delivering a top-quality customer experience requires data collection and analysis, customer segmentation, and timely communication that creates relevant value for each individual.

Digital Automation and Artificial Intelligence (AI) - Digital automation and AI tools in marketing allow companies to optimize resources, improve campaign accuracy, and enhance customer experience (Chaffey, 2021). AI can predict customer behavior, automate email campaigns, create personalized offers, and optimize real-time advertising. Literature shows that companies using AI in marketing achieve increased campaign efficiency, cost reduction, and improved conversion rates. Examples include chatbots for customer support, product recommendation algorithms, and automated social media ad targeting. Digital automation enables campaign scaling, rapid market response, and precise marketing goal achievement.

Integrating these trends into marketing management strategies enables organizations to remain competitive, relevant, and profitable. Omnichannel marketing, data-driven approaches, CSR, personalization, and AI collectively enhance customer engagement, optimize resources, and create long-term value.

CONCLUSION

Effective marketing management is a key factor for competitive advantage in modern organizations. This study has analyzed the determinants contributing to marketing management success, including strategic planning, digital transformation, innovation, customer relationship management, organizational capabilities, and data analytics. Literature analysis indicates that integrating these factors enables organizations to accurately target customers, optimize resources, and increase profitability. Strategic planning allows for defining long-term objectives, market segmentation, and

brand positioning. Digital transformation and CRM systems enable automation, personalization, and improved data analysis, while innovative campaigns and creativity increase customer engagement. Organizational capabilities and culture contribute to agility and flexibility, which are crucial in a dynamic, modern market. The application of data analytics and KPIs allows continuous performance monitoring and informed decision-making. Empirical examples, such as Amazon, Google, Nike, and Dove, demonstrate the practical application of these principles and the impact of integrated marketing management on business results. KPI analysis shows how organizations can track ROI, engagement, conversions, and customer satisfaction, confirming the direct relationship between effective marketing management and long-term profitability.

In conclusion, effective marketing management requires continuous strategy adaptation, the use of digital tools, innovative approaches, and alignment with organizational objectives. Organizations successfully combining these factors achieve a competitive advantage, enhance customer loyalty, and improve long-term performance. This study confirms that effective marketing management is not merely a function of sales or promotion, but a strategic process requiring a multidimensional approach, customer focus, creativity, technological adaptation, and continuous performance monitoring. Implementing recommended principles and KPIs enables organizations to achieve sustainable competitive advantage and long-term profitability, which is crucial for success in today's business environment.

REFERENCES

Abbas, M. (2024). Integrating knowledge management into marketing for enhanced decision-making and performance. *Advances in Business & Industrial Marketing Research, 2*(2), 72–82.

Abdullah, K. H., Muzawi, R., Gazali, N., & Abd Aziz, F. S. (2023). Digital marketing: A scientometric review. *Contemporary Management Research, 19*(1), 55–79. https://doi.org/10.7903/cmr.22344

Armstrong, G., & Kotler, P. (2020). *Principles of marketing* (18th ed.). Pearson.

Azhar, S. A., Mohd Yusof, Y. L., & Harun, Z. F. (2024). Factors affecting consumer responses to influencer marketing campaigns. *Information Management and Business Review, 16*(2(I)S), 24–35.

Bakalo, A., & Zewude, S. (2023). Determinants of consumers' attitudes toward social media advertising: Systematic review. *European Business & Management, 9*(5), 122–135.

Chaffey, D. (2021). *Digital marketing: Strategy, implementation and practice* (8th ed.). Pearson.

Day, G. S. (2019). *Market-driven strategy: Processes for creating value*. Wiley.

Fitriyani, S., & Tukiran, M. (2024). The role of marketing management in building long-term customer value (literature review). *International Journal of Multidisciplinary Research and Literature, 3*(6), 756–767.

Gokhale, N., & Saha, P. (2023). A review of determinants of marketing analytics adoption by business enterprises. *International Journal of Electronic Marketing and Retailing, 14*(4), 453–471.

Han, Z. (2023). The effectiveness of marketing strategies from the perspective of consumer psychology. *Advances in Economics, Management and Political Sciences, 26*, 343–349.

Hermayanto, R. (2023). Effective marketing strategies in business: Trends and best practices in the digital age. *Jurnal Ad'ministrare, 10*(1).

Hutter, K., Hautz, J., Dennhardt, S., & Füller, J. (2013). The impact of user interactions in social media marketing on brand awareness and purchase intention. *Journal of Interactive Marketing, 27*(4), 342–353.

Kotler, P., & Keller, K. L. (2022). *Marketing management* (16th ed.). Pearson.

Kotler, P., Kartajaya, H., & Setiawan, I. (2021). *Marketing 5.0: Technology for humanity*. Wiley.

Kumar, V., Ramachandran, D., & Kumar, B. (2021). Customer experience and value creation: A review and managerial implications. *Journal of Marketing, 85*(1), 1–19.*

Payne, A., & Frow, P. (2017). *Strategic customer management: Integrating relationship marketing and CRM*. Routledge.

Rust, R. T., & Huang, M.-H. (2020). Marketing analytics for customer value and firm performance. *Journal of Marketing Research, 57*(3), 349–360.*

Stošić Mihajlović, L., & Trajković, S. (2020). The importance of marketing instruments for market approach and operation of export companies. *Journal of Process Management – New Technologies, International, 8*(1), 45–53.

Wamba, S. F., Gunasekaran, A., Akter, S., Ren, S. J.-F., Dubey, R., & Childe, S. J. (2017). Big data analytics and firm performance: Effects of dynamic capabilities. *Journal of Business Research, 70*, 356–365. https://doi.org/10.1016/j.jbusres.2016.08.009

OMNICHANNEL RETAILING STRATEGY

DOI: 10.5937/EMC26220Z

Bruno Završnik
University of Maribor, Faculty of Economics and Business, Slovenia
E-mail: bruno.zavrsnik@um.si

ABSTRACT

Omnichannel represents a new perspective in understanding marketing – it is not just about being present on multiple channels, but about their consistent integration and synchronization from a user experience perspective. The main goal of our research was to explore and analyse how consumers understand and use omnichannel in pre-purchase decision-making and then also in the purchasing process itself. We also wanted to find out how often respondents use three different sales channels: website, physical store, and mobile app. The research confirmed that omnichannel is not just a technological upgrade of existing sales channels but represents a fundamental transformation of the way retailers do business and their relationship with consumers. The research also shows that social media plays a key role in implementing an omnichannel strategy.

Key words: Omnichannel marketing, Retailing, Sales channels, Digital channels

INTRODUCTION

Omnichannel management remains a major challenge for brands as customers become more demanding and expect companies to provide them with a superior shopping experience along their journey to the customer. With the proliferation of mobile technologies and social media, this customer journey has become more complex; the simultaneous use of different communication channels by customers is enabling the emergence of new behaviours such as “showrooming” or showrooms and “webrooming” or online rooms (Mosquera, et al., 2017).

The development of mobile applications that are influencing the field of omnichannel is a result of the transition of the smartphone into a key component of the online and physical retail environment. At the same time, shoppers who highly value this practice differ significantly from others in the weight they place on retailers and their demands for omnichannel integration during offline shopping (Lazaris, et al., 2015).

In an omnichannel strategy, retail operations management must adapt to the diverse and fluctuating demands of a market that is increasingly consumer centric. While offering customers a variety of channels, such as online and offline, to search, purchase, deliver, and return a product, omnichannel retail strives to create a seamless and consistent view of physical and data flows between its intermediaries, such as retail brick-and-mortar stores, delivery services, and data service providers (Mirzabeiki & Saghiri, 2021).

OMNICHANNEL MARKETING

Omnichannel marketing means giving customers a consistent brand experience whether they’re shopping on a desktop or mobile device, browsing social media, or walking into a brick and mortar store. The goal is to align messaging across all marketing channels so customers feel connected to your brand no matter where they interact with it (Camphouse, 2025).
The use of a customer-centric strategy that provides customers with a comprehensive shopping experience by allowing them to use multiple channels of consumer-to-physical store interaction simultaneously is known as omnichannel marketing (e.g., using mobile Internet access in a physical

retail store to research products and/or compare prices). The blurring of channel boundaries is another differentiator of omnichannel shopping. A seamless experience that increases convenience and engagement and provides a consistent brand experience can be achieved when all channels are integrated, allowing customers to start their journey in one and end it in another. Finally, data integration is also related to omnichannel management. It provides new potential sources of data, especially through social media and mobile channels.

Omnichannel marketing is about delivering a seamless and integrated customer experience across multiple platforms – online, offline, mobile, or social. However, true omnichannel is not possible without the help of innovative technology solutions. With the help of these solutions, companies can connect multiple channels, which also helps to improve and personalize interactions at every touchpoint (Anozie, et al., 2024).

As a result, omnichannel marketing prioritizes the customer and offers a "holistic" shopping experience, where the customer's shopping process is fluid and not hindered by the channels they use. In this sense, the most important thing in an omnichannel setting is to engage with the brand, not the channel (Payne, Peltier, & Barger, 2017).

OMNICHANNEL IN RETAILING

The omnichannel phenomenon is the result of modern technologies that allow retailers to integrate all the information offered by today's expanding channels and touchpoints. The term "omnichannel strategy" describes a customer management approach that is applied at every stage of a customer's relationship with a company. With this approach, the retailer ensures that all touchpoints and channels that customers can choose to communicate with the company at any given time – primarily the physical store, the online channel, the mobile channel, and social media – are coherent and consistent (Mosquera, et al., 2017).

In an omnichannel strategy, retail operations management must adapt to the diverse and fluctuating demands of a market that is increasingly consumer centric. While offering customers a variety of channels, such as online and offline, to search, purchase, deliver, and return a product, omnichannel retail strives to create a seamless and consistent view of physical and data flows between its intermediaries, such as retail brick-and-mortar stores, delivery services, and data service providers (Mirzabeiki & Saghiri, 2021

As consumers use different channels and touchpoints during their shopping journey, modern and future retail must now provide an engaging omnichannel experience to survive. However, many retailers are unable to offer their customers a truly seamless omnichannel experience. Therefore, it is useful to learn from the omnichannel experiences of exceptional stores (Dang, 2022).

EMPIRICAL FINDINGS

We used quantitative research, as we wanted to obtain data on their behaviours, attitude and expectations regarding omnichannel marketing in retail through a larger number of respondents. As a research method, we used an online survey questionnaire, which was designed in the 1KA tool. The survey questionnaire consisted of several content sections:

The survey involved 134 respondents, who were recruited using a convenience sample, as they were reached via online channels. There were slightly more women among the participants, namely 83, representing 61.94%, and 51 men, representing the remaining 38.06%.

The age structure of the respondents shows that younger consumers predominate, as almost half of the participants (47.02% or 63 people) are between 21 and 30 years old. They are followed by respondents in the age group from 31 to 40 years old (20.15% or 27 people) and those between 41 and 50 years old (13.43% or 18 people). A smaller share is represented by people up to 20 years old (5.97% or 8

people), respondents between 51 and 60 years old (8.21% or 11 people) and respondents aged 61 years or older (5.22% or 7 people).

Regarding the educational structure, most of the participants have a secondary school or higher education. The largest number of respondents are graduates, namely 47 people (35.07%), followed by respondents with secondary education, 36 people (26.87%), and those with higher professional education, 28 people (20.90%). Higher education, that is, a master's degree or higher, is held by 21 people (15.67%), and the smallest share is represented by respondents with completed primary school, namely only 2 people (1.49%).

In the first question, we asked about three different purchasing channels: website, physical store, and mobile app. For each of these channels, it was possible to indicate how often they choose one of these channels. Figure 1 shows how often respondents choose the website as a place to buy.

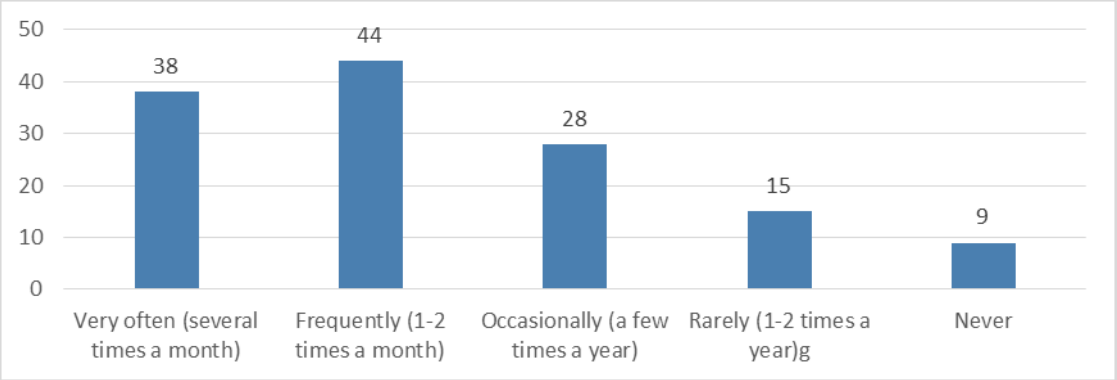


Figure 1: Website as a sales channel

Analysis of data on the frequency of online shopping shows that this channel is relatively popular among consumers. The largest share of respondents shops online frequently, i.e. once or twice a month, namely 44 people. This is followed by the group of those who use websites for shopping very frequently, several times a month, namely 38 people. In total, this means that more than 60% of respondents shop online at least once a month, which indicates a high level of acceptance of this channel. At the same time, a fifth of respondents, i.e. 28 shops occasionally, i.e. a few times a year, which indicates the extent of those who use online stores more occasionally. A smaller share of respondents decides to shop online rarely, only 15, and only 9 respondents, do not use online stores at all.

The results confirm that retailer websites are an important sales channel, with most shoppers returning to them regularly. Websites are becoming a standardized part of the shopping experience, used by consumers for both regular and occasional purchases. How often respondents choose a physical store as their place of purchase is shown in Figure 2.

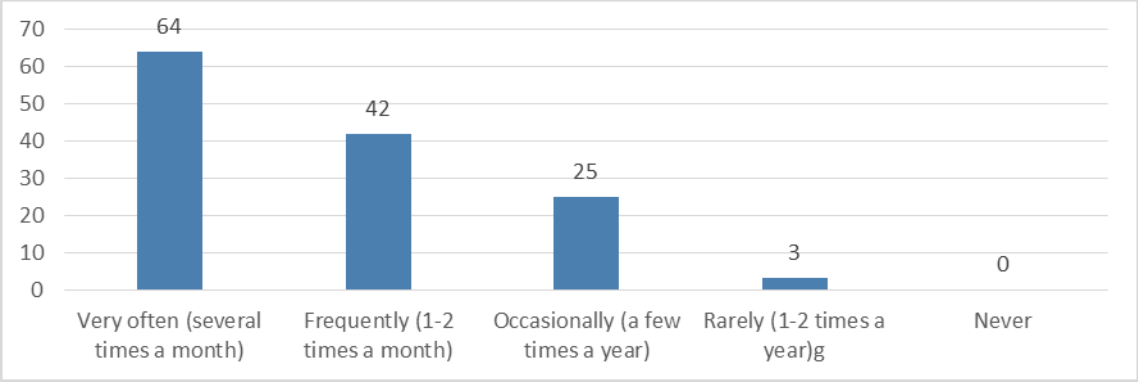


Figure 2: Physical store as a sales channel

Data analysis shows that most respondents shop in physical stores most often. As many as 64 respondents, stated that they shop in physical stores very often, i.e. several times a month. 42 respondents they shop in physical stores frequently, meaning once or twice a month. 25 respondents stated that they buy in physical stores occasionally, i.e. a few times a year, while 3 respondents do so rarely, once or twice a year. None of the respondents stated that they never buy clothes in physical stores.

These results clearly show that physical stores still represent the most important sales channel for purchases, as 106 visit them often or very often, confirming the strong presence of traditional shopping behavior despite the increasing presence of online shopping. Figure 3 shows how often respondents choose a mobile app as a place to make purchases.

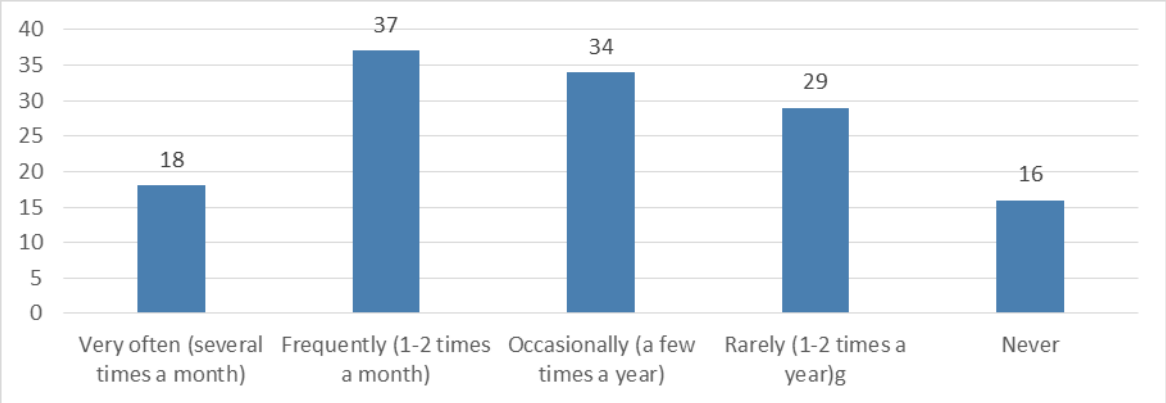


Figure 3: Mobile application as a sales channel

The results of the survey show that 8 respondents shop via mobile applications very often, i.e. several times a month. 37 respondents answered that they shop frequently, meaning once to twice a month. 34 respondents described shopping via mobile applications as occasional, while 29 do so rarely, once to twice a year. 16 respondents stated that they never shop via mobile applications.

The results show that the use of mobile applications for shopping is quite widespread among respondents, as 89 shops in this way often, very often or at least occasionally. Nevertheless, the data show that this channel is not yet dominant, which indicates the possibility of further growth in the future, especially considering the increasing digitalization and accessibility of mobile platforms.

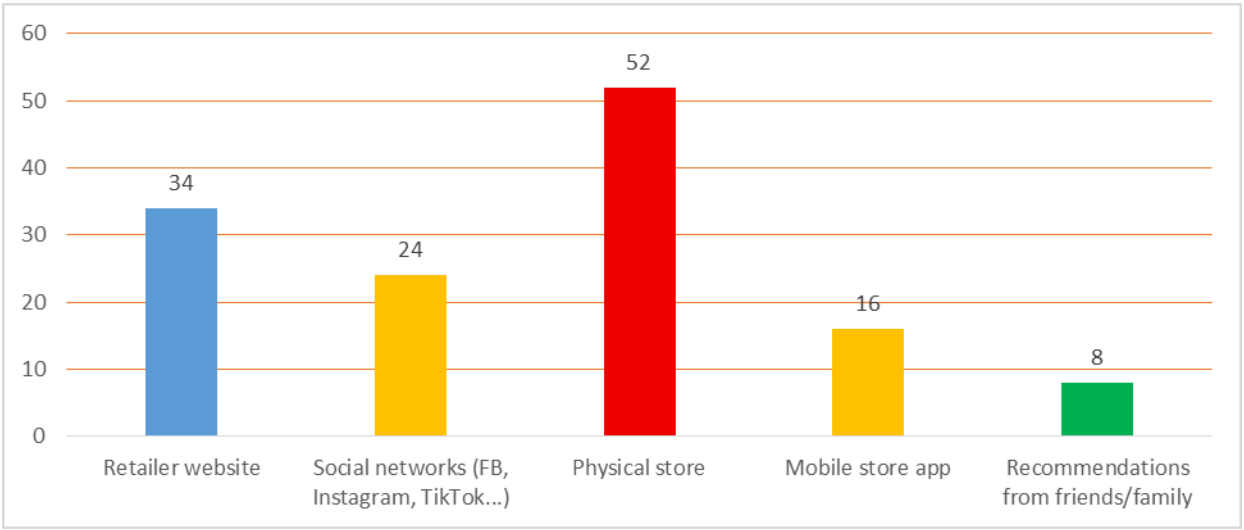


Figure 4: Using pre-purchase channels

The results show that most respondents visited a physical store before making a purchase, namely 52 respondents. The second most frequently used channel was the retailer's website, which was used by 34 respondents. Social networks (Facebook, Instagram, TikTok and similar) were chosen as a source of information before making a purchase by 24 respondents. A smaller proportion of respondents used the abundant store applications, namely 16 respondents. Recommendations from friends and family were trusted by 8 respondents.

The results show that despite widespread digitalization, respondents still strongly trust physical shopping experiences, while digital channels and social networks represent an important but slightly less frequently used source of information. We were also interested in how often respondents use different sales channels (omnichannel).

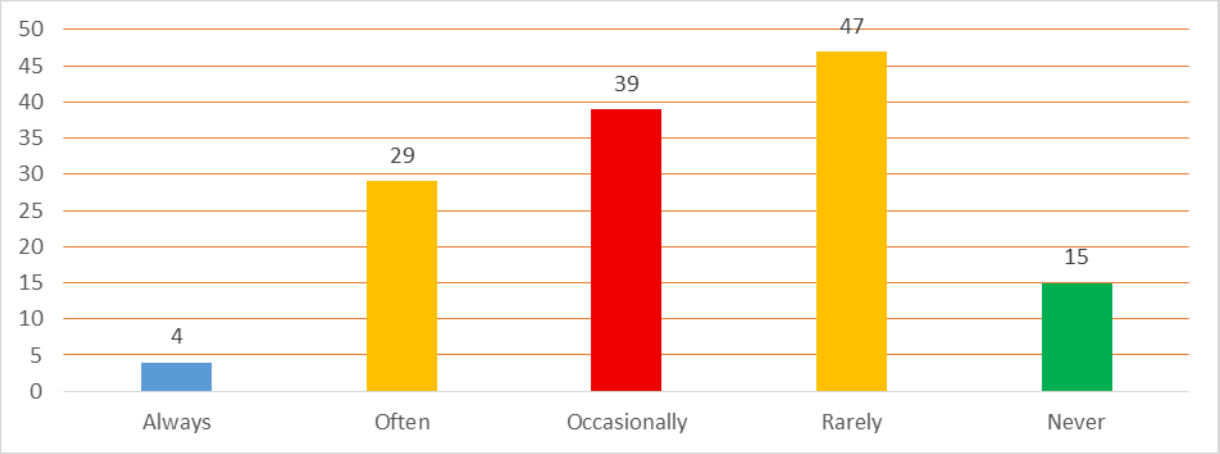


Figure 5: Frequency using omnichannel strategy

The results show that only a small proportion of respondents do this always, namely 4 respondents. 29 respondents often use a combination of channels, while 39 respondents use it occasionally. The largest proportion of respondents rarely use a combination of channels, namely 47 respondents, while 15 respondents never use a combination of channels.

The results show that the majority of respondents do not combine purchasing channels regularly, which suggests that despite the availability of digital channels, physical stores remain an important source for the final purchase, while the integration of multiple channels is still limited.

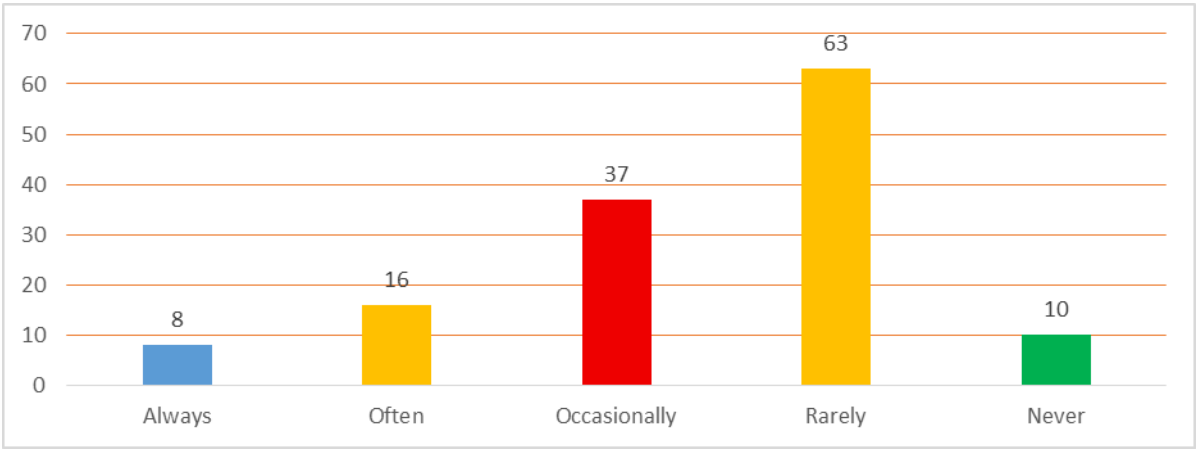


Figure 6: Using omnichannel for a single purchase

When asked about the frequency of using multiple channels (web, physical store, mobile app) within the framework of a single purchase, the results showed that most respondents use this practice rarely. As many as 63 respondents answered that they rarely use multi-channel shopping, while 37 do it

occasionally. Only a smaller proportion turned out to be more pronounced users of the multi-channel approach, namely 16 respondents stated that they do it often, and only 8 respondents always combine multiple channels in the purchasing process. On the other hand, ten respondents never use more than one channel in the purchase process.

The results show that although multi-channel shopping exists, it is still more of an exception than a rule for users, as most tend to use one primary channel, either due to simplicity, habits, or lack of perceived benefits in combining different sales channels.

CONCLUSION

Omnichannel marketing in retail is no longer the future, it is the present. As the research has shown, consumers expect flexibility, personalization and consistency. Companies that do not take these expectations into account risk losing relevance and market share. However, the concept of omnichannel itself is not enough; the quality of implementation is critical. The fact that respondents did not perceive a significant improvement in the user experience clearly shows that retailers must go beyond just being present on multiple channels and provide a truly integrated, seamless experience.

Key success factors include technological maturity with a robust infrastructure and advanced tools, organizational readiness with a culture of collaboration and agility, user focus with an understanding of needs and expectations, and continuous improvement through testing, learning and adaptation. The research confirmed the transformative potential of advanced technologies and the key role of social media, opening up new opportunities for retailers who are ready to invest in digital transformation.

The omnichannel approach thus represents a bridge between the digital and physical worlds, where the focus is no longer on the channel itself, but on the person with their voice, their needs and their expectations. This is the fundamental paradigm that will define the success of retailers in the coming decade. Those who successfully implement omnichannel strategies not only gain loyal customers but also create a long-term competitive advantage that is difficult to replace in the digital age. The future of retail is omnichannel, user-centric and supported by technology. The question is no longer whether, but how well and how quickly companies will adapt to this. At a time when digitalization is flooding all spheres of human life and when the boundaries between the physical and virtual worlds are increasingly blurred, omnichannel marketing is not only a competitive advantage, but a necessity for survival and success in the modern retail environments.

REFERENCES

Anozie, U., Onyenahazi, O., Ekeocha, P., Adekola, A., Ukadike, C., & Oloko, O. (2024). Advancements in artificial intelligence for omnichannel marketing and customer service: Enhancing predictive analytics, automation, and operational efficiency. *International Journal of Science and Research Archive*, 1621–1629.

Camphouse. (2025). *Omnichannel marketing: Strategies, tips, and best practices*. https://camphouse.io/blog/omnichannel-marketing

Dang, Y. (2022). *Key factors in designing successful retail omnichannel* (Bachelor's thesis, LAB University of Applied Sciences). https://www.theseus.fi/bitstream/10024/753277/4/Dang_Yen.pdf

Lazaris, C., Vrechopoulos, A., Doukidis, G., & Fraidaki, A. (2015). Mobile apps for omnichannel retailing: Revealing the emerging showroom phenomenon. In *MCIS 2015 Proceedings*.

Mirzabeiki, V., & Saghiri, S. (2021). Omni-channel integration: The matter of information and digital technology. *International Journal of Operations & Production Management, 41*(10), 1660–1710.

Mosquera, A., Olarte Pascual, C., & Juaneda Ayensa, E. (2017). Understanding the customer experience in the age of omni-channel shopping. *Icono 14, 15*(2), 166–185. https://icono14.net/ojs/index.php/icono14/article/view/1070

Payne, E. M., Peltier, J. W., & Barger, V. A. (2017). Omni-channel marketing, integrated marketing communications, and consumer engagement: A research agenda. *Journal of Research in Interactive Marketing, 11*(2), 185–197. https://doi.org/10.1108/JRIM-08-2016-0091

Session D: ECONOMY

Papers (pp. 229-272):

Mohammad Anisseh, Rohullah Sajed
EVALUATING THE IMPACT OF DOLLAR AUCTION POLICY ON EXCHANGE RATE STABILITY IN AFGHANISTAN: AN ARDL APPROACH ...229

Marijana Dukić Mijatović, Andrea Ivanišević, Otilija Sedlak, Aleksandra Marcikić Horvat, Biljana Pajin
DIGITALIZATION AS A DRIVER OF CIRCULAR ECONOMY TRANSITION: A CONCEPTUAL FRAMEWORK FOR EMERGING ECONOMIES ...236

Branimir Kalaš, Ines Đokić
FINANCIAL CONSIDERATIONS OF AI ADOPTION IN HIGHER EDUCATION ...241

Mila Krivokuća
ENTREPRENEURSHIP AND CORPORATE SOCIAL RESPONSIBILITY ...245

Mila Krivokuća
ENTREPRENEURSHIP AND THE CONCEPT OF SUSTAINABLE DEVELOPMENT ...251

Vladimir Marković
HYPERCOMPETITIVE RELATIONS AND THE NECESSITY OF BENCHMARKING IN DOMESTIC ENTERPRISES ...257

Vladimir Milošev, Dubravko Marić, Ali Reza Afshari
NETWORK MODEL OF REGIONAL ENTREPRENEURIAL ECOSYSTEMS IN SERBIA ...262

Miloš Pjanić, Jelena Andrašić, Milica Inđić, Mirela Mitrašević
FACTORS IN THE DEVELOPMENT OF THE LIFE INSURANCE MARKET IN THE REPUBLIC OF SERBIA ...267

EVALUATING THE IMPACT OF DOLLAR AUCTION POLICY ON EXCHANGE RATE STABILITY IN AFGHANISTAN: AN ARDL APPROACH

DOI: 10.5937/EMC26229A

Mohammad Anisseh
Imam Khomeini International University, Department of Industrial Management, Qazvin, Iran
E-mail: manisseh@soc.ikiu.ac.ir
Rohullah Sajed
Takhar University, Faculty of Economics, Department of Management and Business Administration, Takhar, Afghanistan

ABSTRACT

This study evaluates the efficacy of the Central Bank of Afghanistan's dollar auction policy in stabilizing the Afghani exchange rate, utilizing an autoregressive distributed lag (ARDL) model. Based on 17 years of annual data, it quantifies the relationship between dollar supply (exogenous variable) and nominal exchange rate volatility (endogenous variable). Quantitative analysis employed secondary data, with descriptive statistics via Excel and ARDL bounds testing/estimation in EViews. Results reveal a significant negative correlation: a one-million-unit increase in dollar supply yields a 0.003% exchange rate depreciation. The adjusted R^2 (0.5273) indicates dollar supply explains over 52% of Afghani-dollar fluctuations. Findings illuminate monetary transmission in emerging economies, highlighting the Central Bank's role in exchange rate management. By calibrating auction impacts, this research informs targeted interventions for macroeconomic stability and currency preservation, with implications for policymakers and econometric modeling of central bank strategies.

Key words: Central Bank of Afghanistan, Dollar auction policy, Exchange rate stability, Afghani currency, ARDL model

INTRODUCTION

Monetary policy is a central tool of macroeconomic governance, with central banks responsible for its formulation and implementation to achieve objectives such as price stability, economic growth, and exchange rate stability. This study evaluates the efficacy of the Central Bank of Afghanistan's (CBA) dollar auction mechanism in maintaining exchange rate stability and preserving the Afghani's value.

The CBA employs various monetary tools—including open market operations and foreign exchange policies—to regulate inflation and sustain currency valuation (Gohary, 2016). The deployment of monetary policy instruments, particularly open market operations and dollar auction mechanisms, has assumed considerable significance in inflation management and currency value preservation in recent years (Noor abad, 2014). However, Afghanistan's underdeveloped domestic securities market (due to fiscal deficits financed primarily through external assistance) has made foreign exchange intervention, particularly dollar auctions, the predominant monetary policy instrument.

Afghanistan faces severe currency instability, with the Afghani experiencing its most significant depreciation since the introduction of new currency denominations in 2002. The country has adopted a monetary policy framework premised on liquidity management, grounded in the quantity theory of money—which posits a direct proportional relationship between monetary aggregates and the general price level (Massoud, 2018). This depreciation affects both imported and domestically produced goods, undermining civilian welfare. While exogenous factors contribute, suboptimal monetary policy implementation by monetary authorities also plays a role. This research examines whether the CBA's

dollar auction mechanism has effectively stabilized the Afghani against the US dollar and whether it offers sustainable long-term benefits or if alternative policies should be considered given Afghanistan's socioeconomic context (Ghafari, 2018). Specifically, it addresses:

- How the dollar auction policy has affected Afghan currency stability,
- Whether alternative tools exist to prevent currency fluctuations,
- The policy's effectiveness in stabilizing the Afghani's value.

THEORETICAL FRAMEWORK, AND RESEARCH BACKGROUND

Monetary policies are measures employed by central banks to control economic activity, divided into expansionary (increasing money supply) and contractionary (decreasing money supply) policies (Nikjou, 2018). Key objectives include price stability, economic growth, full employment, trade balance equilibrium, and interest rate stability. Under Article 2 of the Central Bank of Afghanistan law, the primary goal is domestic price stability, which requires maintaining exchange rate stability given Afghanistan's open economy with a trade deficit. The CBA operates under a managed floating exchange rate system, intervening to prevent sharp exchange rate fluctuations that would affect price levels (Kakar, 2017). Currency value depends on supply-demand factors, with government expenditures being the primary demand driver. Monetary policy formulation considers fiscal policy, seasonal changes, and real sector conditions to achieve price stability and reduce exchange rate fluctuations (Kakar, 2017).

- ***Liquidity (Monetary Base and Money in Circulation):*** The monetary base (reserve money) includes money in circulation, current accounts, and required reserves. Larger monetary base ratios indicate higher liquidity, inflation, and lower currency value. The CBA uses the quantity theory of money to set monetary base targets based on expected growth and inflation. Fiscal year targets included: 7% (2015, actual ~9 billion Afghanis below ceiling), 10% → 10.97% (2016, +3.16% vs. 2015), and 12% → 10.07% (2017, -0.96% vs. 2016), demonstrating relative management success. Money in circulation (all issued money except CBA vault cash) is the secondary operational target. Targets were: 7% (2015, actual below ceiling), 10% → 11% (2016, exceeded target), and 12% → showing 2.4% growth (demonstrating good management).
- ***Monetary Policy Tools:*** The CBA employs three main tools: exchange rate policy, legal reserves, and market operations policy.
- ***Exchange Rate Policy:*** This stabilizes domestic currency value against foreign currencies. Afghanistan faces challenges including insufficient foreign currency and negative trade balance, creating high foreign currency demand. Foreign currency auctions (twice weekly: Saturdays and Tuesdays) balance supply-demand, control liquidity, and prevent inflation. This is effective short-term but may negatively impact exchange reserves long-term; the CBA is expanding capital note sales (Masoud, 2018). Foreign reserves increased from $245 million (2002) to $5 billion (2010), now covering 13–14 months of imports. Gold reserves rose from 244 million dollars (2002, $350/oz) to 955 million dollars (2010, $1,402/oz).
- ***Exchange rate policy includes:*** Qualitative Policy: Distinguishes "good" (freely convertible, high credibility) currencies. Interest Rate Spread Policy: When balance of payments is negative and foreign interest rates exceed domestic rates, the CBA pays the difference to lenders, encouraging domestic investment and maintaining money market liquidity (Masoud, 2018)
- ***Legal Reserves:*** Legal reserves include gold, precious metals, convertible foreign currencies, foreign bank accounts, IMF Special Drawing Rights (SDRs), and forward purchase/swaps. The CBA maintains adequate reserves for monetary/exchange rate policies and international transactions. If reserves decrease to insufficient levels, the CBA implements corrective measures and reports to the Council of Ministers (Masoud, 2014).
- ***Market Operations Policy (Securities Policy):*** The CBA buys/sells securities to control money supply, pursue liquidity goals, finance government, and activate money/capital markets. During inflation, it sells securities; during money shortages, it purchases them. Capital Notes (28-day and 182-day maturities, introduced 2014 at 50 million Afghanis each) are sold weekly to commercial banks. By 2008, commercial bank investment reached ~20 billion Afghanis with

average interest rates of 9.39% (28-day) and 10.57% (182-day). In 2008, 52.947 billion Afghanis (28-day) and 12.98 billion Afghanis (182-day) were auctioned, with 1.539 billion Afghanis paid to winning banks (Masoud, 2018).

- ***Central Bank as Financing Agent:*** For Economic Entities: Purchases debt securities/bills from various sectors. For Government: Short/long-term financing through current accounts or purchasing government debt securities. Both government and CBA must align policies and avoid monetary inflation (Masoud, 2018). This research focuses on the market operation policy component pertaining to dollar supply policy.

Theoretical Framework of the Research

Generally, there are two different theories regarding monetary policies, which are as follows:

- Keynesian View: Keynes and his supporters believe that monetary policies do not have the necessary effectiveness in developing economic activities and investment. Instead, fiscal policies within the framework of government expenditure and taxation can play a more significant role during recessionary and inflationary conditions.
- Monetarist View: Monetarists do not consider government intervention in the economy to be beneficial beyond maintaining public order and security. They believe that the best way to combat fluctuations such as inflation and economic recession is through monetary policy. Proponents of monetary policies do not place much value on fiscal policies (Pazhouyan, 2002).

Research Background

Previous studies on monetary policy and exchange rates demonstrate significant relationships between these variables. Mahmoud Hossemand et al. (2012) found that short-term and long-term monetary policy variables exert positive, statistically significant effects on exchange rates in Iran. Similarly, Sharifi Renai et al. (2011) reported that increased money supply raises GDP in the short run but has negative long-term effects, while increasing prices in both periods through the lending channel. Trust in monetary authorities also matters: Keshavarz and Parsa (2019) concluded that greater trust enhances investment, employment, and economic growth in Iran. Regarding Afghanistan specifically, Shaghayegh (2018) argued that the dollar auction policy benefits only a limited segment of society while causing broader purchasing power decline through rising commodity prices. Kakar (2017) examined factors affecting Afghan currency instability (2010–2014) using library and field research. Findings showed nominal GDP had no significant effect on depreciation, though declining investment and economic activity contributed to value loss. Inflation also had no direct effect during the study period. Critically, Kakar (2017) identified the dollar auction mechanism as a contributing factor to currency depreciation, primarily because insufficient market demand created unmet foreign exchange demand and currency supply shortages. Additional factors included political/economic instability, global US dollar appreciation, inadequate monetary backing, widespread foreign currency use in domestic transactions, and the free-floating exchange rate regime. Expert interviews revealed structural weaknesses: supply-demand imbalances, consumption-oriented economy, low production/exports, and limited foreign currency inflows significantly contributed to the currency's decline.

RESEARCH METHODOLOGY

This research is applied in purpose, descriptive-survey in methodology, and utilizes quantitative data collected from secondary sources.

- ***Variables:*** Independent variable: Dollar supply (SUD)**,** Dependent variable: Exchange rate of the dollar against the Afghan currency (EX-rate)
- ***Research Tools:*** For descriptive analysis in this research, Excel is used, and EViews software is employed for model testing.

– ***Research Model:*** The study employs the following regression model: EX-rate=β1+β2× (SUD) +u^I , EX-rate=β1+β2×(SUD)+u^i , where EX-rate = Exchange rate of the dollar, β1 = Constant, β2 = Coefficient of the variable, SUD = Dollar supply, u^i\hat{u}_iu^i = Residual error components in the model. This model examines the relationship between dollar supply and exchange rate stability to evaluate the effectiveness of the Central Bank of Afghanistan's dollar auction mechanism.

RESEARCH FINDINGS

This study examines the impact of the Central Bank of Afghanistan's dollar auction policy on Afghan currency stability using the ARDL model and annual data (17 years) from the Central Bank. This section provides descriptive analysis of the variables across years. As shown in Figure 1, the Central Bank of Afghanistan's dollar supply for currency stability increased from $445 million (2004) to a peak of $3.41 billion (2013), then fluctuated between $1.92–2.79 billion (2014–2020), ending at $2.12 billion (2020). Key movements include steady growth (2004–2009: $445M→$2.05B), a peak in 2013, and relative stabilization at $2–2.8 billion thereafter.

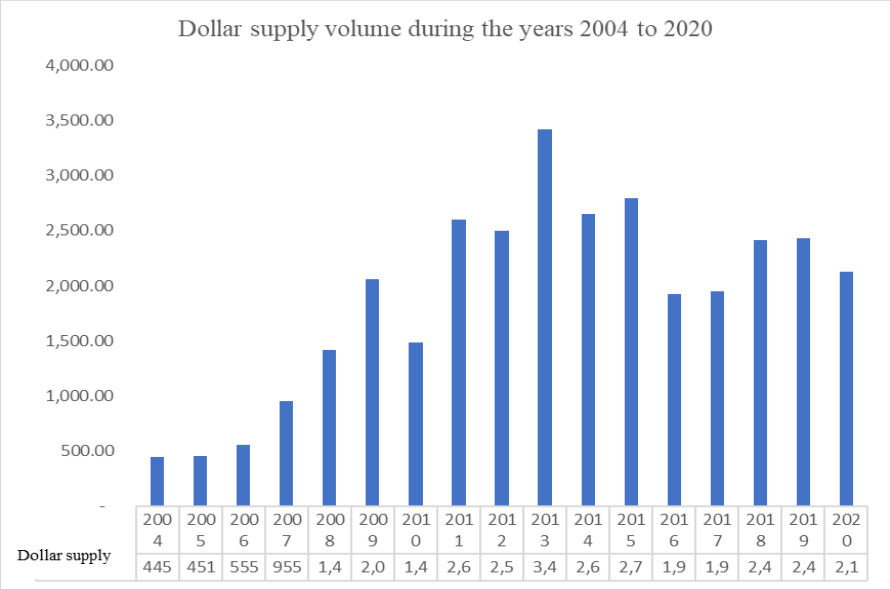


Figure 1: Dollar supply volume during the years 2004 to 2020

As shown in Figure 2, the exchange rate (Afghanis per dollar) rose from 44 (2004) to 77.1 (2020), indicating gradual currency depreciation. The rate remained relatively stable (44–51 Afghanis) during 2004–2012, then increasingly depreciated from 56.4 (2013) to 78.4 (2019), with a slight improvement to 77.1 (2020). The exchange rate continued rising until 2023, but with improved central bank policies, the Afghan currency has since achieved near-stability.

Statistical Explanation of Variables

Model estimation results show that the Central Bank's dollar supply significantly impacts the stability of the Afghan currency (Afghani). ***Coefficient (Impact):*** For every 1 million unit increase in the dollar supply, the exchange rate decreases by 0.003%. ***Explanatory Power (R^2):*** The coefficient of determination (0.5273) indicates that the dollar supply variable accounts for 52.73% of the Afghani's value stability against the US dollar (Tables 1 and 2).

Model estimation results indicate that the Central Bank's dollar supply significantly impacts the stability of the Afghan currency (Afghani):

– ***Marginal Effect:*** Every 1 million unit increase in the dollar supply corresponds to a 0.003% decrease in the exchange rate.

– ***Goodness of Fit (R^2):*** The coefficient of determination (0.5273) shows that the dollar supply variable accounts for 52.73% of the Afghani's value stability against the US dollar

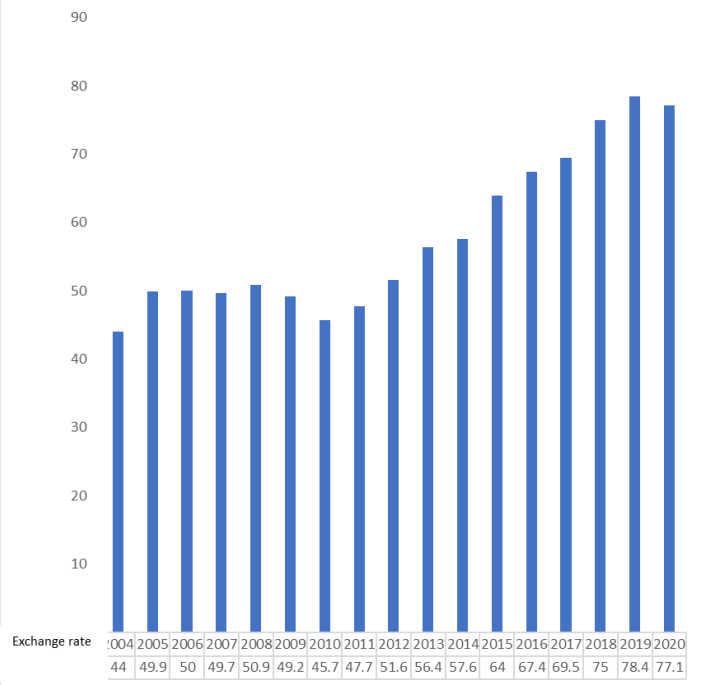


Figure 2: Exchange rate of the dollar against the Afghan Afghani during the years 2004 to 2020

Table 1: Results of the Stationarity Test (Augmented Dickey-Fuller Unit Root Test)

Variables and Hypotheses			At Level			At First Difference			At Second Difference		
Variables	**Hypothesis**		**T-statistic** Critical Value	**P-value**	**Result**	**T-statistic** Critical Value	**P-value**	**Result**	**T-statistic** Critical Value	**P-value**	**Result**
Exchange Rate of the Dollar	Null hypothesis	The exchange rate of the dollar is non-stationary	0.247	0.9668	Accepted	-2.8018	0.0815	Accepted	-3.8693	0.0138	Rejected
	Alternative hypothesis	The exchange rate of the dollar is stationary	-3.03		Rejected	-3.081		Rejected	-3.1199		Accepted
Dollar Supply Amount	Null hypothesis	The dollar supply amount is non-stationary	-1.88	0.3297	Accepted	-5.4483	0.0007	Rejected			
	Alternative hypothesis	The dollar supply amount is stationary	-3.06		Rejected	-3.081		Accepted			

As shown in Figure 3, at the 95 percent confidence level and 5 percent error rate, the dollar auction trend and the stability of the Afghan currency exhibit both positive and negative changes from 2012 to 2020. The CUSUM method is particularly effective in detecting small shifts in the mean that may not be identified by conventional control charts. By cumulatively measuring deviations from the target mean, it enables rapid detection of changes in a process. Positive CUSUM indicates increases in the

mean, whereas negative CUSUM indicates decreases; when the cumulative value exceeds a specified threshold, it signals a significant structural change. Figure 4 presents the CUSUM of squares test, a statistical technique used to detect changes in the variance or dispersion of a process. Overall, the chart indicates that this method is effective for identifying and monitoring variability in data and processes. It can therefore assist Central Bank analysts in responding promptly to unexpected fluctuations in monetary policy outcomes.

Table 2: Results of the Stationarity Test (Augmented Dickey-Fuller Unit Root Test)

Results of Model Estimation 2.1 ARDL				
Variables	Model Coefficients	P-value	R-squared	0.5273
Constant (C)	-0.2797	0.7199		
Dollar Supply	-0.003	0.0649		
Econometric Model of the Research			Y= -0.2797 - 0.0030X +	

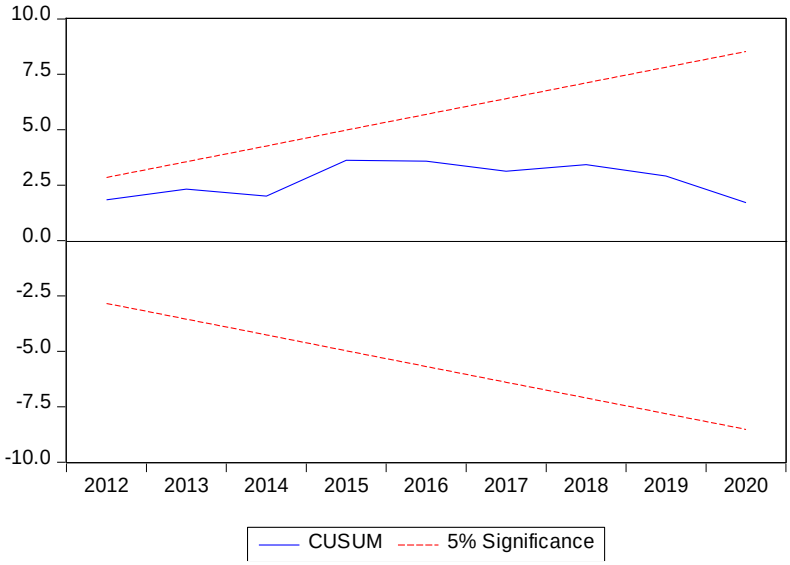


Figure 3: CUSUM Analysis of the Stability of the Afghani Currency and Dollar Auction Policy, 2012–2020

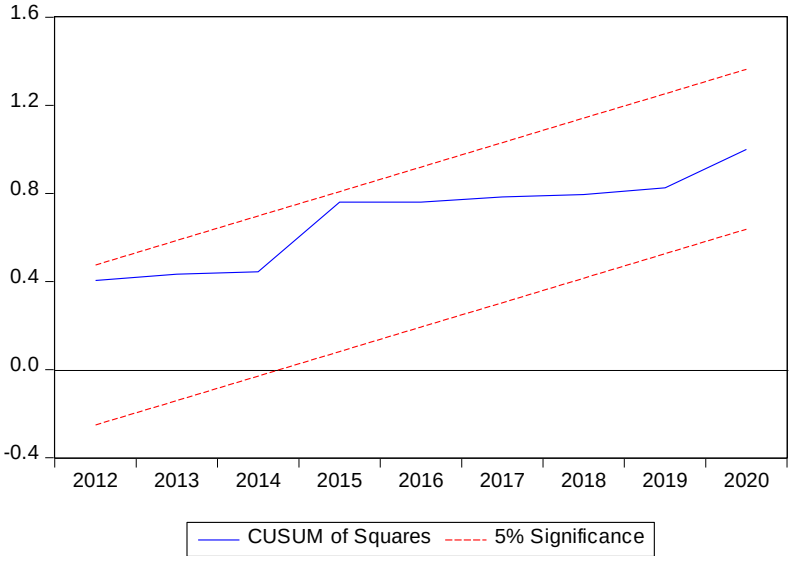


Figure 4: CUSUM of Squares Analysis of Structural Stability in the Dollar Auction Model

CONCLUSION

Central banks play a vital role in economic growth and development through the implementation of monetary policy instruments, including discount policy, open market operations, exchange rate policy, and reserve requirements. Their primary objectives include maintaining price stability, regulating money supply, achieving full employment, and ensuring financial market and currency stability.

In Afghanistan, the Central Bank is responsible for monetary policy formulation and implementation, with a primary focus on price stability alongside broader macroeconomic goals such as employment, production, and export expansion. Currency value stability is a critical issue in monetary economics, as it reflects a country's economic and political strength. However, the Afghan currency has experienced pronounced instability and volatility in recent years, particularly during the National Unity Government period, with persistent depreciation against the US dollar.

The Central Bank of Afghanistan employs instruments such as market operations and dollar supply policies to control inflation and preserve the Afghani's value. This study examines the effectiveness of these monetary policies using 17 years of time-series data. Methodologically, the research is applied, descriptive-survey in nature, and quantitative, relying on secondary data sources. Consistent with monetary theory, the findings reveal a significant relationship between monetary policy and exchange rate stability. Specifically, a one-million-unit increase in dollar supply is associated with a 0.003 percent decline in the exchange rate, with the dollar supply variable explaining over 52 percent (R^2 = 0.5273) of Afghani-dollar exchange rate fluctuations.

REFERENCES

Central Bank of Afghanistan. (2004). *Annual report 2004*. Kabul, Afghanistan.

Central Bank of Afghanistan. (2005–2019). *Annual reports*. Kabul, Afghanistan.

Central Bank of Afghanistan. (2017–2019). *Strategic plan 2017–2019*. Kabul, Afghanistan.

Da Afghanistan Bank. (2004–2020). *Annual reports*. Kabul, Afghanistan.

Faraji, Y. (2018). *Money and banking* (23rd ed.). Business Publishing Company.

Ghafari, A. Z. (2018). *Exchange rate instability in Afghanistan*. Saeed Publishing.

Ghauri, A. R. (2016). *Evaluation of monetary policy implementation in Afghanistan*. Kabul University.

Gohary, A. S. (2016). *Monetary policy tools in Afghanistan*. Karwan Publishing.

Hossemand, M., et al. (2012). The relationship between monetary policy and exchange rate in Iran. *Journal of Economic Studies, 14*(2), 45–62.

Kakar, A. (2017). *Factors of instability in Afghan currency value* (2nd ed.). Said Publications.

Keshavarez, H., & Parsa, H. (2019). The impact of trust in monetary authorities on the effectiveness of monetary policy in Iran. *Iranian Economic Journal, 21*(3), 101–120.

Kooster, W. (2014). *Monetary economics* (A. J. Shaibi, Trans.; 4th ed.). Resalat Publications.

Masood, S. (2014). *Money and credit* (5th ed.). Karwan Press.

Masood, S. (2018a). *Monetary economics*. Yousufzadeh Publications.

Masood, S. (2018b). *Monetary policies* (3rd ed.). Yousufzadeh Publications.

Nikjou, M. R. (2018). *Principles of monetary policy*. Academic Publications.

Noor Abad, H. (2018). Monetary policy and exchange rate stability in Afghanistan. *Faculty of Economics Journal, Kabul University*.

Official Gazette. (2003). *Banking law of Afghanistan*. Kabul, Afghanistan.

Pazhouyan, J. (2002). *Money, currency and banking*. Samt Publications.

Shaghayegh, M. M. (2018). *Exchange rate policies of the Central Bank of Afghanistan*. Research Publication.

Sharifi Renai, H., et al. (2011). The impact of monetary policy on gross domestic product (GDP) through the lending channel. *Economic Research Journal, 9*(1), 77–95.

DIGITALIZATION AS A DRIVER OF CIRCULAR ECONOMY TRANSITION: A CONCEPTUAL FRAMEWORK FOR EMERGING ECONOMIES

DOI: 10.5937/EMC26236D

Marijana Dukić Mijatović
University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Republic of Serbia
Andrea Ivanišević
University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Republic of Serbia
E-mail: andreai@uns.ac.rs
Otilija Sedlak
University of Novi Sad, Faculty of Economics Subotica, Republic of Serbia
Aleksandra Marcikić Horvat
University of Novi Sad, Faculty of Economics Subotica, Republic of Serbia
Biljana Pajin
University of Novi Sad, Faculty of Technology, Novi Sad, Republic of Serbia

ABSTRACT

The transition from a linear to a circular economy (CE) presents significant managerial challenges, particularly for small and medium-sized enterprises (SMEs) in emerging economies. While digitalization is widely recognized as a key enabler of CE practices, its role in supporting business model transformation remains underexplored in developing country contexts. This paper proposes a conceptual framework for integrating digital tools into the implementation of the circular economy, drawing on the case of Serbia. Applying a Quadruple Helix model — encompassing academia, government, industry, and civil society – the paper identifies the main barriers to CE adoption, including limited managerial awareness, weak regulatory incentives, and insufficient digital infrastructure. As a practical solution, the paper proposes a digital waste exchange platform enabling SMEs to advertise surplus materials as inputs for other enterprises, thereby extending product lifecycles and reducing waste. The proposed framework offers actionable guidance for managers and policymakers navigating the dual challenges of the digital and green transitions, and lays the groundwork for future empirical research in this domain.

Key words: Circular economy, Digitalization, SMEs, Sustainable business models, Emerging economies

INTRODUCTION

The transition from a linear to a circular economy (CE) has become a central topic in modern sustainability research. The traditional model "take–make–dispose" is shown to be increasingly unsustainable, due to resource depletion and rising waste generation (Busu, 2019; Kirchherr, Reike & Hekkert, 2017). Recent projections suggest that global resource demand could significantly increase by 2050, further intensifying environmental pressures (Fan & Fang, 2020).

The CE promotes resource efficiency, waste minimization and reuse of materials, contributing to environmental, economic and business benefits (Diemer & Dierickx, 2020; Gravagnuolo, Angrisano & Fusco Girard, 2019). On the other hand, digitalization has emerged as a key enabler of CE practices, allowing organizations to monitor resource flows, optimize processes and enhance transparency (Parida, Sjödin & Reim, 2019; Antikainen, Uusitalo & Kivikytö-Reponen, 2018). This is particularly important for emerging economies, where structural limitations may slow down the transition.

DIGITALIZATION AND CIRCULAR ECONOMY IN EMERGING ECONOMIES

Digital technologies play a critical role in enabling CE practices by improving data availability, traceability and decision-making (Kintscher, Lawrenz, Poschmann, & Sharma, 2020). Through digital tools, companies can track materials, identify inefficiencies and facilitate reuse and recycling processes.

Hence, research shows that digitalization supports new business models aligned with CE principles, such as product-service systems and resource-sharing platforms (Bressanelli, Adrodegari, Perona & Saccani, 2018; Okorie, Salonitis, Charnley, Moreno, Turner & Tiwari, 2018). Additionally, industry 4.0 technologies contribute to the development of more efficient and sustainable production systems (Dantas, De-Souza, Destro, Hammes, Rodriguez & Soares, 2020; De Sousa Jabbour, Jabbour, GodinhoFilho & Roubaud, 2018).

However, in emerging economies, the implementation of digital solutions is often constrained by lower levels of technological development and limited access to infrastructure (Ranta, Aarikka-Stenroos & Väisänen, 2021).

BARRIERS TO CIRCULAR ECONOMY TRANSITION IN EMERGING ECONOMIES

The transition to a CE in emerging economies is hindered by several structural and institutional barriers. One of the main challenges is the limited awareness of CE principles among businesses, which often fail to recognize the potential value of waste as a resource (Popović, Ivanović-Đukić & Miljić, 2022). Regulatory and institutional shortcomings also present significant obstacles, thus, the lack of coherent policies and incentives reduces the motivation for companies to invest in CE solutions (Busu, 2019).

Additionally, insufficient infrastructure and a lack of skilled workforce limit the adoption of digital technologies which are necessary for CE implementation (Chateau, Bibas & Lanzi, 2018). Another important issue is the unclear value proposition of data integration systems, which makes it difficult for organizations to fully leverage digital tools in CE practices (Kintscher et al., 2020).

CONCEPTUAL FRAMEWORK FOR DIGITAL-DRIVEN CIRCULAR ECONOMY TRANSITION

To overcome these, above-mentioned challenges, this manuscript proposes a conceptual framework based on the integration of digital technologies and CE principles.

The framework is grounded in the Quadruple Helix model, which emphasizes collaboration between academia, industry, government, and civil society (Fogarassy & Finger, 2020). Hence, at its core is a digital platform that enables SMEs to exchange waste materials, transforming them into valuable inputs for other companies. Thus, this approach supports resource efficiency, reduces waste and promotes collaboration across sectors.

Digital platforms enhance transparency, improve data sharing, and facilitate the development of circular business models (Antikainen et al., 2018; Ranta et al., 2021). From a managerial perspective, the mentioned framework enables organizations to optimize resource use and reduce operational costs. From a policy perspective, it highlights the importance of digital infrastructure and supportive regulatory environments.

DIGITAL PLATFORMS AND BUSINESS MODEL INNOVATION IN CIRCULAR ECONOMY

The transition toward a CE is not solely a technological shift, but also a transformation of traditional business models. In this context, digital platforms play a crucial role by enabling new forms of value creation, exchange and collaboration among stakeholders.

Unlike conventional linear models, circular business models require continuous interaction between producers, consumers and other actors involved in the product lifecycle. Digital platforms facilitate this interaction by serving as intermediaries that connect supply and demand for secondary resources.

In doing so, they contribute to the creation of, so-called, closed-loop systems in which materials are reused and redistributed rather than discarded.

One of the key contributions of digital platforms is their ability to support the emergence of platform-based ecosystems. These ecosystems enable multiple actors to participate simultaneously, creating network effects that enhance efficiency and scalability. For example, companies can use digital platforms to share information about available waste streams, identify potential partners and coordinate logistics related to material exchange. This will reduce transaction costs and increases the feasibility of circular practices (Van Capelleveen, Amrit, Zijm, Yazan & Abdi, 2021). Furthermore, digital platforms enable the integration of data-driven decision-making into circular business models. By collecting and analyzing data on material flows, organizations can identify inefficiencies, predict demand for secondary resources and optimize resource allocation. This aligns with the broader trend of digital transformation, where data becomes a key strategic asset in achieving sustainability goals (Okorie et al., 2018).

Another important aspect is the role of digital platforms in supporting innovation, as well as, by providing access to shared resources and knowledge, platforms foster experimentation and the development of new circular solutions. Thus, this is particularly relevant for SMEs, which often lack the internal capacity to invest in innovation independently. Through participation in digital ecosystems, SMEs can leverage external knowledge and collaborate with other stakeholders, including research institutions and technology providers. In addition, digital platforms contribute to transparency and trust among stakeholders. In CE systems, where materials may "change hands" multiple times, the availability of reliable information is essential. Digital tools enable traceability of materials, ensuring that quality standards are met and reducing uncertainty in transactions. This, in turn, encourages broader participation in circular practices (Turner, Moreno, Mondini, Salonitis, Charnley, Tiwari & Hutabarat, 2019).

However, the successful implementation of platform-based solutions depends on several factors, such as user adoption, data standardization and interoperability between systems. Without a critical mass of users, platforms may fail to generate sufficient value. Therefore, strategies for user engagement and incentives for participation are essential components of digital platform development in the CE context.

Overall, digital platforms represent a key mechanism for enabling business model innovation in the CE. By facilitating collaboration, improving information flow and supporting data-driven decision-making, they provide a foundation for more sustainable and resilient economic systems.

METHODOLOGY

Research problem and subject of the study

The transition from a linear "take-make-dispose" economic model to a CE model represents a critical sustainability goal, especially because its execution faces significant friction in developing contexts. While digitalization is theoretically recognized as a powerful catalyst for circular practices, there is a distinct lack of actionable mechanisms tailored for SMEs, operating within institutional and infrastructural constraints. Consequently, the main subject of this study is the crossroad of digital tool deployment and circular business model transformation within an emerging economy framework, focusing specifically on the Republic of Serbia.

Research questions and objectives

The main goal of this paper is to construct a comprehensive conceptual framework that identifies how digital technologies can practically drive the CE transition under the specific socio-economic conditions of an emerging market. To achieve this, the study addresses the following research questions:

RQ1: What are the primary structural, institutional and technological barriers that disrupt SMEs in emerging economies from adopting circular economy principles?
RQ2: How can a digital platform be structurally aligned with the Quadruple Helix model to facilitate waste-to-resource exchanges among distributed market participants?
RQ3: In which ways does data-driven decision-making via digital intermediaries raise business model innovation and economic resilience for small-sized enterprises?

Methodological approach

This study employs a qualitative and conceptual research design based on modern literature synthesis and framework development. The methodological flow is implemented in three distinct phases:

I. *Information synthesis and barrier identification* – systematic review of contemporary literature (traverse CE definitions, industry 4.0 applications and institutional economics) was conducted to map out the basic friction points in developing nations;
II. *Structural modeling (Quadruple Helix)* – using the Quadruple Helix framework as a basic lens, it's mapped out the required multi-stakeholder ecosystem. Thus, this involved analyzing the interdependent roles of academia, government, industry and civil society in overcoming the identified adoption barriers;
III. *Conceptual artifact design* – deductive reasoning was employed to design a functional solution, a digital waste exchange platform framework. This platform serves as a conceptual bridge, transforming theoretical multi-sector collaboration into a practical tool for secondary resource optimization and transaction cost reduction.

CONCLUSION

This paper examines the role of digitalization as a driver of CE transition, with a special focus on emerging economies. The analysis has revealed that, while the CE offers significant environmental and economic benefits, its implementation is often hindered by structural, institutional and technological barriers.

Digitalization emerges as a critical enabler in addressing these challenges. Hence, through the use of digital platforms, organizations can improve resource efficiency, enhance collaboration and develop innovative business models that support circular practices. In particular, the proposed framework highlights the importance of integrating digital tools with stakeholder collaboration, as emphasized by the Quadruple Helix model.

The case of emerging economies, such as Republic of Serbia, illustrates both the opportunities and constraints associated with this transition. Limited awareness, insufficient infrastructure and regulatory gaps remain significant obstacles. But, however, the development of digital platforms for resource exchange presents a practical and scalable solution, especially for SMEs. From a managerial perspective, adopting digital circular solutions can lead to cost reduction, improved efficiency and increased competitiveness. Thus, from a policy perspective, creating a supportive environment through investments in digital infrastructure, regulatory alignment and capacity building is essential. The integration of digitalization and CE principles contributes to organizational resilience by reducing dependence on finite resources and enabling more flexible and adaptive business operations.

Future research should focus on empirical validation of the proposed framework and further exploration of digital platform impacts across different sectors and economic contexts.

ACKNOWLEDGMENT

This research was supported by the Autonomous Province of Vojvodina, the Provincial Secretariat for Higher Education and Scientific Research, within the framework of financing a joint research project of scientific research organizations founded by the Autonomous Province of Vojvodina in cooperation with

scientific research organizations from the Republic of Srpska, through the project: *Sustainable Development and the Building of a Circular Economy through the Integration of Digital Technologies.* (Contract No.: 004351354 2025 09418 003 000 000 001 04 002)

REFERENCES

Antikainen, M., Uusitalo, T. & Kivikytö-Reponen, P. (2018). Digitalisation as an enabler of circular economy. *Procedia* CIRP 73, 45-49.

Bressanelli G., Adrodegari A., Perona M. & Saccani N. (2018). The role of digital technologies to overcome Circular Economy challenges in PSS Business Models: an exploratory case study. *Procedia* CIRP, 73, 216-221.

Busu, M. (2019). Adopting Circular Economy at the European Union Level and Its Impact on Economic Growth.*Social Sciences*, 8(5), 159, doi: 10.3390/socsci8050159.

Chateau, J., Bibas, R. & Lanzi, E. (2018). Impacts of Green Growth Policies on Labour Markets and Wage Income Distribution: A General Equilibrium Application to Climate and Energy Policies. *OECD Environment Working Papers*, No. 137, OECD Publishing, Paris, doi: 10.1787/ea3696f4-en.

Dantas, T. E. T., De-Souza, E. D., Destro, I. R., Hammes, G., Rodriguez, C. M. T. & Soares, S. R. (2020). How the combination of circular economy and industry 4.0 can contribute to-wards achieving the Sustainable Development Goals. *Sustainable Production and Consumption*, 26, 213-227, doi: 10.1016/j.spc.2020.10.005.

De Sousa Jabbour, A. B. L., Jabbour, C. J. C., GodinhoFilho, M. & Roubaud, D. (2018). In-dustry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, 270(1-2), 273-286.

Diemer, A. & Dierickx, F. (2020). Circular Economy, A new Paradigm for Europe? In Diemer, A., Nedelciu, E., Schellens, M., Morales, M. E., Oostdijk, M. (eds.), Paradigms, Models, Scenarios and Practices for Strong Sustainability, *Oeconomia Editions*, 161-179.

Fan, Y. & Fang, C. (2020). Circular economy development in China-current situation, evaluation and policy implementations. *Environmental Impact Assessment Review*, 84, 106441, doi: 10.1016/j.eiar.2020.106441.

Fogarassy, C. & Finger, D. (2020). Theoretical and practical approaches of circular economy for business models and technological solutions. *Resources*, 9, 76, doi: 10.3390/resources9060076.

Gravagnuolo, A., Angrisano, M. & Fusco Girard, L. (2019). Circular economy strategies in eight historic port cities: Criteria and indicators towards a circular city assessment frame-work. *Sustainability*, 11(13), 3512.

Kintscher, L., Lawrenz, S., Poschmann, H. & Sharma, P. (2020). Recycling 4.0- Digitalization as a Key for the Advanced Circular Economy. *Journal of Communication*, 15(9), doi: 10.12720/jcm.15.9.652-660.

Kirchherr, J., Reike, D. & Hekkert, M. (2017). Conceptualizing the circular economy: An analy-sis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232, doi: 10.1016/j.resconrec.2017.09.005.

Okorie, O., Salonitis, K., Charnley, F., Moreno, M., Turner, C. & Tiwari, A. (2018). Digitisation and the circular economy: A review of current research and future trends. *Energies*, 11(11), 3009.

Parida, V., Sjödin, D. & Reim, W. (2019). Reviewing literature on digitalization, business mod-el innovation, and sustainable industry: Past achievements and future promises. *Sustainability*, 11(2), 391, doi: 10.3390/su11020391.

Popović, A., Ivanović-Đukić, M. & Milijić, A. (2022). Assessment of the impact of circular economy competitiveness and innovation on European economic growth. *The European Journal of Applied Economics*, 19(2), 1-13, doi: 10.5937/EJAE19-39057.

Ranta, V., Aarikka-Stenroos, L. & Väisänen, J. M. (2021). Digital technologies catalyzing busi-ness model innovation for circular economy – Multiple case study. *Resources, Con-servation and Recycling*, 164, 105155.

Turner, C., Moreno, M., Mondini, L., Salonitis, K., Charnley, F., Tiwari, A. & Hutabarat, W. (2019). Sustainable production in a circular economy: a business model for redistributed manufacturing. *Sustainability*, 11(16), 4291.

Van Capelleveen, G., Amrit, C., Zijm, H., Yazan, D. M. & Abdi, A. (2021). Toward Building Recommender Systems for the Circular Economy: Exploring the Perils of the European Waste Catalogue. *Journal of Environmental Management*, 277, 111430, doi: 10.1016/j.jenvman.2020.111430.

FINANCIAL CONSIDERATIONS OF AI ADOPTION IN HIGHER EDUCATION

DOI: 10.5937/EMC26241K

Branimir Kalaš
University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia
E-mail: branimir.kalas@ef.uns.ac.rs
Ines Đokić
University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia

ABSTRACT

The integration of Artificial Intelligence (AI) in higher education institutions has rapidly expanded, transforming teaching, learning, and administrative processes. While much research has focused on pedagogical benefits, comparatively less attention has been paid to the financial dimensions of AI adoption. This paper examines the costs, funding strategies, and cost–benefit considerations associated with implementing AI in higher education. Drawing on evidence from frontier AI models, case studies, and literature on institutional financing, it highlights the substantial investments required in infrastructure, software, cloud services, and specialized personnel. The study further explores innovative funding mechanisms, including outcome-based financing, public grants, philanthropy, and partnerships with industry, which support sustainable AI deployment. Findings emphasize that strategic planning, continuous cost management, and alignment of investments with measurable educational outcomes are essential to ensure both financial sustainability and long-term institutional value.

Keywords: AI, Higher education, Financial aspect, Cost-benefit analysis

INTRODUCTION

The integration of artificial intelligence into higher education institutions has intensified in recent years, reshaping teaching, research, and administrative practices. The rapid advancement of AI has emerged as a key force in reshaping educational systems, especially within higher education (Mosha et al., 2026). Within education, fundamental AI tools like Machine Learning (ML), Natural Language Processing (NLP), and generative AI are increasingly applied to enrich teaching, learning, and institutional management. While much research emphasizes pedagogical innovation and learning outcomes, comparatively less attention has been paid to the financial foundations necessary for sustainable AI implementation. As AI becomes embedded in institutional operations, issues such as funding models, cost structures, and long-term return on investment have become central to strategic planning (Bearman et al., 2023; Jia et al., 2024).

Implementing AI requires significant initial and ongoing investments. Institutions must allocate resources for digital infrastructure, cloud computing, cybersecurity, data management, and technical support (Moscardini et al., 2020). Beyond technology, effective adoption also demands investment in staff training, organizational restructuring, and governance mechanisms to ensure ethical and responsible use (Shrivastava, 2023).

Funding approaches vary across contexts. Public universities frequently depend on government grants and national digitalization initiatives, whereas private institutions may rely on tuition revenues, philanthropic funding, and partnerships with industry (Alexander et al., 2019). Collaboration with technology companies has become increasingly prominent, enabling shared development of AI solutions while reducing immediate financial burdens. However, such arrangements may introduce concerns related to long-term costs, vendor dependence, and data governance. The aim of this paper is

to examine the financial aspects of AI integration in higher education, analyze the cost–benefit balance of different AI tools, and provide insights into sustainable funding strategies that ensure long-term institutional viability and educational effectiveness. To achieve this, the paper first analyzes the financial implications of AI adoption, highlighting major cost drivers and potential returns on investment before exploring funding strategies and sustainable implementation models.

COST-BENEFIT ANALYSIS OF AI IN HIGHER EDUCATION

Implementing AI in higher education involves significant financial commitments, and understanding the cost–benefit landscape is crucial for informed decision-making. The analysis of frontier AI models shows that the amortized compute cost for training has grown by approximately 2.4× per year (90% CI: 2.0×–2.9×) since 2016, and the total development costs for selected models such as GPT-3, OPT-175B, GPT-4, and Gemini Ultra exceed $100 million, with R&D staff accounting for 29–49% of the total (Cottier, 2025). AI accelerator chips and server components also represent substantial portions of the budget, while energy consumption and cluster-level interconnect contribute additional costs, highlighting the magnitude of investment required even before deployment in higher education.

The KI:connect.nrw case study demonstrates that financing generative AI in higher education requires structured cost management mechanisms and transparent budget allocation. Instead of relying on fixed per-user licenses, a token-based billing model was implemented to ensure that costs reflect actual usage, although this approach demands continuous monitoring and sophisticated tracking systems. The experience at RWTH Aachen University further shows that without predefined usage limits and active cost control, expenditures can quickly exceed allocated budgets, highlighting the importance of ongoing financial oversight and adaptive spending controls (Decker & Dittrich, 2025).

A primary financial risk in AI adoption is not the cost of technology itself, but ineffective implementation. U.S. K–12 districts spent $35 billion on educational technology in 2020 with minimal improvement and many unused software licenses. Outcome-based financing, which ties vendor payments to student progress and allocates funds for professional development and technical support, ensures that investments generate measurable educational gains and sustainable AI use (Dallas, 2025).

The study of Rahmawati et al. (2026) suggests that combining traditional funding sources, such as public grants and philanthropy, with innovative mechanisms like venture capital, social impact bonds, and subscription models, while aligning investments with measurable educational outcomes, is essential for ensuring scalable and financially viable AI integration. Structured financial planning, including usage-based billing, outcome-oriented financing, and diversified funding sources, can mitigate the risks of overspending while aligning AI initiatives with measurable educational outcomes (Rahmawati et al., 2026). While cost-benefit analysis provides insight into potential gains and risks, understanding the broader financial landscape, including operational and maintenance expenses, is essential for sustainable AI integration in higher education.

FINANCIAL ASPECTS OF AI IN HIGHER EDUCATION

The financial challenges associated with AI go beyond initial setup. Acquiring the required hardware, programs, and staff expertise demands considerable capital, while the ongoing upkeep of intelligent systems creates a lasting drain on institutional budgets (Alenezi & Faisal, 2020). According to Alenezi (2023), the level of financial dedication plays a crucial role in whether AI integration can be maintained over time.

To ensure sustainability, institutions must budget for both initial needs such as training and hardware, and ongoing expenses, including software updates, maintenance, and cloud services. This long-term planning transforms AI from experimental adoption into enduring integration (Al-Zahrani & Alasmari, 2025).

Integrating AI into education management requires substantial upfront investment in specialized hardware and software infrastructure, although declining technology costs have gradually improved accessibility (Brown, 2018). Effective adoption further depends on significant financial allocation for staff training, as equipping educators and administrators with the necessary competencies is essential for maximizing the long-term value of AI systems (Ananyi & Nwosu, 2023a).

Integrating AI in educational institutions entails significant financial commitments, including upfront investments in AI software, hardware, and personalized learning platforms, as well as ongoing operational costs related to administrative automation, data analytics, and efficiency-enhancing tools (Ananyi & Somieari-Pepple, 2023). Institutions that strategically allocate funding across technology acquisition, staff development, and operational oversight are more likely to achieve positive outcomes from AI investments (Ananyi & Somieari-Pepple, 2023). These expenditures must be weighed against potential long-term returns such as increased student retention, improved academic performance, reduced administrative overhead, and qualitative benefits like enhanced student satisfaction and institutional competitiveness.

By combining upfront investments in infrastructure, ongoing operational support, and performance-oriented funding strategies, higher education institutions can harness the pedagogical and administrative benefits of AI while maintaining financial prudence and resilience (Rahmawati et al., 2026; Dallas, 2025). Adopting flexible financing models, including subscription-based or outcome-based approaches, can mitigate financial risk while aligning AI use with measurable educational improvements. Combining these strategies enables institutions to manage the substantial costs of AI integration while ensuring that the benefits justify the investment. Such a comprehensive approach ensures that AI initiatives not only deliver pedagogical and administrative improvements but also remain financially viable over the long term.

CONCLUSION

The implementation of AI in higher education presents both significant opportunities and financial challenges. Successful integration requires careful planning, not only for technology acquisition but also for ongoing operational costs, staff training, and governance mechanisms. Institutions must consider both initial and long-term expenditures to ensure that AI solutions are effectively maintained and deliver value. Structured financial planning, including usage-based billing, outcome-oriented financing, and diversified funding sources, can mitigate the risks of overspending while aligning AI initiatives with measurable educational outcomes. Strategic allocation of resources across infrastructure, personnel, and operational support ensures that investments generate tangible benefits, such as improved student retention, enhanced learning experiences, and streamlined administrative processes.

Long-term sustainability also depends on institutional capacity to monitor and adapt expenditures over time, integrating AI into daily operations without compromising financial stability. By combining innovative funding strategies with careful cost management and continuous oversight, higher education institutions can harness the potential of AI to enhance teaching, learning, and administration, while maintaining financial prudence and resilience. Ultimately, the success of AI integration depends on balancing technological innovation with strategic financial stewardship to achieve lasting institutional and educational benefits.

ACKNOWLEDGEMENT

This research was funded by the Provincial Secretariat for Higher Education and Scientific Research of the Autonomous Province of Vojvodina, the Republic of Serbia, during the project “Perceptions and Financial Aspects of Artificial Intelligence Implementation in Higher Education”, grant number: 003797244 2025 09418 003 000 000 001 04 002.

REFERENCES

Alenezi, F. (2023). Artificial intelligence versus Arab universities: An enquiry into the Saudi context. The Scientific Journal of King Faisal University: Humanities and Management Sciences, 24(1), 82–88. https://doi.org/10.37575/h/edu/220038

Alenezi, H. S., & Faisal, M. H. (2020). Utilizing crowdsourcing and machine learning in education: Literature review. Education and Information Technologies, 25(4), 2971–2986. https://doi.org/10.1007/s10639-020-10102-w

Alexander, B., Ashford-Rowe, K., Barajas-Murphy, N., Dobbin, G., Knott, J., McCormack, M., Pomerantz, J., Seilhamer, R., & Weber, N. (2019). EDUCAUSE horizon report: 2019 higher education edition. Retrieved from: https://library.educause.edu/-/media/files/library/2019/4/2019horizonreport

Al-Zahrani, A. M., & Alasmari, T. M. (2025). A comprehensive analysis of AI adoption, implementation strategies, and challenges in higher education across the Middle East and North Africa (MENA) region. Education and Information Technologies, 30, 11339–11389. https://doi.org/10.1007/s10639-024-13300-y

Ananyi, S. O., & Nwosu, L. K. (2023a). Utilizing artificial intelligence for enhancing the economic aspects of Nigerian public universities. In N. P. Ololube, T. Koroye, & D. T. Elisha (Eds.), Proceedings of the 3rd International Conference on Institutional Leadership and Capacity Building in Africa (pp. 383–398). University of Africa, ToruOrua, Bayelsa State, Nigeria.

Ananyi, S. O., & Somieari-Pepple, E. (2023). Cost-benefit analysis of artificial intelligence integration in education management: Leadership perspectives. International Journal of Economics, Environmental Development and Society, 4(3), 353–370.

Bearman, M., Ryan, J., & Ajjawi, R. (2023). Discourses of artificial intelligence in higher education: A critical literature review. Higher Education, 86(2), 369–385. https://doi.org/10.1007/s10734-022-00937-2

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. IEEE Access, 8, 75264–75278.

Cottier, B., Rahman, R., Fattorini, L., Maslej, N., Besiroglu, T., & Owen, D. (2025). The rising costs of training frontier AI models. arXiv. https://doi.org/10.48550/arXiv.2405.21015

Dallas, D. (2025). AI implementation is essential education infrastructure. Day One Project. Retrieved from: https://fas.org/publication/ai-implementation-is-essential-education-infrastructure/

Decker, B., & Dittrich, D. (2025). Cost management for the use of generative AI in higher education: A case study from North Rhine-Westphalia. In EPIC Series in Computing, Proceedings of EUNIS 2025 Belfast (pp. 107–116).

Jia, F., Sun, D., & Looi, C.-K. (2024). Artificial intelligence in science education (2013–2023): Research trends in ten years. Journal of Science Education and Technology, 33(1), 94–117. https://doi.org/10.1007/s10956-023-10077-6

Moscardini, A. O., Strachan, R., & Vlasova, T. (2020). The role of universities in modern society. Studies in Higher Education, 47(4), 812–830. https://doi.org/10.1080/03075079.2020.1807493

Mosha, N. F. V., Chigwada, J., Ketchiwou, G. F., & Ngulube, P. (2026). A systematic review of artificial intelligence in higher education institutions (HEIs): Functionalities, challenges, and best practices. Education Sciences, 16(2), 185. https://doi.org/10.3390/educsci16020185

Rahmawati, R., Sudirman, R., Duriani, D., & Yunus, Y. (2026). Funding models for AI in education: Ensuring sustainability and impact. In A. Asrifan (Ed.), AI, policy, and the future of human-centered education (pp. 223–248). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-5781-2.ch009

Shrivastava, R. (2023). Role of Artificial Intelligence in Future of Education. International Journal of Professional Business Review, 8(1), e0840. https://doi.org/10.26668/businessreview/2023.v8i1.840

ENTREPRENEURSHIP AND CORPORATE SOCIAL RESPONSIBILITY

DOI: 10.5937/EMC26245K

Mila Krivokuća
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: mila.krivokuca93@gmail.com

ABSTRACT

This paper examines corporate social responsibility (CSR) in modern entrepreneurship, focusing on its role in sustainable business development. CSR is defined as a voluntary commitment that integrates economic, social, and environmental objectives into business practice. The paper highlights the key CSR principles, sustainability, accountability, and transparency and their importance in responsible decision-making. The study also explores how entrepreneurship influences CSR implementation due to the specific characteristics of small, owner-managed firms. Entrepreneurs contribute to economic growth, innovation, and employment, while also affecting society and the environment. Their personal values and stakeholder relationships play an important role in shaping CSR practices. The findings indicate that CSR-oriented entrepreneurship improves stakeholder trust, reputation, and long-term competitiveness. Overall, CSR represents an essential framework that supports both business success and social well-being.

Key words: Social Responsibility, Entrepreneurship, Stakeholders, Ethical Business, Sustainable Development

INTRODUCTION

Corporate social responsibility is based on the concept that companies have an obligation to direct their business activities toward meeting the needs of their stakeholders and to engage in the process of creating value rather than wealth (Jamali and Mirshak, 2006). In contemporary societies, there are numerous reasons why companies must implement the concept of corporate social responsibility, among which the most important are (Spence, Gherib and Biwole, 2011):

- moral obligations, which arise from the fact that companies must demonstrate responsibility toward society and the environment in which they operate,
- sustainability, which must be directed toward environmental preservation and the advancement of society,
- licenses to operate, which represent the obligation of all companies to obtain explicit or implicit permissions from states, local communities, or various stakeholder groups in order to conduct business activities, and
- reputation, which companies use to enhance their image, strengthen their brand, and increase share value through the implementation of various corporate social responsibility activities.

Most companies, in the course of their operations, create significant social value in a variety of ways, such as job creation, improvement of working conditions, tax payments, engagement in environmental protection activities, and similar initiatives. In contemporary markets, an increasing number of companies attempt to generate social value through various activities related to corporate social responsibility. The application of the corporate social responsibility concept is increasingly less seen as a source of competitive advantage and is more often regarded as a mandatory element of all business operations.

Corporate social responsibility can be defined as the voluntary commitment of companies to contribute to sustainable economic development by integrating concern for society and the

environment into their business operations and interactions (Banerjee, 2008). It represents an obligation that companies undertake in order to improve social welfare through optional business activities and the resources at their disposal. One of the fundamental and most important characteristics of corporate social responsibility is its voluntary nature, as there is no legal regulation that obliges companies to implement activities in this area.

Most companies focus their corporate social responsibility activities on improving their brands and creating a positive image among consumers and the general public. Managers and company owners increasingly feel pressure from various stakeholders, who demand the implementation of activities aimed at addressing different social and environmental issues. A large number of companies incorrectly perceive corporate social responsibility, believing that it is sufficient to donate money and provide support to various initiatives that are carried out.

FUNDAMENTAL PRINCIPLES OF CORPORATE SOCIAL RESPONSIBILITY

The uncertainty associated with the nature of corporate social responsibility activities significantly complicates the definition of this concept and the identification of activities that fall within its scope. The nature of corporate social responsibility imposes the imperative of identifying activities that can be classified within this concept. In order for a certain activity to be classified as part of corporate social responsibility, it must be based on three fundamental principles (Crowther and Aras, 2008):

- sustainability,
- accountability, and
- transparency.

Viewing companies as segments of broader social and economic systems implies the obligation to consider the effects of their operations on these systems. In addition to measuring costs and value generated in the present, these effects must also be taken into account due to their impact on the future of the companies themselves. Sustainability indicators show the rate at which resources are used by a company and the relationship between this consumption and the rate of their regeneration.

Company activities that are not sustainable in nature can be addressed in two ways: by developing sustainable practices or by planning for future shortages of resources that are currently being overused. Most companies, as a means of reducing the negative effects resulting from excessive resource consumption, most often implement activities aimed at improving resource efficiency. One example of such activities includes various energy efficiency improvement programs, which are widely used by many companies.

The principle of accountability encompasses situations in which companies recognize the impacts of their activities on the external environment and assume responsibility for the effects they have caused (Moon, 2007). The concept underlying the principle of accountability involves the quantification of the effects resulting from corporate actions. This quantification includes both internal effects, which arise within the organization, and external effects, which occur in the company's surrounding environment. As part of corporate social responsibility, the concept of accountability establishes the obligation to report to all stakeholders affected by corporate activities. This includes reporting to external stakeholders on the effects of corporate actions, while clearly highlighting the consequences for each stakeholder group (Moon, 2007).

The accountability dimension emphasizes the need to view the company as part of a broader social environment. Companies have responsibilities toward the entire environment in which they operate, not only toward their owners. In addition to corporate acceptance of responsibility, it must also be acknowledged that external stakeholders possess sufficient influence to affect corporate activities. External stakeholders play a role in determining whether a given corporate activity is justified from their perspective and what its cost is for the company and other stakeholders.

The principle of accountability requires companies to implement appropriate measures that ensure adequate levels of impact control over their operations and transparent reporting of their activities. These activities result in additional costs for the company, related to the development, collection, and publication of information. In order for these activities to have value for both the company and its environment, the

benefits achieved must exceed the associated costs. The effects are assessed based on the usefulness of selected measures for decision-making processes and on the way resources are allocated within the company and between the company and its stakeholders. Such reporting must be based on the following characteristics (Crowther and Aras, 2008):

- clarity and comprehensibility for all stakeholders,
- relevance of information for users,
- reliability in terms of measurement accuracy, impact representation, and elimination of bias,
- comparability, which implies consistency over time and across different companies.

Corporate social responsibility reports published by companies almost always include both qualitative facts and assessments, which typically complement quantitative elements. Qualitatively expressed components of reports significantly reduce their comparability over time, which is why certain users evaluate the impacts of activities differently, interpreting them within the context of their personal values and priorities. This can significantly increase the influence of subjective factors in the process of drawing conclusions.

The lack of a clear and precise understanding of effects, combined with inevitable subjective elements influencing assessments of relative impact, results in a limited number of standardized indicators for measuring the principle of accountability as a component of corporate social responsibility. This limitation reduces the possibility of comparing corporate social responsibility information across companies. Despite these constraints posing challenges for the development of environmental accounting, they can also be beneficial for corporate managers, as the lack of comparability of performance requires them to consistently demonstrate strong results in their operations.

Transparency is a principle which implies that the external impacts of a company's activities can be assessed in a real and objective manner based on its reports. In order for a report to be considered transparent, no significant fact or piece of information must be concealed. The aim of transparency is to ensure that all effects, including external impacts resulting from corporate activities, are clearly visible to all stakeholders through the reporting mechanisms employed by the company.

The application of the transparency principle is particularly important for external users of information, as they do not have access to the same level of knowledge and detail available to internal users regarding corporate social responsibility practices. Transparency represents an extension of the principles of sustainability and accountability, and it can also be viewed as part of the process of recognizing a company's responsibility for the external effects generated by its activities. It also represents a highly important element in the process of delegating authority to external stakeholders.

THE NECESSITY OF CORPORATE SOCIAL RESPONSIBILITY IN BUSINESS

Corporate social responsibility (CSR) represents a business philosophy that is increasingly applied in contemporary business conditions. The aim of CSR policies implemented by companies is to create self-regulatory mechanisms that enable monitoring of activities and ensure effective compliance with legal regulations, international standards, and ethical principles (Asemah, Okpanachi and Edegoh, 2013). The necessity of CSR arises from the elements on which it is based. CSR represents a voluntarily accepted commitment by companies to carry out activities that protect and enhance the well-being of society, while simultaneously safeguarding their own interests. Managers are not only responsible for achieving company-related objectives, but also for objectives that generate benefits for society as a whole.

The necessity of CSR stems from the fact that it represents a continuous commitment by companies to ethical business conduct and contribution to economic development, while simultaneously improving the quality of life of employees, their families, local communities, and society at large. CSR enables the integration of economic, social, and environmental considerations into corporate processes and decision-making structures. It facilitates the progress of all segments of society through the use of innovation to develop creative and value-adding solutions to various challenges faced by society and the environment.

The role of CSR is reflected in the inclusion of internal and external stakeholders and cooperation with them in order to more effectively manage potential risks and build corporate credibility and trust among all segments of society. The importance of CSR lies in its approach, which considers the interests of all

stakeholders within the organization and society, and incorporates these interests into strategy development and implementation (Ali et al., 2010).

The necessity of CSR is also evident in its ability to provide companies with opportunities for differentiation from competitors and for reducing operational costs. In modern societies, CSR represents a management strategy that enables companies to generate positive impacts on their environment through their business activities (Asemah, Okpanachi and Edegoh, 2013). Companies operate within their environment in order to maintain or enhance their reputation among stakeholders and thereby improve their financial and non-financial performance.

The financial and non-financial effects of the crisis led to numerous negative phenomena, among which a significant decline in trust at the level of national economies stands out. The challenges companies faced forced them to focus on economic performance and to ignore the impact of their activities on future generations and the environment.

Awareness of the negative consequences of such business practices highlighted the necessity of implementing CSR across all segments of corporate operations. In contemporary markets, corporate behavior focused solely on economic outcomes, while ignoring social and environmental impacts, is no longer acceptable (Wustenhagen et al., 2007). Companies must simultaneously pursue profit maximization and environmental and social responsibility in the societies in which they operate.

The necessity of CSR has imposed an imperative for changes in corporate business models, procedures, rules, and operational practices. Companies must continuously improve their operations in order to adapt to rapid and frequent changes in the markets in which they operate. CSR represents an indispensable component of modern business and encompasses issues of business ethics, corporate performance in relation to society and the environment, and the management of relationships with various stakeholder groups.

ENTREPRENEURSHIP IN ACCORDANCE WITH THE PRINCIPLES OF CORPORATE SOCIAL RESPONSIBILITY

The small size of companies and the limited number of employees are often considered the most important characteristics of entrepreneurship. These characteristics typically result in a high level of homogeneity among entrepreneurial firms, which significantly influences entrepreneurs' attitudes toward corporate social responsibility (CSR). In addition to size, there are numerous other internal and external factors that affect the ways in which entrepreneurs apply CSR principles in their business activities (Jenkins, 2006).

The behavior of entrepreneurial firms is often observed from the perspective of their owners, i.e., the entrepreneurs themselves. Entrepreneurship is frequently characterized by management styles that are strongly linked to the personality of the entrepreneur. These management styles are generally less formal in nature and may vary significantly depending on individual traits, which also strongly influence entrepreneurs' attitudes toward the implementation of CSR principles in business practice.

The most common form of entrepreneurship consists of owner-managed businesses, in which the same individual holds both ownership and decision-making authority. This close relationship between the entrepreneur and the company significantly influences corporate strategies, policies, practices, and the role of the firm within society. All of these elements have a direct impact on the implementation of CSR principles in entrepreneurship (Hamman, Habisch and Pechlaner, 2009).

An organizational structure in which the entrepreneur is both owner and manager enables a high level of autonomy and directly affects the ways and motivations for applying CSR principles. Research findings indicate that entrepreneurial firms have favorable preconditions for demonstrating socially responsible behavior (Lepoutre and Heene, 2006). Entrepreneurial firms often create new jobs, stimulate economic growth, and introduce innovations that drive national economic development and improve various aspects of quality of life in the communities and environments in which they operate.

During their operations, entrepreneurs exhibit behaviors that allow them to align with the expectations and demands of their stakeholders, including employees, consumers, and the local community. These stakeholder groups are particularly important in the implementation of CSR-related activities by entrepreneurs (Turker, 2009). CSR toward employees includes activities directly related to their physical and psychological working environment. CSR toward consumers refers to the extent to which companies build and maintain strong relationships with their customers and includes offering high-quality products or providing reliable information about their activities. From the perspective of CSR in entrepreneurship, society includes local communities, the natural environment, future organizations, and non-governmental organizations.

Entrepreneurship in accordance with CSR principles involves the following forms of entrepreneurial behavior (European Commission - Directorate-General for Enterprise and Industry, 2004):

- fair and honest relations with consumers, business partners, and competitors,
- concern for the health, safety, and overall well-being of employees and consumers,
- motivation of employees through opportunities for training and personal development,
- maintaining good relationships with and providing support to the local community, and
- demonstrating care for natural resources and the environment.

The implementation of entrepreneurship in line with CSR principles is based on conducting business in a way that strengthens its positive contributions to society while simultaneously minimizing negative impacts on people and the environment. Entrepreneurs who apply CSR principles maintain continuous communication with their key stakeholders. Communication with consumers and business partners takes place in the market, with employees in the workplace within the company, while communication with the local community and the broader environment occurs across multiple different settings.

All activities related to corporate social responsibility are carried out in compliance with legal obligations, as well as through the implementation of activities that are not prescribed as the minimum required obligations and are voluntarily undertaken by entrepreneurs. In modern markets, entrepreneurs play a highly significant role in creating and securing jobs, producing goods and providing services needed by society, as well as paying taxes from which the normal functioning of the state is financed.

The importance of entrepreneurship is reflected in the fact that it is also the most important driver of innovation and competitiveness. Corporate social responsibility should ensure a balance between economic, social, and environmental objectives of business, which require the implementation of various types of trade-offs (European Commission - Directorate-General for Enterprise and Industry, 2004). Activities undertaken by companies in order to achieve CSR objectives are not mutually exclusive and, if implemented appropriately, can provide numerous new business opportunities and strengthen their market position. Significant advantages that can be achieved through the application of CSR include higher levels of customer satisfaction and loyalty, increased employee motivation, improved relations with local communities and public authorities, cost reduction, and enhanced reputation (Dunne and McBrayer, 2019).

The primary motivation of many entrepreneurs to engage in socially responsible business practices lies in their personal values rather than in the expected financial benefits. Such behavior is particularly evident in situations where activities are aimed at contributing to the local communities in which entrepreneurs live and work. Despite the fact that these activities are often carried out without clear planning and are not explicitly linked to business strategies, they demonstrate the genuine voluntary nature of entrepreneurs' involvement in the application of corporate social responsibility principles.

CONCLUSION

Corporate social responsibility has become an indispensable element of contemporary business practice, particularly in the context of entrepreneurship. The analysis presented in this paper shows that CSR is not merely a voluntary addition to business activities, but a necessary framework for ensuring sustainable and responsible development. By integrating the principles of sustainability, accountability, and transparency, companies are able to better manage their impact on society and the environment.

Entrepreneurship, due to its structure and close connection between ownership and management, provides both opportunities and challenges for CSR implementation. Entrepreneurs significantly contribute to economic growth, innovation, and employment, but at the same time must consider the broader consequences of their actions on stakeholders and society as a whole. Their personal values and ethical perspectives often play a decisive role in the extent to which CSR principles are applied in practice.

The findings suggest that CSR-oriented entrepreneurship leads to multiple benefits, including improved stakeholder trust, stronger reputation, increased competitiveness, and better long-term sustainability. Therefore, CSR should be viewed not as a constraint on entrepreneurial activity, but as a strategic approach that enhances business performance while simultaneously contributing to societal well-being.

From a practical standpoint, these findings imply that owner-managers should intentionally embed CSR principles into their core business strategies to unlock tangible long-term benefits like heightened stakeholder trust and cost efficiency. On a broader social scale, a structured shift toward ethical entrepreneurship ensures that small firms, which drive innovation and employment, actively contribute to community resilience and sustainable regional development.

REFERENCES

Ali, I., Rehman, K. U., Yilmaz, A. K., Nazir, S. and Ali, J. F. (2010). Effects of corporate social responsibility on consumer retention in cellular industry of Pakistan. African Journal of Business Management, 4(4), pp. 475-485.

Asemah, E., Okpanachi, R. and Edegoh, L. (2013). Business Advantages of Corporate Social Responsibility Practice: A Critical Review. New Media and Mass Communication, 18, pp. 45-55.

Banerjee, S. B. (2008). Corporate Social Responsibility: The Good, the Bad and the Ugly. Critical Sociology, 34(1), pp. 51-79.

Crowther, D. and Aras, G. (2008). Corporate Social Responsibility. London: Ventus Publishing

Dunne, T. C. and McBrayer, G. A. (2019). In the interest of small business' cost of debt: A matter of CSR disclosure. Journal of Small Business Strategy, 29(2), pp. 58-71

European Commission, Directorate-General for Enterprise and Industry (2004). Responsible entrepreneurship: a collection of good practice cases among small and medium-sized enterprises across Europe. Brussels: European Commission Publications Office

Hamman, E. M., Habisch, A. and Pechlaner, H. (2009). Values that create value: Socially responsible business practices in SMEs - empirical evidence from German companies. Business Ethics: A European Review, 18(1), pp. 37-51.

Jamali, D. and Mirshak, R. (2006). Corporate Social Responsibility (CSR): Theory and Practice in a Developing Country Context. Journal of Business Ethics, 72(3), pp. 243-262.

Jenkins, H. (2006). Small business champions for corporate social responsibility. Journal of Business Ethics, 67(3), pp. 241-256.

Lepoutre, J. and Heene, A. (2006). Investigating the impact of firm size on small business social responsibility: A critical review. Journal of Business Ethics, 67(3), pp. 257-273.

Moon, J. (2007). The contribution of Corporate Social Responsibility to Sustainable Development. Sustainable Development, 15(2), pp. 296-306.

Spence, M., Gherib, J. B. B. and Biwole, V. O. (2011). Sustainable Entrepreneurship: Is Entrepreneurial will Enough? A North-South Comparison. Journal of Business Ethics, 99(3), pp. 335-367.

Turker, D. (2009). How corporate social responsibility influences organizational commitment. Journal of Business Ethics, 89(2), pp. 189-204

Wustenhagen, R. Hamschmidt, J. Sharma, S. and Starik; M. (2007). Sustainable Innovation and Entrepreneurship. Cheltenham: Edward Elgar

ENTREPRENEURSHIP AND THE CONCEPT OF SUSTAINABLE DEVELOPMENT

DOI: 10.5937/EMC26251K

Mila Krivokuća
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: mila.krivokuca93@gmail.com

ABSTRACT

Entrepreneurship represents an important driver of economic growth, innovation, and social development in contemporary societies. At the same time, the growing importance of sustainable development has increased the need for business activities that balance economic objectives with environmental protection and social responsibility. This paper examines the relationship between entrepreneurship and sustainable development, with particular emphasis on sustainable entrepreneurship as an approach that transforms environmental and social challenges into business opportunities. The paper analyzes the principles of sustainable development and the influence of entrepreneurial orientation dimensions, such as proactiveness, innovativeness, and risk-taking, on sustainable business strategies. The findings indicate that sustainable entrepreneurship contributes to innovation, employment creation, efficient resource use, and long-term competitive advantages, while simultaneously generating positive effects for society and the environment. The paper concludes that integrating sustainability principles into entrepreneurial activities is essential for achieving balanced economic and social development.

Key words: sustainable development, sustainable entrepreneurship, innovation, entrepreneurial orientation, social responsibility

INTRODUCTION

Sustainable development has become increasingly important in contemporary societies, largely as a consequence of the accelerating depletion of non-renewable resources and the growing number of environmental problems. The emphasis placed on sustainable development is primarily the result of the necessity to implement actions aimed at ensuring uninterrupted living conditions for future generations..The complexity of sustainable development and its importance in contemporary societies have resulted in a large number of definitions of this concept. The National Sustainable Development Strategy of the Republic of Serbia defines it in a broader sense as a concept "implemented over the long term and intended to ensure the achievement of continuous economic growth" (Government of the Republic of Serbia, 2008). The goal of sustainable development is to ensure that future generations have equal opportunities to utilize natural resources. The concept of sustainable development encompasses all patterns of behavior that enable the fulfillment of requirements associated with intergenerational solidarity (Kula, 1998).Achieving long-term sustainable development is an extremely complex task that requires the implementation of a large number of diverse activities and the participation of numerous stakeholders. The importance of sustainable development in modern societies has resulted in a situation in which almost all stakeholder groups, directly or indirectly, actively participate in activities related to it or show interest in this concept. The significance of sustainable development has also contributed to the emergence of numerous theoretical models used to describe its fundamental aspects and most important elements.

The Munasinghe model of sustainable development is classified among the models with the greatest practical application and theoretical significance. Within this model, all elements of sustainable development are categorized into three dimensions: social, ecological, and economic (Munasinghe, 1993).The advantage of the Munasinghe model lies in the fact that its application places emphasis on all the most significant aspects of sustainable development. In addition to economic effects, the application of this model clearly highlights the social and environmental effects that specific activities may have on sustainable development. The use of the Munasinghe model enables the precise and clear identification of

the impacts that activities have on each aspect of sustainable development. One of the main problems associated with the practical implementation of sustainable development is the excessive emphasis placed on economic effects, while insufficient attention is devoted to its other dimensions (Ferreira, Teixeira and Rammal, 2021).

THE NECESSITY OF THE CONCEPT OF SUSTAINABLE DEVELOPMENT

The application of the concept of sustainable development represents a necessity in contemporary societies. Without adherence to the principles on which sustainable development is based, it is not possible to ensure the functioning of economic systems and the business entities operating within them in a manner that provides long-term sustainable competitive advantages. The necessity of applying the concept of sustainable development can best be understood through the definition provided by the Brundtland Commission. The implementation of sustainable development must ensure economic growth while preserving the environment and its resources, thereby enabling future generations to use them in the same or even better manner than at present (Klarin, 2018). The necessity of implementing the concept of sustainable development also largely arises from the need to fulfill requirements across all major segments of the functioning of contemporary societies. The concept of sustainable development places the satisfaction of human needs at the forefront, as this represents its fundamental and most important element. It enables economic growth while preserving resources for future generations and creating the basis for a fairer distribution of resources between wealthy and poor countries and individuals. From the perspective of society, sustainable development also enables broader inclusion of different stakeholder groups in implemented activities, resulting in greater public oversight and control.

The implementation of the concept of sustainable development, particularly in the environmental segment, results in the emergence of numerous limitations that must be respected in order to preserve the environment for future generations. These limitations are not absolute in nature; rather, in most cases, they are a consequence of the current level of technological development and the relationship societies have toward resources originating from the environment. Limitations associated with sustainable development are also often a consequence of the biosphere's capacity to absorb the various effects of human activities (Hall, Daneke and Lenox, 2010).

The effective implementation of sustainable development and adherence to the principles upon which it is based enable the balanced development of all segments of contemporary societies. Most of the problems faced today by individual countries and the planet as a whole are the result of placing excessive emphasis on economic growth and profit generation regardless of their cost, that is, regardless of the consequences caused by economic activities. Sustainable development represents one of the most effective approaches to solving problems that have arisen as a consequence of excessive economic growth, which in most cases was pursued without concern for natural resources, the environment, and the impacts such activities have on local communities and the countries in which economic activities are conducted. Another aspect of sustainable development that significantly contributes to the necessity of its implementation in contemporary societies is reflected in the areas in which improvements should be achieved. The concept of sustainable development is based on emphasizing the development of: people, the economy and society. (Klarin, 2018):Before the emergence of the concept of sustainable development and during the initial stages of its implementation, the primary emphasis was placed on achieving economic growth through job creation, increasing consumption, and expanding the wealth of individuals and society as a whole. Toward the end of the twentieth century, significant changes occurred in approaches to sustainable development, resulting in a shift of emphasis toward human-centered aspects of development. Attention began to focus on values and goals such as increasing life expectancy, wealth, levels of education, and creating equal opportunities for all individuals. During this phase, numerous favorable conditions for the development of entrepreneurship were also created, primarily through expanding opportunities for individuals without sufficient capital to initiate entrepreneurial ventures and implement their ideas.

ENTREPRENEURSHIP AND BUSINESS OPERATIONS WITHIN THE FRAMEWORK OF SUSTAINABLE DEVELOPMENT

When examining the relationship between entrepreneurship and business operations within the framework of sustainable development, it is necessary to include in the analysis the impacts on sustainable

development arising from different perspectives of entrepreneurship and various meanings of this concept. The concept of entrepreneurship is multidimensional and often insufficiently clear. Observing entrepreneurship from different perspectives leads to different approaches to connecting entrepreneurship with sustainable development, as well as to different impacts on sustainable development as a whole and on its fundamental components (the economy, the environment, and society).

Entrepreneurship and business operations within the framework of sustainable development can best be analyzed through the basic dimensions of entrepreneurial orientation: proactiveness, risk-taking, innovativeness, autonomy and competitive aggressiveness. (Gawel, 2012).
Proactiveness represents one of the most important characteristics of contemporary entrepreneurs across all industries and markets. It involves a future-oriented focus and the active search for market opportunities, which entrepreneurs transform into new business ventures. The proactive approach adopted by entrepreneurs has a positive effect on achieving sustainable development on both the demand and supply sides. From the demand perspective, entrepreneurship contributes to preserving or increasing the purchasing power of future generations, while promoting higher levels of social equality and reducing social exclusion. Entrepreneurship enables the inclusion of large numbers of individuals from various marginalized groups in business activities, thereby increasing their purchasing power and reducing poverty among the most vulnerable social groups. From the supply perspective, entrepreneurship enables continuous access to various renewable natural resources that serve as substitutes for non-renewable resources, thereby ensuring access to production factors that support sustainable development.The proactive business approach typically adopted by entrepreneurs also enables the achievement of savings resulting from the implementation of the concept of sustainable development. In most cases, these savings arise from the more efficient use of natural resources. Entrepreneurs who apply a proactive approach to business operations are leaders in identifying and utilizing market opportunities and can more easily recognize and exploit opportunities created by sustainable development.The implementation of the concept of sustainable development requires changes in ways of thinking and conducting business activities, resulting in new market and social needs that entrepreneurs can satisfy more efficiently and rapidly than large companies. Emphasizing the concept of sustainable development may serve as a driver of change in companies' operational strategies, encouraging them to take advantage of these opportunities (Gawel, 2012). In this way, entrepreneurs who demonstrate proactive approaches in their business operations are provided with opportunities to discover new areas for the development of entrepreneurial ventures.

The previously defined relationships can also be viewed through business opportunities associated with sustainable development, which enable entrepreneurs to generate profit while simultaneously producing positive effects on the environment and the social communities in which they operate. Business activities carried out by entrepreneurs in connection with sustainable development often generate benefits for other companies and society as a whole. Research findings indicate that entrepreneurs' openness toward identifying business opportunities related to sustainable development largely depends on their level of knowledge regarding the natural and social environment in which they operate (Patzelt and Shepherd, 2011).

Innovativeness involves the ability to introduce new products, services, and technologies to the market and to enter new markets, and it represents one of the fundamental and most important elements upon which contemporary entrepreneurs base their operations. Innovativeness can be highly beneficial in achieving sustainability, considering that sustainable development requires changes in production and consumption patterns that result in the more rational use of natural resources and the achievement of the goals of intergenerational solidarity.The introduction of innovations, while simultaneously placing emphasis on the rational use of natural resources, may enable entrepreneurs to reduce production costs, resulting in increased profitability and improved market competitiveness. In order for innovations, as one of the most important elements of entrepreneurial business operations, to have a positive effect on sustainability, they must be directed toward achieving the goals contained within the principles upon which sustainable development is based. Innovations implemented by entrepreneurs always involve the introduction of novelties to the market, although their specific nature is not always defined.

Most entrepreneurs are also characterized by higher levels of risk-taking propensity, which may have a highly significant impact on sustainable development, primarily through their willingness to more readily adopt new technologies with fewer negative environmental impacts. In practice, it is often incorrectly

assumed that risk-taking propensity and orientation toward sustainable business operations have little in common (Gawel, 2012). In reality, risk-taking propensity and sustainability are fundamentally interconnected, primarily because risk-taking involves carrying out activities whose outcomes are uncertain. The implementation of activities related to sustainable development also involves undertaking actions whose results are unknown and will only become evident in the future. Risk-taking propensity therefore represents an entrepreneurial orientation that may provide significant support for sustainable development.The implementation of the principles of sustainable development also involves activities whose effects are not immediately known but will become apparent in the future, while there are no guarantees that the desired goals will be achieved (Patzelt and Shepherd, 2011). Risk-taking propensity also includes activities aimed at predicting the future, with the resulting profit being viewed as a consequence of accurate forecasting. Sustainable development is similarly based on the assumption that anticipating future events may influence society and the environment in ways that may never fully materialize. These similarities indicate the possibility of a relationship between risk-taking and sustainable development, provided that they share common social and environmental goals. As a rule, however, risk-taking has a shorter time horizon compared to sustainable development.

Competitive aggressiveness refers to the level of effort entrepreneurs must exert in order to achieve better results than their competitors (Dess and Lumpkin, 2005). It is characterized by aggressive responses to competitors' activities aimed at improving entrepreneurs' positions within the markets in which they operate. The perspective of sustainable development is always long-term in nature, whereas the activities entrepreneurs undertake in order to achieve competitive advantages are generally oriented toward shorter time horizons. This difference in temporal perspectives may lead to situations in which entrepreneurs focus on current conditions rather than long-term trends when defining the activities they will implement.The effective implementation of sustainable development in entrepreneurial business operations can only be achieved in situations where it contributes to the creation of long-term competitive advantages. Academic literature increasingly supports the view that sustainable development and competitiveness are interconnected elements that can be jointly developed through the application of the concept of sustainable competitiveness (Balkyte and Tvaronaviciene, 2010). Research findings indicate that entrepreneurs are primarily involved in sustainable development activities directly related to their business operations, while less attention is devoted to activities aimed at generating positive effects for the environment and society as a whole (Wikstrom, 2010).

It can be assumed that an entrepreneurial approach to business operations may have positive effects on the implementation of the concept of sustainable development if activities directed toward the environment and society generate measurable profits for the companies that implement them. If companies wish to adhere to the principles of sustainable development, they must possess a certain combination of different dimensions of entrepreneurial orientation, which may be highly beneficial in the implementation of sustainable business strategies. Research findings indicate that the highest levels of sustainable entrepreneurial business operations can be achieved in situations where entrepreneurs demonstrate high levels of proactiveness and innovativeness, moderate levels of risk-taking propensity and competitive aggressiveness, and low levels of autonomy (Klarin, 2018).

SUSTAINABLE ENTREPRENEURSHIP

Entrepreneurship in contemporary societies represents a highly significant means of addressing problems related to unemployment and poverty, which also constitute one of the fundamental objectives upon which the concept of sustainable development is based (Bogan and Darity, 2008). Among entrepreneurs, there is an increasing recognition that success cannot be achieved solely through the maximization of short-term profits, but that emphasis must also be placed on corporate social responsibility and adherence to the principles of sustainable development (Iyigun, 2013). In contemporary societies, entrepreneurship and small businesses represent the primary drivers of innovation across all fields of business, including sustainable development.

Sustainable entrepreneurship represents a combination of entrepreneurship and sustainability aimed at ensuring a responsible relationship of entrepreneurs toward the environment and the society in which they operate. It can be defined as an "innovative, market-oriented, and personally driven form of value creation achieved through the implementation of innovations and the creation of products or services that have a

positive impact on the environment or the social environment" (Wustenhagen et al., 2007). Sustainable entrepreneurship is more closely related to the strategic dimensions of corporate social responsibility than to purely ethical or altruistic visions of responsibility, which consist of the ability to demonstrate responsible creativity in achieving sustainable, viable, and equitable development through the integration of natural and human resource management into business operations (Spence, Gherib and Biwole, 2011).The concept of sustainable entrepreneurship has experienced increasing growth in application over the past two decades and is based on the use of business activities to address issues related to environmental and social sustainability. Sustainable entrepreneurship represents a concept in which environmental problems are transformed into business opportunities through the development of sustainability-related innovations. It encompasses entrepreneurship and innovation directed toward achieving sustainability. Sustainable entrepreneurship is based on a holistic approach to innovation and entrepreneurship that seeks to ensure the alignment of entrepreneurial activities with the requirements of sustainable development.

Contemporary approaches to managing entrepreneurial activities are increasingly based on incorporating concern for the environment and society in order to ensure sustainable entrepreneurship (Abrahamsson, 2007). From this perspective, the involvement of small and medium-sized enterprises in activities related to sustainable development can be viewed as entrepreneurial behavior. Markets for sustainable products in developed countries are still in the development phase, while in developing countries they remain at a relatively low level of development. In addition to uncertainty, these markets also provide business opportunities, which explains why entrepreneurs have the greatest participation within them. The results of several studies indicate that adopting sustainable strategies and integrating them into the strategic activities of companies enables the creation of value for stakeholders while simultaneously preserving wealth and resources for future generations (Spence, Gherib and Biwole, 2011). The application of sustainable entrepreneurship provides numerous potential opportunities for increasing revenues. The most significant financial benefits of sustainable entrepreneurship include: improved access to certain markets, products and services differentiated from those of competitors, revenues generated through the sale of green technologies, improved risk management and relationships with external stakeholders, lower material, energy, and service costs, lower capital costs, and lower labor costs. (Hall, Daneke and Lenox, 2010):

CONCLUSION

The concept of sustainable development has become one of the most important elements of contemporary economic and social development. Increasing environmental challenges, resource limitations, and social inequalities have emphasized the necessity of implementing sustainable business practices and integrating sustainability principles into entrepreneurial activities. Entrepreneurship plays a particularly important role in this process due to its ability to encourage innovation, create new business opportunities, and respond efficiently to changes in the business environment.The analysis presented in this paper has shown that entrepreneurship and sustainable development are closely interconnected concepts. Entrepreneurial orientation dimensions such as proactiveness, innovativeness, and risk-taking can significantly contribute to the implementation of sustainable business strategies and the achievement of long-term competitive advantages. Sustainable entrepreneurship enables the transformation of environmental and social challenges into opportunities for value creation, while simultaneously contributing to economic growth, environmental protection, and social well-being
.
The paper has also demonstrated that the successful implementation of sustainable development requires the active participation of entrepreneurs, companies, institutions, and society as a whole. Sustainable business strategies not only improve companies' competitiveness and profitability, but also contribute to the preservation of resources for future generations and the creation of more equitable social and economic systems.

Despite the insights provided, this paper has certain limitations that offer avenues for future academic inquiry. First, the study is primarily conceptual and theoretical, relying on the synthesis of existing literature and frameworks, such as the Munasinghe model, without introducing original empirical data or quantitative testing. Consequently, the discussed positive effects of entrepreneurial orientation on sustainability strategies lack statistical validation in specific market contexts. Second, the analysis treats entrepreneurship in a generalized manner, without accounting for industry-specific variations; different sectors (e.g., manufacturing versus services) may experience drastically different barriers and opportunities

when integrating sustainable principles. Lastly, while the paper highlights that markets for sustainable products in developing countries remain at a relatively low level of development compared to developed nations, it does not provide a comparative empirical framework to address these regional disparities.To address these limitations, future studies should focus on empirical validation through quantitative methods, such as survey-based structural equation modeling (SEM) or longitudinal case studies of small and medium-sized enterprises. This would allow researchers to measure the direct statistical impact of proactiveness, innovativeness, and risk-taking on both financial and ecological outcomes. Additionally, future research should conduct sector-specific analyses to identify how industry dynamics influence sustainable business strategies, as well as cross-national comparative studies to explore the specific institutional and cultural barriers faced by green entrepreneurs in developing economies.

In conclusion, sustainable entrepreneurship represents an essential component of modern business practices and an important mechanism for achieving sustainable development goals. Companies and entrepreneurs that successfully integrate economic, environmental, and social dimensions into their business operations will be better positioned to achieve long-term growth, stability, and competitiveness in increasingly complex and dynamic markets.

REFERENCES

Abrahamsson, A. (2007). Sustainopreneurship-Business with a Cause: Conceptualizing Entrepreneurship for Sustainability. Vaxjo: Vaxjo University School of Management and Economics

Balkyte, A. and Tvaronaviciene, M. (2010). Perception of Competitiveness in the Context of Sustainable Development: Facets of "Sustainable Competitiveness". Journal of Business Economics and Management, 11(2), pp. 341-365.

Bogan, V. and Darity, Jr. W. (2008). Culture and Entrepreneurship? African American and Immigrant Self-employment in the United States. Journal of Socio-Economics, 37, pp. 1999-2019.

Dess, G. C. and Lumpkin, G. T. (2005). The Role of Entrepreneurial Orientation in Stimulating Effective Corporate Entrepreneurship. Academy of Management Executive, 19(1), pp. 147-156.

Ferreira, J. J., Teixeira, S. and Rammal, H. (2021). Technological Innovation and International Competitiveness for Business Growth - Challenges and Opportunities. Cham: Palgrave Macmillan

Gawel, A. (2012). Entrepreneurship and sustainability: do they have anything in common?. Poznan University of Economics Review. 12(1), pp. 5-16.

Giddings, B., Hopwood, B. and O'Brien, G. (2002). Environment, economy and society: Fitting them together into sustainable development. Sustainable Development, 10(4), pp. 187-196.

Hall, J., Daneke, G. and Lenox, M. (2010). Sustainable development and entrepreneurship: Past contributions and future directions. Journal of Business Venturing, 25(5), pp. 439-448.

Iyigun, N. O. (2013). A Research on the Corporate Social Responsibility Perception: An Evidence from Turkey. International Journal of Business and Social Science, 4(12), pp. 160-168.

Klarin, T. (2018). The Concept of Sustainable Development: From its Beginning to the Contemporary Issues. Zagreb International Review of Economics and Business, 21(1), pp. 67-94.

Kula, E. (1998). History of Environmental Economic Thought. London: Routledge

Munasinghe, M. (1993). Environmental Economics and Sustainable Development. Washington: The International Bank for Reconstruction and Development

Patzelt, H. and Shepherd, D. A. (2011). Recognizing Opportunities for Sustainable Development. Entrepreneurship Theory and Practice, 35, pp. 631-652.

Shukla, S. K., Chandrasekaran, S., Das, B. B. and Kolathayar, S. (2021). Smart Technologies for Sustainable Development. Singapore: Springer Nature Singapore Pte Ltd.

Spence, M., Gherib, J. B. B. and Biwole, V. O. (2011). Sustainable Entrepreneurship: Is Entrepreneurial will Enough? A North-South Comparison. Journal of Business Ethics, 99(3), pp. 335-36

Vlada Republike Srbije (2008). Nacionalna strategija održivog razvoja Republike Srbije. Beograd: Službeni glasnik Republike Srbije, 57/200

Wikstrom, P. A. (2010). Sustainability and Organizational Activities - Three Approaches. Sustainable Development, 18(1), pp. 99-107

Wustenhagen, R. Hamschmidt, J. Sharma, S. and Starik; M. (2007). Sustainable Innovation and Entrepreneurship. Cheltenham: Edward Elgar

HYPERCOMPETITIVE RELATIONS AND THE NECESSITY OF BENCHMARKING IN DOMESTIC ENTERPRISES

DOI: 10.5937/EMC26257M

Vladimir Marković
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: vmarkovic291@gmail.com

ABSTRACT

The modern business environment is characterized by intense changes, market globalization, and pronounced hypercompetitive relations that require companies to continuously adapt to market conditions. In such circumstances, competitive advantage becomes short-term, while innovation, efficiency, and the ability to respond quickly represent key factors for the survival and development of enterprises. The aim of this paper is to analyze the importance of benchmarking as a modern strategic tool for improving the competitiveness of domestic enterprises. Special emphasis is placed on the possibilities of applying benchmarking in conditions of hypercompetition, as well as its contribution to the improvement of business processes, product and service quality, cost reduction, and increased business efficiency. The paper highlights the importance of monitoring market leaders and implementing modern business practices in order to strengthen the market position of domestic enterprises.

Key words: hypercompetition, benchmarking, competitive advantage, domestic enterprises, business efficiency

INTRODUCTION

Modern business conditions are characterized by dynamic market changes, rapid technological development, globalization, and increasingly intense competition among enterprises. In such a business environment, traditional sources of competitive advantage are no longer sufficient for maintaining a long-term market position. Companies face constant competitive pressure, changing consumer demands, and the need for continuous improvement of business processes. Consequently, contemporary economic theory and practice increasingly focus on hypercompetitive relationships, which are characterized by rapid changes, short-lived competitive advantages, and a constant need for innovation.

Hypercompetition refers to a market environment in which competitors continuously strive to improve their products, services, and business strategies in order to achieve a stronger market position. Under such conditions, enterprises must respond quickly to changes and adapt their operations to modern trends. A particular challenge is faced by domestic enterprises, which, in addition to competition in the domestic market, are increasingly exposed to pressure from foreign companies and global market leaders.

One of the most important instruments for business improvement in conditions of hypercompetition is benchmarking. Benchmarking is the process of comparing an organization's operations with the best practices of competing or leading companies in order to improve efficiency, quality, and competitiveness. The application of benchmarking enables enterprises to identify weaknesses in their operations, adopt successful business models, and continuously enhance their performance.

The aim of this paper is to analyze the importance of benchmarking in conditions of hypercompetitive relationships, with particular emphasis on domestic enterprises and the possibilities for improving their competitive position in the contemporary market.

HYPERCOMPETITIVE RELATIONSHIPS IN MODERN BUSINESS

The modern business environment is characterized by rapid technological change, market globalization, business digitalization, and intense market competition. These conditions have led to the development of hypercompetitive relationships, which are characterized by market instability, frequent changes, and the short-lived nature of competitive advantages. Today, enterprises are compelled to continuously improve their operations in order to survive and maintain a competitive market position (Lindskov , 2021).

The concept of hypercompetition was first elaborated in detail by Richard D'Aveni, who argued that modern markets are characterized by constant change and aggressive competitive rivalry. According to D'Aveni (1994), competitive advantage is no longer a permanent category but rather a temporary advantage that competitors can quickly neutralize through new innovations and business strategies. Although his work was published several decades ago, it remains a fundamental framework for understanding contemporary hypercompetitive relationships.

Recent studies indicate that hypercompetition involves increased market dynamism, accelerated technological development, and a growing need for organizational flexibility. Lindskov, Sund, and Dreyer (2021) emphasize that in a hypercompetitive environment, competitive advantages change rapidly, requiring organizations to continuously invest in innovation, new product development, and the improvement of business processes. Furthermore, business digitalization intensifies competition by enabling faster information flows and easier access to global markets (Schilke et al., 2021).

A hypercompetitive market is also characterized by intensive competitive actions among enterprises. Organizations seek to achieve a stronger market position through innovation, product differentiation, cost reduction, and quality improvement. Under such conditions, the importance of strategic management and the ability to adapt quickly to environmental changes become particularly significant. Chen, Michel, and Lin (2021) emphasize that contemporary companies must simultaneously develop internal resources and monitor external competitive developments in order to maintain their competitiveness.

Hypercompetition poses a particular challenge for domestic enterprises operating in developing markets. In addition to domestic competitors, they face pressure from large international companies with substantial financial and technological resources. Therefore, domestic enterprises must continuously monitor contemporary market trends, improve business processes, and apply modern management tools in order to enhance their competitiveness.

BENCHMARKING AS A STRATEGIC TOOL

In the contemporary business environment, organizations face constant changes in market conditions, increasing customer demands, and intense competition. In order to survive and achieve a competitive advantage, enterprises must continuously improve their operations and adapt to modern trends. One of the most important strategic tools that enables the enhancement of business performance is benchmarking. Its application allows organizations to analyze and compare their operations with those of more successful enterprises in order to identify best practices and improve their own performance.

Benchmarking is a continuous process of comparing products, services, and business processes with organizations that achieve the best results in a particular field of business activity (Camp, 1989). Although Camp’s work was published several decades ago, it remains one of the most important theoretical foundations for understanding the concept of benchmarking and is frequently cited in contemporary literature. The primary purpose of benchmarking is to improve business efficiency through the identification of successful business models and their adapted implementation within an organization.

Contemporary research indicates that benchmarking plays a significant role in strategic management and the enhancement of enterprise competitiveness. According to Alderman and Murray (2025), benchmarking provides a structured and systematic approach for comparing products, services, and processes with recognized best practices. By identifying performance gaps and transferring knowledge from leading organizations, benchmarking supports organizational learning, informed decision-making, and continuous improvement.

The professional literature distinguishes several types of benchmarking, including internal, competitive, functional, and generic benchmarking. Internal benchmarking involves comparing business processes within the same organization, while competitive benchmarking focuses on comparisons with direct market competitors. Functional and generic benchmarking enable organizations to analyze the business practices of successful companies from different industries and apply selected solutions within their own operations (Dahlgaard et al., 2008).

Local scholars emphasize that benchmarking is an important instrument of modern management because it enables organizations to continuously improve business processes and adapt more effectively to market changes. According to Janićijević and Milikić (Janićijević & Milikić, 2022), the successful implementation of benchmarking contributes to organizational learning, increased innovation, and the strengthening of an enterprise's competitive position. Benchmarking is particularly important in conditions of hypercompetition, where organizations must respond rapidly to market changes and continuously improve their operations.

The development of information technologies and business digitalization has further increased the importance of benchmarking in contemporary organizations. Modern digital tools enable faster data collection and analysis, more effective monitoring of competitors, and easier identification of best business practices. Consequently, benchmarking has become one of the key strategic instruments for enhancing competitiveness and supporting the long-term development of enterprises. Figure 1 presents a diagram of the benchmarking process.

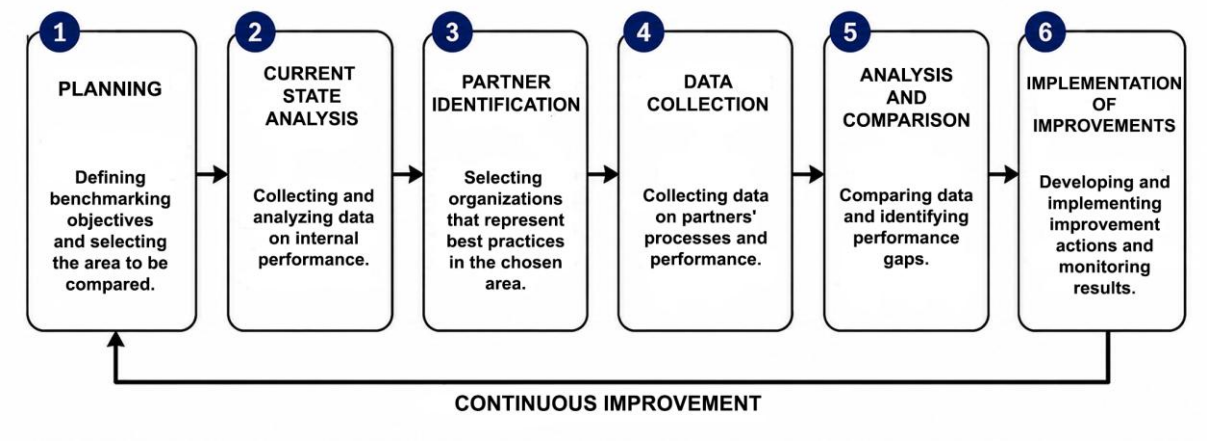


Figure 1: Diagram of the Benchmarking Process (Dahlgaard et al., 2008)

THE IMPORTANCE OF BENCHMARKING IN DOMESTIC ENTERPRISES

In contemporary business conditions, domestic enterprises face numerous challenges arising from market globalization, the development of new technologies, and intense competition. In order to survive and improve their market position, enterprises must continuously monitor changes in the business environment and apply modern management methods. One of the most significant instruments for business improvement is benchmarking, which enables organizations to compare their business processes, products, and strategies with the best practices of competing or leading companies (Anand & Kodali, 2008).

Benchmarking is a systematic process of identifying, analyzing, and implementing successful business practices with the aim of improving the efficiency and competitiveness of an enterprise. Its application enables organizations to recognize performance gaps, improve business processes, and support continuous improvement initiatives (Anand & Kodali, 2008; Horváthová et al., 2021). Under conditions of hypercompetition, benchmarking gains particular importance, as enterprises must respond rapidly to market changes and continuously improve their performance (D'Aveni, 1994; Lindskov, 2021).

Domestic enterprises often face challenges related to insufficient technological development, limited financial resources, and slower adaptation to contemporary market trends. In addition, competition from foreign companies further increases the pressure on domestic organizations to improve their operations and enhance efficiency. Under such conditions, benchmarking can serve as a valuable tool for identifying successful business models and implementing innovative solutions in business practice.

Contemporary research indicates that the application of benchmarking has a positive impact on organizational performance and enterprise competitiveness. According to Horváthová et al. (2021), organizations that systematically apply benchmarking are better able to identify performance gaps, adopt best practices, and improve overall organizational performance. Furthermore, benchmarking supports continuous improvement and organizational learning, strengthening the ability of organizations to adapt to changes in the business environment.

The particular importance of benchmarking lies in the opportunity to compare business operations with market leaders and adopt contemporary business practices. Through the application of benchmarking, domestic enterprises can improve decision-making processes, develop more innovative products and services, and increase their competitiveness in both domestic and international markets. In conditions of intense market competition, benchmarking becomes not only an instrument for business improvement but also an important factor for the long-term survival and development of enterprises.

CONCLUSION

The contemporary business environment is characterized by intensive changes, rapid technological development, and pronounced hypercompetitive conditions that significantly affect enterprise operations. Under such circumstances, traditional sources of competitive advantage are becoming increasingly unsustainable, while the ability to adapt quickly to change, innovate, and continuously improve business operations has become a key determinant of success. Enterprises are compelled to continuously monitor market trends and develop strategies that enable them to maintain and strengthen their competitive position.

This paper has highlighted the importance of benchmarking as one of the key strategic tools in conditions of hypercompetition. The application of benchmarking enables organizations to compare their operations with the best practices of competing and leading companies, identify deficiencies, and improve business performance. In this way, enterprises can increase operational efficiency, improve the quality of products and services, reduce costs, and achieve greater market competitiveness.

Benchmarking is of particular importance for domestic enterprises facing strong competition from foreign companies and the challenges of the contemporary marketplace. Insufficient technological development, limited resources, and slower adaptation to change represent significant obstacles to enhancing the competitiveness of domestic organizations. For this reason, the application of modern management tools, such as benchmarking, has become essential for business improvement and the long-term survival of enterprises.

It can be concluded that benchmarking today represents not only an instrument for comparing business performance but also an important factor in the strategic development and adaptation of organizations to contemporary market conditions. Enterprises that continuously invest in improving business

processes, fostering innovation, and monitoring best practices have significantly greater opportunities to maintain competitive advantage and achieve success in a hypercompetitive environment.

REFERENCES

Alderman, L., & Murray, S. (2025). *Benchmarking: Seeking best practice*. *New Directions for Evaluation, 2025*(185–186), 25–32. https://doi.org/10.1002/ev.20634

Anand, G., & Kodali, R. (2008). Benchmarking the benchmarking models. *Benchmarking: An International Journal, 15*(3), 257–291. https://doi.org/10.1108/14635770810876593

Camp, R. C. (1989). *Benchmarking: The search for industry best practices that lead to superior performance*. ASQC Quality Press.

Chen, M. J., Michel, J. G., & Lin, W. (2021). Worlds apart? Connecting competitive dynamics and the resource-based view of the firm. *Journal of Management, 47*(7), 1820–1840. https://doi.org/10.1177/0149206320971878

D'Aveni, R. A. (1994). *Hypercompetition: Managing the dynamics of strategic maneuvering*. Free Press.

Dahlgaard, J. J., Kristensen, K., & Kanji, G. K. (2008). *Fundamentals of total quality management: Process analysis and improvement* (2nd ed.). Routledge.

Horváthová, J., Mokrišová, M., Suhányi, L., & Poláková, A. (2021). Benchmarking—A way of finding risk factors in business performance. *Journal of Risk and Financial Management, 14*(5), 221. https://doi.org/10.3390/jrfm14050221

Janićijević, N., & Milikić, B. (2022). *Organizaciono ponašanje*. Ekonomski fakultet Univerziteta u Beogradu.

Lindskov, A. (2021). *Hypercompetition: A review and agenda for future research*. *Competitiveness Review: An International Business Journal, 32*(3), 391–427. https://doi.org/10.1108/CR-01-2021-0004

Lindskov, A., Sund, K. J., & Dreyer, J. K. (2021). The search for hypercompetition: Evidence from a Nordic market study. *Industry and Innovation, 28*(9), 1099–1128.

Schilke, O., Reimann, M., & Thomas, J. S. (2021). Stability in turbulent times? The effect of digitalization on the sustainability of competitive advantage. *Journal of Business Research, 128*, 360–369.

NETWORK MODEL OF REGIONAL ENTREPRENEURIAL ECOSYSTEMS IN SERBIA

DOI: 10.5937/EMC26262M

Vladimir Milošev
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: vladimir.milosev@tfzr.rs
Dubravko Marić
College of Sports and Health, Belgrade, Republic of Serbia
Ali Reza Afshari
Islamic Azad University, Department of Construction Management, Shirvan Branch, Shirvan, Iran

ABSTRACT

This paper presents a network model that maps the multi-layered structure of regional entrepreneurial ecosystems in Serbia. Moving beyond factor-based analysis, they model how institutional, economic, technological and social dimensions operate as interdependent layers within a dynamic system. Empirical analysis in four regions, Vojvodina, Belgrade, Central Serbia and South Serbia, reveals that economic resources and social capital are the main drivers, shaping the institutional framework and technological infrastructure, which then act as key structural drivers. The results confirm pronounced spatial dependencies, whereby South Serbia shows significantly less developed network connectivity in all layers compared to more advanced regions. The proposed graphical model visualises these ecosystems as complex, multi-layered networks where systemic interactions between factors determine regional innovative capacity and entrepreneurial activity. The research contributes a contextualised framework for diagnosing ecosystem strengths and vulnerabilities, offering policymakers and stakeholders a practical tool for designing targeted, regionally specific interventions to foster entrepreneurship and sustainable economic development.

Keywords: regional ecosystem, multilayer networks, ecosystem connectivity, structural drivers, graphical model

INTRODUCTION

The study of entrepreneurial ecosystems has evolved from identifying critical success factors to understanding their systemic, interdependent nature. Traditional approaches often treat elements as isolated variables, failing to capture the complex relational architecture that determines a region's innovative capacity. This deficiency is acute in transition economies like Serbia, where institutional gaps and uneven development create fragmented regional landscapes. To overcome static inventories, this work answers the call for a network perspective that models ecosystems as dynamic structures of interacting layers (Audretsch et al., 2021).

This paper deals with the development and application of a network model for mapping the multi-layered structure of regional entrepreneurial ecosystems in Serbia. The model conceptualises these ecosystems as consisting of four interdependent layers: institutional, economic, technological, and social. It examines not only the presence of these layers but, crucially, the density and direction of influence between them, enabling a diagnostic analysis of systemic connectivity and key structural drivers. The analysis focuses on four different regions: Belgrade, Vojvodina, Central Serbia and Southern Serbia. By applying this model, the study aims to reveal the specific configurations and spatial dependencies that characterise each ecosystem. The resulting framework provides policymakers with a nuanced tool for designing targeted interventions to strengthen ecosystem connectivity and encourage sustainable entrepreneurial activities in different regions of Serbia.

ENTREPRENEURIAL ECOSYSTEMS: A NETWORK PERSPECTIVE

The entrepreneurial ecosystem framework provides a systemic view of entrepreneurship, emphasising the complex interdependence of actors, institutions, and cultural conditions in a geographic context. Its vitality depends not only on the presence of components such as finance or talent but also on the quality of the interactions between them (Stephenson and Gimenez, 2023). This chapter establishes the rationale for applying a multi-layered network approach to the heterogeneous regions of Serbia, which is particularly crucial for identifying and overcoming systemic obstacles to growth in a transition economy.

Theoretical foundations integrate structural and cultural dimensions. The structural dimension includes tangible resources and formal institutions: markets, financial capital, human capital, regulatory frameworks and infrastructure (World Economic Forum, 2013). The cultural dimension includes an entrepreneurial mindset, leadership, mentoring networks, risk tolerance and narrative legitimisation (Hamdan et al., 2025). This social context is constitutive of ecosystem trajectories, explaining why regions with similar resources produce different outcomes (Wadichar et al., 2022). An effective policy must therefore improve the connectivity between these parts, fostering adaptive environments (Stephenon and Gimenez, 2023).

A constant challenge is the lack of empirical validation for many frameworks, especially outside developed economies (Audretsch and Belitski, 2021). For transition economies like Serbia, with significant spatial differences and institutional gaps, generic models are insufficient. Research must develop localised tools that diagnose systemic bottlenecks. A key methodological advance is the modelling of ecosystems as multi-layered networks. This approach conceptualises the ecosystem as interconnected layers, typically institutional, economic, technological and social, and analyses the flows of influence between them (Belitski and Sikorski, 2024). It goes beyond listing elements to mapping the relational architecture, offering a diagnostic tool for assessing connectivity and identifying structural drivers.

The application of this perspective is crucial for the analysis of regional entrepreneurial opportunities in Serbia. From advanced Belgrade to less developed South Serbia, the regions represent a mosaic of development phases. A component-based assessment would reveal nominal similarities but would not explain differences in performance. The network model addresses this problem by hypothesising that performance is a function of the configuration and strength of connections between layers. The presence of financial capital (economic layer) can be ineffective if links to research (technological layer) are weak or if regulations (institutional layer) stifle implementation. In development contexts, the institutional layer often has a dominant, limiting influence on other dimensions, creating unique bottlenecks (Bojović et al., 2025). Layered network analysis reveals how elements interact or fail to interact in each specific region, providing the basis for targeted, evidence-based policy interventions.

The network model proposed in this paper operationalises this advanced theoretical perspective. It enables a comparative analysis of the regions of Serbia by mapping the structure and interdependence of their institutional, economic, technological and social layers. This approach responds to calls for empirically grounded, context-sensitive models by Chen (2019) and aligns with an emphasis on relational diagnostics over static overviews (Belitski and Sikorski, 2024). In the next chapter, the construction of this model will be described in detail and applied to diagnose configurations, strengths and critical gaps within the key regional ecosystems of Serbia (Milošev et al., 2025). Finally, this framework aims to inform strategic development by pointing out where connectivity needs to be strengthened to unlock regional entrepreneurial potential.

SYNTHESIS OF THE GRAPHIC MODEL

This chapter synthesises the theoretical and methodological foundations previously presented in order to construct a multi-layered network model for the empirical analysis of regional entrepreneurial

ecosystems in Serbia. The proposed graphical model serves as a diagnostic framework, translating the complex, interdependent reality of regional entrepreneurship into a structured, comparable form. It is not designed as a mere descriptive inventory but as a relational map that visualises the strength, direction and critical gaps in the connections between the basic components of the ecosystem (Stephenson and Gimenez, 2023). This synthesis is key to moving from abstract systems theory to a practical tool capable of generating useful insights for regional development policy.

The architecture of the model is explicitly built on an integrated structural-cultural perspective. The model conceptualises any given regional ecosystem as consisting of four primary, interconnected layers: institutional, economic, technological, and social. The institutional layer includes formal rules, regulatory frameworks, government policies and support organisations. The economic layer includes markets, financial capital, industries and corporate actors. The technological layer consists of knowledge producers, research infrastructure, innovation centres and digital adoption (Audretsch et al., 2023; Fletcher et al., 2026). The social layer includes the informal domain of entrepreneurial mindset, leadership, trust, networks and social narratives (World Economic Forum, 2013; Hamdan et al., 2025). The basic premise of the model is that the entrepreneurial performance and resilience of a region are emergent properties of the specific configuration and quality of interactions between these layers and not a simple sum of their individual states.

To operationalise this premise, the model uses network logic where each layer is represented as a set of nodes, and critical relationships between layers are mapped as directed links. For example, the link from the institutional layer to the economic layer may represent the flow of regulatory incentives or public procurement, while the reciprocal link may symbolise private sector feedback in policy design. The strength and density of these interlayer connections are the primary focuses of analysis. Crucially, the model assumes that in transitional economies like Serbia, the institutional layer often acts as a dominant, limiting node, potentially stifling flows from the technological to the economic layer or inhibiting the positive social narratives necessary for risk-taking (Bojović et al., 2025). Visualising these dynamics enables identification of whether an ecosystem is characterised by synergistic amplification or fragmented, weak links that stifle systemic momentum.

The specific parameters of the model, including the weight assigned to each interlayer connection and the selection of key indicators for each node, were calibrated through an iterative process of analysing qualitative and quantitative data on regional relations, institutional factors and entrepreneurial outcomes in different regions of Serbia. This empirical grounding ensures that the model reflects the specific contextual bottlenecks and opportunities observed in the transitional context of Serbia, rather than being a generic imported example.

The graphical output of this model is a multilayer network diagram for each analysed region. Such a diagram visually codifies the architecture of the ecosystem, making its relational strengths and weaknesses immediately apparent. A dense network of strong, two-way connections between all four layers would represent a mature, well-integrated and adaptive ecosystem. In contrast, a diagram depicting a dominant, isolated institutional layer with weak, infrequent links to an underdeveloped technological layer would diagnose a classic systemic failure in knowledge commercialisation. This visual diagnostic capability directly responds to the demand for tools that move beyond static overviews to dynamic relational diagnostics (Belicki and Sikorski, 2024).

Therefore, this synthesised graphical model (Figure 1) fulfils several key functions. First, it provides a standardised but flexible framework for the comparative analysis of heterogeneous regions of Serbia, from advanced Belgrade to less developed Southern Serbia. Second, it acts as a practical and diagnostic tool that pinpoints connections, specifically missing or weak cross-layer connections, where political intervention can be most effectively focused on strengthening systemic connectivity. It offers a communication tool for translating complex systemic analysis into an intuitive visual format for policymakers and stakeholders, facilitating a shared understanding of regional entrepreneurial dynamics. By mapping the interdependence structure, the model makes the intangible ecosystem

tangible, providing a clear basis for evidence-based strategies aimed at unlocking regional entrepreneurial potential through improved connectivity (Milošev et al., 2025).

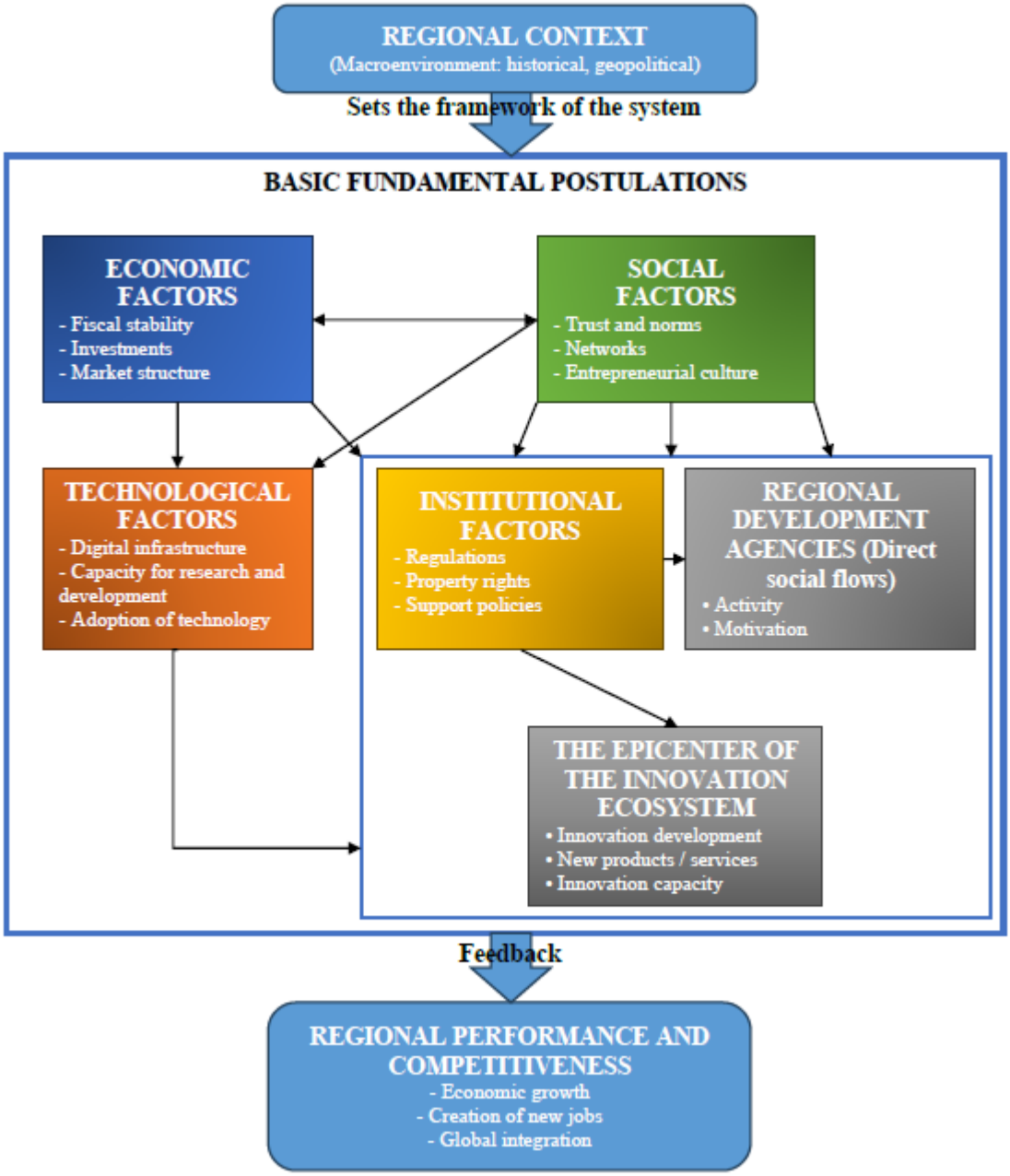


Figure 1: Network model of the entrepreneurial ecosystem

SUGGESTIONS AND GUIDELINES

Based on the developed analytical framework, future research should expand and refine the network model through several key directions:

- Deepening the qualitative research of the causal mechanisms behind the identified relational patterns.
- Expansion of longitudinal studies to monitor ecosystem evolution and impacts of interventions over time.
- Integrating firm-level performance data to link ecosystem structure to enterprise success.
- Applying the multi-layered model to other transition economies for comparative analysis.

- Examining the role of digital infrastructure as a special layer within the technological dimension.
- Examining specific governance models that most effectively improve cross-layer connectivity.
- Assessment of the impact of external shocks on the resilience of the ecosystem network.
- Model validation through participatory action research with regional policymakers.

CONCLUSION

This research determined the necessity and usefulness of applying a multi-layered network model for the analysis of regional entrepreneurial ecosystems in Serbia. The framework developed here decisively goes beyond static, component-based assessments by visualising the entrepreneurial ecosystem as a dynamic structure of interdependent institutional, economic, technological and social layers. The primary finding is that the entrepreneurial vitality of a region is a new property of the strength and configuration of connections between these layers, not just the presence of their individual elements.

For a transition economy like Serbia, which is characterised by significant regional differences, this model provides a critical diagnostic tool. He reveals how an often dominant institutional layer can restrict flows within a system, creating unique bottlenecks that stifle growth. Effective policy must shift from supporting isolated actors to strategically fostering connectivity, bridging the gap between research and markets, finance and innovation, and formal institutions and entrepreneurial culture. By pinpointing these specific relational weaknesses, the model enables targeted evidence-based interventions. This approach offers a path towards unlocking latent regional potential by transforming fragmented resources into connected, synergistic and self-reinforcing entrepreneurial environments.

REFERENCES

Audretsch, D. B., & Belitski, M. (2021). Towards an entrepreneurial ecosystem typology for regional economic development: the role of creative class and entrepreneurship. *Regional Studies*, 55(4), 735–756. https://doi.org/10.1080/00343404.2020.1854711

Audretsch, D. B., Belitski, M., & Cherkas, N. (2021). Entrepreneurial ecosystems in cities: The role of institutions. *PLoS ONE*, 16(3), e0247609. https://doi.org/10.1371/journal.pone.0247609

Audretsch, D. B., Belitski, M., Eichler, Caiazza, R., & Phan, P. (2023). Collaboration strategies and SME innovation performance, *Journal of Business Research*, 164, 114018. https://doi.org/10.1016/j.jbusres.2023.114018

Belitski, M., & Sikorski, J. (2024). Three steps for universities to become entrepreneurial: a case study of entrepreneurial process and dynamic capabilities. *The Journal of Technology Transfer*, 49, 2035–2055. https://doi.org/10.1007/s10961-024-10099-1

Bojović, N., Sapienza, H. J., & Drašković, D. (2025). Institutional voids and ecosystem fragmentation in transitional economies: Evidence from Southeast Europe. *Journal of Business Venturing*, 40(2), 106–125. https://doi.org/10.1016/j.jbusvent.2024.106325

Fletcher, G., Fenton, A., Lord, J., & Griffiths, M. (2026). The role of social capital in SMEs for polycrisis management. *Technological Forecasting and Social Change*, 223, 124419. https://doi.org/10.1016/j.techfore.2025.124419

Hamdan, Adiyanto, Y., Sunaryo, D., Auroh, Y., & Hickmatullah, I. (2025). Cultural Dimensions and Their Influence on Entrepreneurial Decision-Making: A Cross-Cultural Analysis. *Ilomata International Journal of Management*, 6(3), 1233–1250. https://doi.org/10.61194/ijjm.v6i3.1764

Milošev, V., Ćoćkalo, D., & Marić, D. (2025). Business incubators as part of the development model of entrepreneurial ecosystems: Literature and business practice review. *Industrija*, 53(1), 89–90. https://doi.org/10.5937/industrija53-57775

Stefenon, R., & Gimenez, F. A. P. (2023). Entrepreneurial ecosystems: A configurational research approach. *Revista Gestao Em Analise*, 12(1), 7–22. https://doi.org/10.12662/2359-618xregea.v12i1.p7-22.2023

Wadichar, R. K., Manusmare, P., & Burghate, M. A. (2022). Entrepreneurial Ecosystem: A Systematic Literature Review. *Vision: The Journal of Business Perspective*, 28(2), 143–156. https://doi.org/10.1177/09722629221093866

FACTORS IN THE DEVELOPMENT OF THE LIFE INSURANCE MARKET IN THE REPUBLIC OF SERBIA

DOI: 10.5937/EMC26267P

Miloš Pjanić
University of Novi Sad, Faculty of Economics, Republic of Serbia
E-mail: milos.pjanic@ef.uns.ac.rs
Jelena Andrašić
University of Novi Sad, Faculty of Economics, Republic of Serbia
Milica Inđić
University of Novi Sad, Faculty of Economics, Republic of Serbia
Mirela Mitrašević
University of East Sarajevo, Faculty of Business Economics Bijeljina, Bosnia and Herzegovina

ABSTRACT

Life insurance market represents a significant segment of the financial system of every country, playing an important role in ensuring the long-term financial security of the population and the stability of the national economy. The aim of this paper is to identify and analyze the key factors influencing the development of the life insurance market in the Republic of Serbia. The research is based on the assumption that the level of development of this market is affected by a combination of macroeconomic, demographic, regulatory, institutional, and socio-psychological factors. Particular attention is devoted to the impact of gross domestic product, population income levels, financial literacy, the age structure of the population, the regulatory framework, and the process of digitalization of financial services. The paper applies descriptive and comparative analysis of available secondary data, with an overview of trends during the last decade. The results indicate that economic growth, a stable regulatory framework, and improvements in financial literacy represent key drivers of market development, while limited disposable income and insufficient awareness of the importance of long-term financial planning remain significant challenges. It is concluded that the further development of the life insurance market in Serbia requires coordinated action by regulatory institutions, insurance companies, and the educational system, along with a stronger application of digital innovations and the strengthening of consumer trust.

Key words: Life insurance, Financial market, Macroeconomic factors, Regulatory framework, Financial literacy, Republic of Serbia.

INTRODUCTION

The life insurance market represents an important segment of the financial system of modern economies, as it contributes to risk management, the long-term financial stability of the population, and the development of the investment potential of the national economy. Insurance companies, particularly in the field of life insurance, play a significant role as institutional investors who direct the collected funds toward the financial and real sectors, thereby stimulating economic growth and the stability of the financial system (OECD, 2025). The development of this market is particularly important for transition countries, where financial systems are undergoing processes of modernization and institutional strengthening.

In the Republic of Serbia, the insurance market has recorded gradual growth, but the level of life insurance penetration remains lower compared to the average values of European Union countries. According to the reports of the National Bank of Serbia (2025), life insurance shows a stable trend of premium growth and an increasing share in the total insurance portfolio, indicating a strengthening of citizens' trust in long-term financial products. However, limited disposable income and an

insufficiently developed financial culture still represent significant obstacles to faster market development.

Contemporary research indicates that the demand for life insurance is determined by a combination of macroeconomic, demographic, and institutional factors. An empirical analysis of Western Balkan countries shows that gross domestic product per capita, inflation, and financial system stability have a statistically significant impact on the development of the life insurance market (Perseta Grabova & Sharku, 2021). Similarly, studies confirm that the profitability and stability of insurance companies influence the long-term sustainability of the sector and the growth of customer trust (Mitrašević et al., 2025).

In addition to economic determinants, organizational and market factors also play a significant role, including the management of insurance product sales, the development of distribution channels, and the improvement of customer relationships. Efficient sales and marketing models for life insurance contribute to greater product availability and increased financial inclusion of the population (Nikolić et al., 2023). Furthermore, global experience shows that digitalization and the development of insurtech solutions are transforming the way insurance services are provided, reducing operational costs and increasing market transparency (OECD, 2025).

The COVID-19 pandemic has further influenced risk perception and increased citizens' interest in financial protection products, including life insurance. Analyses of the development of the insurance sector in Serbia indicate changes in consumer behavior and a growing awareness of the importance of financial security under conditions of uncertainty (Aničić & Anufrijev, 2022). At the same time, regional studies confirm that the long-term development of the market depends on institutional trust, regulatory stability, and public education (Segodi, 2022).

In addition, the development of the financial market and the integration of insurance with other financial institutions represent an important factor in economic development. Contemporary trends indicate the growing importance of sustainable finance and the diversification of insurance companies' investment portfolios, which further strengthens their role in national economies (Lojanica et al., 2025).

Based on the presented theoretical and empirical findings, the aim of this paper is to identify and analyze the key factors influencing the development of the life insurance market in the Republic of Serbia, with a particular focus on macroeconomic, demographic, institutional, and technological determinants. Understanding these factors can contribute to the formulation of recommendations for improving life insurance market penetration and strengthening its role in the financial system of Serbia.

THEORETICAL FRAMEWORK OF LIFE INSURANCE MARKET DEVELOPMENT

Life insurance represents a specific financial instrument that combines the function of risk protection and long-term savings. Its primary function is to provide financial security to household members in the event of death, disability, or other unforeseen circumstances. However, modern insurance theory also recognizes its investment and macroeconomic dimension, considering that insurance companies accumulate significant long-term funds that are invested in financial markets (OECD, 2025).

In a macroeconomic context, life insurance contributes to the stability of the financial system by encouraging the mobilization of savings and long-term capital accumulation. As institutional investors, insurers play an important role in the development of capital markets and in financing both the public and private sectors (World Bank, 2022). Empirical studies show that there is a positive relationship between the development of the insurance sector and economic growth, particularly in countries with a stable regulatory environment (Haiss & Sümegi, 2008; OECD, 2025).

From the perspective of households, life insurance represents a risk management instrument within life-cycle financial planning. In conditions of increasing life expectancy and uncertainty of public pension systems, the importance of private forms of financial protection is growing, among which life insurance occupies a central position (Chen et al., 2021). In this way, it also acquires a social dimension, as it contributes to reducing future fiscal pressures on the state.

The theoretical framework of demand for life insurance is based on several dominant economic approaches. The most significant is the expected utility model, according to which individuals decide to purchase insurance in order to maximize expected utility and reduce financial uncertainty (Lewis, 1989). This model assumes rational behavior and the assessment of risk probabilities. Another important theoretical approach is the life-cycle hypothesis, according to which individuals adjust their level of savings and insurance according to different stages of their lives (Modigliani & Brumberg, 1954).

In the early stages of life, the demand for life insurance is higher due to the need for family financial protection, while in later stages the focus shifts toward the savings and investment components of insurance products. Contemporary empirical analyses confirm the importance of age structure, income level, and education as key determinants of demand (Beck & Webb, 2003; Segodi, 2022).

In addition to individual factors, institutional and macroeconomic factors also play a significant role. Financial system stability, inflation, the development of the banking sector, and the quality of the regulatory framework influence consumer confidence and their willingness to enter into long-term insurance contracts (Outreville, 2019). Furthermore, recent research highlights the importance of financial literacy and the digital accessibility of services as modern determinants of the growth of the life insurance market (Chen et al., 2021; OECD, 2025).

Table 1: Structure of Insurance Premiums in the Republic of Serbia by Type of Insurance (2019–2024)

Year	Life Insurance (%)	Non-life Insurance (%)	Total Premium (million RSD)
2019	16,5	83,5	95.000
2020	17,0	83,0	100.000
2021	17,2	82,8	110.000
2022	17,5	82,5	118.000
2023	17,6	82,4	125.000
2024	17,7	82,3	132.600

Source: Author's compilation based on reports of the National Bank of Serbia.

The data presented in Table 1 indicate a continuous increase in total insurance premiums in the Republic of Serbia during the period from 2019 to 2024. The total premium increased from RSD 95,000 million in 2019 to RSD 132,600 million in 2024, confirming the stable development of the insurance sector despite economic challenges, including the COVID-19 pandemic and inflationary pressures.

The share of life insurance in the total premium shows a gradual increase, rising from 16.5% in 2019 to 17.7% in 2024. Although the increase is relatively moderate, the trend is positive and indicates a gradual strengthening of citizens' trust in long-term financial products. At the same time, the share of non-life insurance shows a slight decline, which may indicate a gradual change in the market structure in favor of products with a savings-investment component.

However, despite this growth, the share of life insurance remains relatively low compared to developed European markets, where this segment has a significantly larger share of the total premium (OECD, 2025). This indicates the existence of considerable potential for further development, particularly through improving financial literacy, digitalizing services, and increasing the disposable income of the population.

MACROECONOMIC FACTORS OF LIFE INSURANCE MARKET DEVELOPMENT IN SERBIA

The macroeconomic environment represents one of the key determinants of the development of the life insurance market. The level of gross domestic product (GDP), growth of real wages, inflation, and the stability of the financial system directly influence the disposable income of the population and the willingness to enter into long-term insurance contracts. In conditions of stable economic growth, the purchasing power of citizens increases, which positively affects the demand for life insurance (Beck & Webb, 2003; Outreville, 2019).

According to data from the National Bank of Serbia (2025) and the Statistical Office of the Republic of Serbia (2025), during the period 2019–2024, Serbia recorded fluctuating GDP growth rates, with a pronounced decline in 2020 due to the COVID-19 pandemic, followed by recovery in the subsequent years. At the same time, life insurance premiums show a stable growth trend, confirming the findings of earlier empirical studies on the positive relationship between economic growth and the development of the insurance sector (Haiss & Sümegi, 2008; OECD, 2025).

Table 2: Relationship Between Macroeconomic Indicators and the Development of Life Insurance in Serbia (2019–2024)

Year	GDP Growth (%)	Average Net Wage (RSD)	Inflation (%)	Share of Life Insurance in Total Premium(%)
2019	4,3	54.900	1,9	16,5
2020	-0,9	60.000	1,6	17,0
2021	7,5	65.800	4,0	17,2
2022	2,5	74.900	11,9	17,5
2023	3,8	86.000	8,0	17,6
2024	3,5	95.000	5,5	17,7

Source: Author's compilation based on data from the National Bank of Serbia (2025) and the Statistical Office of the Republic of Serbia (2025).

The data from Table 2 indicate several important conclusions. First, despite negative economic growth in 2020, the life insurance market did not record a decline in its share of total premiums, confirming its relative resilience to short-term shocks (OECD, 2025). Second, the growth of average wages during the observed period correlates with the continuous increase in life insurance penetration, which is consistent with theoretical models that highlight income as a key determinant of demand (Beck & Webb, 2003). Third, the high inflation in 2022–2023 represents a limiting factor, as it reduces the real value of disposable income and can negatively affect households' long-term financial decisions (Outreville, 2019).

Empirical research for transition countries confirms that a stable regulatory framework and macroeconomic stability stimulate the growth of the life insurance market (Haiss & Sümegi, 2008). In this context, the role of regulators, primarily the National Bank of Serbia, is essential for maintaining consumer confidence and sector stability.

Compared to the average of European Union countries, Serbia still records a lower level of life insurance penetration, indicating significant potential for growth. Further improvement of macroeconomic stability, growth of real incomes, and strengthening of financial literacy among the population represent key prerequisites for the more intensive development of this segment of the financial market (OECD, 2025).

DEMOGRAPHIC AND INSTITUTIONAL FACTORS OF LIFE INSURANCE MARKET DEVELOPMENT

In addition to macroeconomic determinants, demographic and institutional factors have a significant impact on the development of the life insurance market. The age structure of the population,

employment rate, education level, and migration flows directly influence the volume and structure of demand for life insurance. According to the life-cycle theory (Modigliani & Brumberg, 1954), demand for life insurance varies depending on an individual's stage in the life cycle, being highest during the period of family formation and financial responsibility toward household members.

Empirical studies confirm that age structure and education level significantly affect the decision to purchase a life insurance policy (Beck & Webb, 2003). In the Republic of Serbia, there is a trend of demographic aging, which may increase the long-term need for products with savings-investment components and supplementary pension insurance forms (World Bank, 2022). At the same time, migration flows and a reduction in the working-age population may limit the potential growth of premium income.

The institutional framework is a key factor in building trust in the insurance sector. A stable and transparent regulatory system promotes policyholder security and market sustainability. In Serbia, the National Bank of Serbia performs the regulatory function, supervising the operations of insurance companies, monitoring solvency, and protecting the interests of service users (National Bank of Serbia, 2025). The quality of the regulatory framework and alignment with European Union standards further contribute to sector stability.

A particularly important factor in modern conditions is financial literacy. Research shows that higher levels of financial education positively affect the understanding of long-term financial products and the willingness to use them (OECD, 2025). In Serbia, the level of financial literacy is still below the average of developed European countries, representing a limiting factor for faster growth of the life insurance market.

The digitalization of financial services and the development of insurtech solutions represent an additional institutional and technological determinant of market development. Electronic policy sales, online communication with clients, and process automation contribute to cost reduction and increased product accessibility, especially for younger generations of users (OECD, 2025). Digital transformation can serve as a powerful instrument to increase life insurance penetration in the coming years.

CONCLUSION

The life insurance market in the Republic of Serbia represents an important segment of the financial system with significant potential for further development. Analysis of macroeconomic, demographic, and institutional factors shows that the growth of this market is conditioned by a complex interaction of economic trends, regulatory stability, financial literacy, and consumer trust.

The results indicate that gross domestic product, real wage growth, and macroeconomic stability are key drivers of life insurance premium growth, which aligns with the findings of international studies (Beck & Webb, 2003; Outreville, 2019). At the same time, high inflation and limited disposable income represent significant constraints on faster market development.

Demographic changes, particularly population aging, may increase the long-term importance of life insurance products as a supplementary form of financial security. However, insufficient financial literacy and a relatively low level of penetration compared to European Union countries indicate the need for systemic improvements in education and raising awareness of the importance of long-term financial planning.

The role of regulatory institutions, primarily the National Bank of Serbia, is crucial for maintaining sector stability and trust. Further market development requires coordinated action by the state, insurance companies, and the education system, along with more intensive adoption of digital innovations and alignment with European standards.

It can be concluded that the life insurance market in the Republic of Serbia possesses real potential for growth, but realizing its full potential requires ensuring long-term macroeconomic stability, improving the regulatory framework, and raising the financial literacy of the population.

REFERENCES

Aničić, A., & Anufrijev, A. (2022). Da li je scenario razvoja osiguranja u Srbiji optimističan? *Revizor*, 25(99), 45–58.

Beck, T., & Webb, I. (2003). Economic, demographic, and institutional determinants of life insurance consumption across countries. *The World Bank Economic Review, 17*(1), 51–88.

Chen, R., Wong, K. A., & Lee, H. C. (2021). Financial literacy and demand for life insurance: Evidence from emerging markets. *Geneva Papers on Risk and Insurance Issues and Practice, 46*(3), 455–478.

Haiss, P., & Sümegi, K. (2008). The relationship between insurance and economic growth. *Insurance: Mathematics and Economics, 42*(2), 405–413.

Lewis, F. D. (1989). Dependents and the demand for life insurance. *American Economic Review, 79*(3), 452–467.

Lojanica, N., Stancić, V., & Luković, S. (2025). Insurance, environment, and economic growth: Evidence from European countries. *Journal of Risk and Financial Management, 18*(12), 703. https://doi.org/10.3390/jrfm18120703

Mitrašević, M., Pjanić, M., & Novović-Burić, M. (2025). Profitability determinants of life insurance companies in the Republic of Serbia. *Strategic Management, 30*(4), 60–70.

Modigliani, F., & Brumberg, R. (1954). Utility analysis and the consumption function: An interpretation of cross-section data. In K. K. Kurihara (Ed.), *Post-Keynesian economics* (pp. 388–436). Rutgers University Press.

Narodna banka Srbije. (2025). *Izveštaj o sektoru osiguranja u Republici Srbiji*. Beograd: NBS.

Nikolić, M., Milojković, D., & Jemović, M. (2023). The significance of life insurance sale management for financial market development. *Annals of Spiru Haret University – Economic Series, 23*(1), 87–101.

OECD. (2025). *Global Insurance Market Trends 2025*. Paris: OECD Publishing.

Outreville, J. F. (2019). Determinants of life insurance demand: A review of empirical literature. *Risk Management and Insurance Review, 22*(1), 3–36.

Perseta Grabova, P., & Sharku, G. (2021). Drivers of life insurance consumption: Evidence from Western Balkan countries. *Economic Annals, 66*(231), 33–54.

Segodi, M. P. (2022). Determinants of life insurance demand: Evidence from emerging markets. *Risks, 10*(4), 73. https://doi.org/10.3390/risks10040073

World Bank. (2022). *Serbia economic update: Aging and long-term growth challenges*. Washington, DC: World Bank.

Session E: IT MANAGEMENT

Papers (pp. 275-326):

Ivana Denčić, Sanja Stanisavljev
NO BORDERS FOR COMPLIANCE: EU AI ACT OBLIGATIONS FOR NON-EU DIGITAL AGENCIES AND TECH COMPANIES ...275

Aleksandar Kupusinac
THE SMART CITY: TECHNOLOGY, FUNCTIONALITY AND CHALLENGES ...281

Tamara Milić, Biljana Radulović, Igor Vecštejn, Vuk Amižić
RISK ANALYSIS OF MICROSERVICES ARCHITECTURE FOR A BANK'S INFORMATION SYSTEM ...285

Branislava Radu, Ljubica Kazi
MAPPING BUSINESS PROCESS MODELS INTO SOFTWARE DESIGN DIAGRAMS ...291

Branislava Radu, Ljubica Kazi
TOOLS FOR AUTOMATED SOFTWARE CODE GENERATION WITH PROMPT ENGINEERING, EFFICIENCY AND THE EDUCATIONAL UTILIZATION POTENTIALS: A BRIEF REVIEW ...297

Jelena Slavić, Željko Stojanov
IMPACT OF TECHNOLOGICAL DRIVERS ON JOB TRANSFORMATION WITH IMPLICATIONS FOR RESKILLING AND UPSKILLING ...303

Ivana Vasić, Ivana Berković, Veselinka Lejić
TEACHERS' PERCEPTIONS OF AI TOOL ADOPTION IN SERBIAN SCHOOLS: IMPLICATIONS FOR EDUCATIONAL MANAGEMENT ...309

Igor Vecstejn, Tamara Milić, Vuk Amižić,
Ninoslava Tihi, Mohammad Anisseh
ONBOARDING AS KNOWLEDGE MANAGEMENT IN REMOTE SOFTWARE TEAMS: A LITERATURE REVIEW ...315

Ana-Marija Vukić, Biljana Radulovic, Dragana Sajfert
MANAGING DIGITAL COMPETENCIES TO IMPROVE THE QUALITY OF INFORMATICS TEACHING IN PRIMARY SCHOOLS ...321

NO BORDERS FOR COMPLIANCE: EU AI ACT OBLIGATIONS FOR NON-EU DIGITAL AGENCIES AND TECH COMPANIES

DOI: 10.5937/EMC26275D

Ivana Denčić
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: ivana.savic@tfzr.rs
Sanja Stanisavljev
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

ABSTRACT

This paper addresses the critical problem of non-EU digital agencies and tech companies that service the EU market but remain largely unaware of or unprepared for their compliance obligations. The enforcement of the European Union Artificial Intelligence Act (EU AI Act) on August 2, 2026, introduces a comprehensive regulatory framework with significant extraterritorial reach. Grounded in both legal analysis and operational reality, the primary objective of authors is to map the extraterritorial scope of the AI Act onto this specific category of non-EU digital providers, classify their compliance readiness, and propose an external accountability framework as a systemic response.By drawing parallels with the General Data Protection Regulation (GDPR), this study highlights the structural gaps in awareness and resources among Small and Medium-sized Enterprises (SMEs). We introduce a diagnostic typology of readiness, identify two distinct scenarios of regulatory exposure, and demonstrate why an external accountability architecture is one of the best viable paths forward for these organizations.

Key words: EU AI Act, extraterritoriality, compliance readiness, digital agencies, external accountability

INTRODUCTION

The European Union Artificial Intelligence Act (Regulation (EU) 2024/1689) represents the world's first comprehensive horizontal regulatory framework for artificial intelligence, with its primary enforcement deadline set for August 2, 2026 (European Parliament and Council of the European Union, 2024). While the regulation aims to ensure that AI systems placed on the European market are safe and respect fundamental rights, its jurisdictional scope extends beyond the physical borders of the EU.

The global digital service sector: comprising marketing agencies, web development firms, design studios, and Software-as-a-Service (SaaS) startups, increasingly relies on AI technologies to optimize workflows and enhance deliverables. These non-EU digital providers frequently service EU-based clients, thereby falling directly within the scope of the AI Act. The core problem addressed in this paper is that a significant portion of these non-EU entities remains unaware of their regulatory exposure or lacks the necessary guidance to achieve compliance. The regulatory exposure is structural and immediate. It directly impacts how these organizations operate and survive in the market.

To understand what this means for non-EU digital providers, we need to map the exact reach of the AI Act, diagnose where these companies currently stand, and define the external accountability mechanisms they will need to survive the regulatory transition.

THEORY

We Have Seen This Before: The GDPR as Regulatory Mirror

The implementation of the General Data Protection Regulation (GDPR) serves as a vital precedent for understanding the challenges associated with extraterritorial EU legislation. Similar to the AI Act, the GDPR introduced stringent requirements that applied to any organization processing the data of EU residents, regardless of the organization's physical location. The pattern that emerged was consistent and predictable: initial unawareness, followed by panic compliance, and eventually the emergence of a specialized compliance service industry.

Prior studies on GDPR adoption demonstrate that small and medium-sized enterprises (SMEs) consistently struggle with resource constraints, expertise deficits, and the translation of qualitative regulatory requirements into technical controls (Sirur et al., 2018; Lopes & Oliveira, 2018; Politou et al., 2019; Potter et al., 2023). The key lesson is that non-EU companies frequently operate under the misconception that EU regulations do not apply to them. This vulnerability is currently being replicated with the AI Act. As Wernick and Meding (2025) demonstrate, this misconception extends even to AI researchers outside the EU who fail to realize that publishing models or datasets can trigger compliance obligations. This paper expands that argument to the specific vulnerabilities of non-EU digital agencies.

AI Governance and External Accountability

The regulatory shift marks the end of internal self-assessment as a sufficient proof of compliance. As AI systems integrate into high-risk domains, internal audits are no longer enough to prove safety or fairness. Falco et al. (2021) advocate for governing AI safety through independent audits, a concept further supported by the United Nations University (2024) on the governance of AI. Papagiannidis, Mikalef, and Conboy (2025) propose a comprehensive research framework for responsible AI governance, emphasizing the need for external oversight. Herrera-Poyatos et al. (2025) argue that responsible AI systems require a holistic approach integrating auditability, accountability, and governance across the AI lifecycle.

The missing piece in this literature is operational: who builds the accountability infrastructure for an SME that has no legal team, no compliance officer, and no budget for either? This paper addresses that gap directly.

METHODS

This paper employs a conceptual and analytical research design grounded in a systematic legal analysis of Regulation (EU) 2024/1689 and its technical annexes. We started from our core research question regarding when and how non-EU digital providers fall within the Act. From there, we identified and interpreted the relevant provisions. We verified our reading against official implementation guidance and legal commentary from practitioners.

From this analysis, we develop two scenarios that show how a non-EU agency becomes exposed to the Act depending on where AI sits in its work. We also develop a typology that classifies these providers into three groups by the structural nature of their compliance gap. Building on these findings, we then propose an external accountability model as a systemic response to that gap. The two scenarios and the typology are diagnostic instruments derived from the analysis. They have not yet been validated against empirical data.

FINDINGS

Operational Scenarios of Extraterritorial Exposure

Article 2 establishes output-based jurisdiction, applying the rules to providers placing AI systems on the market or putting them into service in the EU, regardless of their physical location (European Parliament and Council of the European Union, 2024). Article 3 distinguishes between a provider, the entity that develops an AI system or has it developed and places it on the market under its own name. Also a deployer, the entity using the AI system under its authority.

However, the most critical mechanism for non-EU digital agencies is not Article 3, but Article 25. Article 25 creates a transformation mechanism: any agency that rebrands, substantially modifies, or changes the intended purpose of a third-party AI system automatically assumes the full obligations of a provider. An agency that applies its own brand to a third-party AI system and delivers it to an EU client has, under Article 25, assumed full provider obligations. Where the system is high-risk, this includes the requirement to appoint an EU authorized representative under Article 22 (William Fry LLP, 2024; Holland & Knight, 2026). As Fabiano (2025) emphasizes, entities cannot escape provider obligations through outsourcing arrangements. Article 22 therefore functions as a latent obligation, one that is frequently triggered by standard industry practices like white-labeling.

The exposure of non-EU digital providers to the AI Act can be categorized into two primary scenarios with fundamentally different compliance implications. Scenario A covers AI embedded in delivered products: a non-EU agency develops a product, such as a custom SaaS platform or a mobile application—that incorporates an AI system and delivers it to an EU client. If the agency places the system on the market under its own name or substantially modifies an existing high-risk system, it assumes the full obligations of a provider under Article 16.

Scenario B covers AI used in the production process. The critical determinant under Article 2(1)(c) is not the transit of static output into the EU, but whether that output triggers specific obligations. Two channels are relevant: first, when AI-generated content falls under the transparency requirements of Article 50 (e.g., synthetic media delivered to EU audiences); second, when AI-assisted code or systems are integrated into Annex III high-risk categories by the EU client. Standard internal efficiency use does not automatically constitute provider status. The regulatory risk escalates when the agency's output directly shapes the risk profile of a system deployed within the EU. This exposure represents an immediate operational reality across the digital service sector, rather than a distant regulatory horizon.

Regulatory Obligations and Readiness Typology

Non-EU digital providers caught within the scope of the AI Act face a tiered set of obligations based on the risk classification of the AI systems they provide or deploy. Table 1 maps the key articles, their substantive requirements, and their practical implications for non-EU digital agencies.

The compliance infrastructure required by the AI Act remains largely unavailable to SMEs. Harmonized standards are incomplete, regulatory sandboxes are not yet operational in most member states, and national supervisory authorities have not been designated in the majority of EU countries.

From this starting point, we propose a diagnostic typology of compliance readiness categorized into three distinct groups. Table 2 maps the current state, the required state, and the gap between them. Tsakalakis et al. (2025) confirm that while the Act's SME support measures reduce procedural burden, they do not alter the substantive compliance obligations that apply to providers. Accountancy Europe (2025) similarly notes that SMEs must independently assess applicability and take required steps regardless of size.

Table 1: Key EU AI Act Articles and Their Implications for Non-EU Digital Providers

Article	Requirement	Practical Implication for Non-EU Digital Agency
Art. 4	AI Literacy	All staff using AI must demonstrate sufficient understanding of its capabilities and risks. No SME exemption.
Art. 5	Prohibited Practices	Absolute ban on manipulative AI, social scoring, and real-time biometric identification. In force since February 2025.
Art. 16	Provider Obligations (High-Risk)	QMS, technical documentation, human oversight, EU database registration, and conformity assessment required before market placement.
Art. 22	Authorized Representative	Triggered via Article 25 white-labeling. Requires a written-mandate EU authorized representative before market placement.
Art. 50	Transparency	AI systems interacting with humans or generating synthetic content must disclose their AI nature.
Art. 62	SME Support Measures	Priority sandbox access and simplified QMS templates. Does not eliminate substantive obligations (Accountancy Europe, 2025; Tsakalakis et al., 2025).
Art. 99	Penalties	Up to €35M/7% turnover for prohibited practices; €15M/3% for high-risk violations; €7.5M/1% for incorrect information.

Table 2: Compliance Readiness Typology — Current State vs. Required State for Non-EU Digital Providers

Category	Current State	Required State (AI Act)	Key Gap & Risk
Unaware	No knowledge that the AI Act applies extraterritorially. Operates under the assumption that non-EU status provides immunity.	Accurate self-classification as provider or deployer; basic AI literacy; awareness of prohibited practices (Art. 5).	Highest penalty exposure. Sudden market exclusion when EU clients demand compliance verification. No time to remediate.
Aware but lost	Aware of the AI Act's existence but unable to determine how it applies to their specific business model (e.g., confusion between Scenario A and B, or provider vs. deployer classification).	Correct role classification; mapped AI inventory; understanding of which articles apply to which systems.	Misclassification risk: acting as a provider but complying only as a deployer. Resources spent on wrong compliance track.
Aware but stuck	Understands obligations but lacks financial, technical, or legal resources to implement them (e.g., cannot establish a QMS, cannot afford an EU authorized representative).	Operational QMS; appointed EU authorized representative; registered high-risk systems in EU database; technical documentation maintained.	Good faith effort does not protect from enforcement. May be forced to exit the EU market due to prohibitive compliance costs without external support.

DISCUSSION

The compliance gap among non-EU digital providers runs deeper than information. Closing it requires more than awareness campaigns; it requires a redesign of how compliance infrastructure is delivered to entities that lack the scale to build it internally. The complexity of the AI Act, combined with the resource constraints typical of SMEs, creates a market entry barrier that is invisible until it becomes a market exclusion event.

The most significant blind spot is the Article 25 trigger mechanism. Agencies that consider themselves mere deployers can become providers without realizing it through the everyday practice of white-labeling. Once triggered, this activates the Article 22 requirement to appoint an authorized representative within the EU before placing a high-risk AI system on the market. This mandate is creating a nascent market for representation services, analogous to the GDPR DPO market post-2018. However, non-EU SMEs currently lack clear, affordable pathways to access it. While Article 62 introduces proportionality measures for SMEs, these provisions reduce procedural complexity without eliminating substantive obligations (European Parliament, 2025; Walters et al., 2024). An SME that cannot afford a QMS consultant is not protected by the existence of a simplified QMS template.

The institutional framework for this pressure is already in place: the EU Community of Practice on Public Procurement of AI published Model Contractual Clauses for AI (MCC-AI) in March 2025, providing standardized templates through which EU clients can transfer compliance obligations to their suppliers (European Commission Community of Practice on Public Procurement of AI, 2025). Once Article 26 deployer obligations take full effect in August 2026, vendor due diligence will shift from best practice to legal requirement. Failure to provide verifiable compliance documentation results in immediate procurement exclusion by EU enterprise clients. External accountability architecture is the only viable path for SMEs that need to stay in the EU market without building an internal legal department. This architecture operationalizes a Compliance-as-a-Service (CaaS) model based on three integrated elements: pooled technical documentation, fractional authorized representation under Article 22, and automated Annex III inventory mapping. By distributing fixed compliance costs across a portfolio of non-EU providers, the framework renders prohibitive regulatory requirements economically viable at scale.

CONCLUSIONS AND IMPLICATIONS

The EU AI Act establishes a regulatory perimeter that extends globally, capturing non-EU digital agencies and tech companies that service the European market regardless of their physical location. This paper has mapped the extraterritorial mechanisms of the Act, demonstrating that outsourcing does not eliminate provider obligations (Fabiano, 2025), and that Article 25 acts as a hidden trigger transforming deployers into providers through practices like white-labeling. Two primary scenarios of exposure a) AI embedded in delivered products and b) AI used in the production process, carry materially different compliance requirements, with Scenario B representing an underexplored regulatory blind spot.

The proposed typology of compliance readiness diagnoses three structurally distinct failure modes that cannot be resolved by the same intervention. Resource constraints and regulatory complexity drive the gap, and the response must match that reality.

Practical Implications: Non-EU digital agencies must take three concrete steps immediately. First, inventory all AI tools used in the production process and those delivered to clients. Second, verify whether any of these systems, or the agency's modification/rebranding of them, fall into Annex III high-risk categories. Third, if servicing EU clients and delivering AI-embedded products under their own name, consult on Article 22 obligations before August 2026.
The typology proposed here serves a diagnostic purpose. The next step is empirical validation. We need to know how many agencies are unaware, how many are lost, and how many are stuck. That data does not yet exist. Building it is the research agenda.

Limitations: The practical enforcement of the AI Act, particularly concerning Scenario B, remains to be tested in legal precedents and regulatory actions post-August 2026. The compliance window is open now, not at some future enforcement horizon.

REFERENCES

Accountancy Europe. (2025). The EU AI Act: A guide for SME accountants. https://accountancyeurope.eu/wp-content/uploads/2025/02/250219_SME-AI-Act.pdf

European Parliament. (2025). Interplay between the AI Act and the EU digital legislative framework (Study PE 778.575). Policy Department for Transformation, Innovation and Health. https://www.europarl.europa.eu/RegData/etudes/STUD/2025/778575/ECTI_STU(2025)778575_EN.pdf

European Parliament and Council of the European Union. (2024). Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence (Artificial Intelligence Act). Official Journal of the European Union, L 2024/1689. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32024R1689

Fabiano, N. (2025). Subject roles in the EU AI Act: Mapping and regulatory implications. arXiv. https://arxiv.org/html/2510.13591v1

Falco, G., et al. (2021). Governing AI safety through independent audits. Nature Machine Intelligence, 3, 566–568. https://www.nature.com/articles/s42256-021-00370-7

Herrera-Poyatos, A., Del Ser, J., López de Prado, M., Wang, F.-Y., Herrera-Viedma, E., & Herrera, F. (2025). A framework for responsible AI systems: Building societal trust through domain definition, trustworthy AI design, auditability, accountability, and governance. arXiv. https://arxiv.org/pdf/2503.04739

Holland & Knight. (2026, April 28). U.S. companies face EU AI Act's possible August 2026 compliance deadline. Holland & Knight Cybersecurity and Privacy Blog. https://www.hklaw.com/en/insights/publications/2026/04/us-companies-face-eu-ai-acts-possible-august-2026-compliance-deadline

Lopes, I., & Oliveira, P. (2018). GDPR compliance in SMEs: There is much to be done. In Proceedings of the International Conference on Information Systems and Technology Management. https://www.researchgate.net/publication/328862700_GDPR_Compliance_in_SMEs_There_is_much_to_be_done

Papagiannidis, E., Mikalef, P., & Conboy, K. (2025). Responsible AI governance: A review and research framework. Journal of Strategic Information Systems, 34(1), 101835. https://www.sciencedirect.com/science/article/pii/S0963868724000672

Politou, E., Alepis, E., & Patsakis, C. (2019). A framework for GDPR compliance for SMEs. European Journal for Security Research, 4(2), 145–173. https://link.springer.com/article/10.1007/s41125-019-00042-z

Potter, Y., Corren, E., Munilla Garrido, G., Hoofnagle, C., & Song, D. (2023). SoK: The gap between data rights ideals and reality. arXiv. https://arxiv.org/abs/2312.01511

Sirur, S., Nurse, J. R. C., & Webb, H. (2018). Are we there yet? Understanding the challenges faced in complying with the General Data Protection Regulation (GDPR). In Proceedings of the 2nd International Workshop on Multimedia Privacy and Security (MPS '18). ACM. https://arxiv.org/pdf/1808.07338

Tsakalakis, N., Stalla-Bourdillon, S., Walker, M., & Carmichael, L. (2025). A framework for compliance with Regulation (EU) 2024/1689 for SMEs. Laws, 5(3), 40. https://www.mdpi.com/2624-800X/5/3/40

United Nations University. (2024). Framework for the governance of artificial intelligence (UNU Tech Brief No. 5). https://digitallibrary.un.org/record/4082680/files/UNU-TB_5-2024_Framework-for-Governance-of-AI.pdf

Walters, J., Dey, D., Bhaumik, D., & Horsman, S. (2024). Complying with the EU AI Act. In S. Nowaczyk et al. (Eds.), Artificial Intelligence. ECAI 2023 International Workshops (pp. 65–75). Springer. https://link.springer.com/chapter/10.1007/978-3-031-50485-3_5

Wernick, A., & Meding, K. (2025). Beware! The AI Act can also apply to your AI research practices. arXiv. https://arxiv.org/abs/2506.03218

William Fry LLP. (2024). A practical guide to the extraterritorial reach of the AI Act. https://www.williamfry.com/knowledge/a-practical-guide-to-the-extraterritorial-reach-of-the-ai-act/

European Commission Community of Practice on Public Procurement of AI. (2025). EU AI Model Contractual Clauses (MCC-AI). https://public-buyers-community.ec.europa.eu/communities/procurement-ai/resources/updated-eu-ai-model-contractual-clauses

THE SMART CITY: TECHNOLOGY, FUNCTIONALITY AND CHALLENGES

DOI: 10.5937/EMC26281K

Aleksandar Kupusinac
University of Novi Sad, Faculty of Technical Sciences; Novi Sad, Republic of Serbia
E-mail: sasak@uns.ac.rs

ABSTRACT

There has been a constant trend of urban population growth in the world, putting pressure on existing infrastructure, resources, governance, public health and ecosystems. The city management is becoming very big challenge. Smart city implies an intelligent city management that uses information and communication technologies (ICT) to create a more sustainable, humane and efficient environment. This paper considers concept of smart city, its technologies, functionalities and challenges.

Key words: smart city, infrastructure, intelligent city management.

INTRODUCTION

During the past centuries, there are a constant trend of world urban population growth, i.e. the process of urbanization. The United Nations predicts that nearly 70% of the population in the world will live in cities by 2050 (United Nations, 2019). This constant growth in urban population makes pressure on existing infrastructure, resources, governance, public health and ecosystems. Traditional models of urban governance are becoming unsustainable under the burden of energy crises, water consumption, inefficient waste management, traffic congestion and air pollution.

The solution is the concept of a smart city (Albino et al., 2015). In general, smart city uses different technologies (Big Data, Cloud Computing, Machine Learning & Artificial Intelligence, Internet of Things) to improve the infrastructure management, optimization of city functions, quality of life of its citizens, intelligent governance and fostering economic growth. The essence of a smart city is not in the technology itself, but in its application to create an efficient, sustainable and humane environment.

The population in the cities mainly lives from industry, trade and services, unlike villages where the majority of the population lives from agriculture. The increase in the number of inhabitants in cities has had its great advantages (quality education, availability of cultural content, exchange of goods and ideas, accessibility of markets, cheaper and more efficient transport, hydrotechnical and telecommunication systems, high-quality energy, etc.), but also disadvantages (pollution, higher cost of living, smaller living space, increased crime, increased mortality, increased stress, etc.) (Caragliu et al., 2011). In this context, the smart city represents a possible solution to create an efficient, friendly and safe environment for people by alleviating the current shortcomings. The main goal of a smart city is to improve the lives of its residents through the application of information and communication technologies and intelligent decision-making based on the analysis of large amounts of data.

In the big cities, management of critical infrastructure presents a challenge of the future (Rinaldi et al, 2001) (Lewis, 2014). The term infrastructure consists of two parts, both of which originate from the Latin language - the first part "infra" means below, lower or under, and the second part "structure" means construction, masonry or building. The translation of the word infrastructure would be "under buildings", which does not correspond to the real circumstances, because a significant part of the

infrastructure is not in the ground, i.e. under buildings. Based on this, we distinguish between underground and aboveground infrastructure. Of particular importance is the so-called critical infrastructure, whose disruptions cause serious consequences for the population - they can endanger people's lives and health, and they can threaten the security and economic stability of the state and its citizens.

THE TECHNOLOGICAL ARCHITECTURE

To make a city "smart", it is necessary to establish a multi-layered technological architecture that allows for the collection, transmission, analysis and decision-making based on real-time data. This complex architecture generally consists of the four key technology layers:

1) The physical layer that includes sensors and devices (Internet of Things - IoT). Sensors constantly collect data about the city, and devices implement smart decisions. This layer consists of billions of connected sensors and devices (smart water and electricity meters, air quality and noise level sensors, traffic surveillance cameras and sensors in waste containers, devices that smartly manage city infrastructure, etc.).

2) The communication layer, which is based on the data transmission network. Data collected from sensors must be quickly and securely transmitted to central systems where they are processed and analyzed. A key role here is played by next-generation networks (e.g. 5G networks), which enable mass data exchange.

3) Data and analytics layer that includes data storage and processing. Raw and unstructured data has no value without analysis. Through cloud platforms (Cloud Computing) and the application of machine learning (ML) and artificial intelligence (AI) algorithms, city systems analyze data, recognize patterns and predict events (e.g. predicting traffic congestion, early detection of failures in the electricity distribution network or water supply network, etc.).

4) Application layer includes platforms for managing the city and its infrastructure, as well as applications for citizens (e.g. applications for public surveys, reporting utility problems, finding parking spaces, paying for services, submitting requests, etc.).

THE SMART CITY FUNCTIONALITY

The effect of a smart city can be observed at the level of its individual functions, but also at the level where the same individual functions are integrated into a harmonious whole. This section will discuss functions of a smart city through various examples from common urban life.

Smart traffic systems

It is well known that traditional traffic systems in large cities are one of the biggest sources of congestion, stress and pollution with a bad effect on people's health. Smart traffic lights adjust cycle times to the current flow of vehicles and significantly reduce congestion and stress. In addition, smart traffic lights force the green light for the passage of public transport and emergency vehicles. Smart parking systems presents the number of free parking spaces in real time and optimally direct drivers, in order to reduce unnecessary congestion. Mobile applications of the public transport allow citizens to optimally plan their trips through the city. The use of electric and autonomous public transport vehicles is becoming increasingly common in the numerous cities.

Smart traffic systems are based on a network of cameras, sensors and devices, which collect data in real time. By analyzing this data, city services can quickly respond to traffic jams and accidents, as well as risky weather conditions. These systems also encourage the use of bicycles and other sustainable modes of transport through the development of smart bike lanes and bike-sharing systems.

Such systems reduce fuel consumption and the negative impact of traffic on the environment, while improving the quality of life of citizens.

Smart energy consumption and sustainability

Smart grids are modern power grids that enable the two-way flow of electricity and information, thereby ensuring more efficient management of energy production, distribution and consumption. They enable easier integration of renewable energy sources (e.g. solar panels, wind turbines, etc.), contributing to greater energy efficiency, system reliability and reduced negative environmental impact. An increasing number of cities are implementing smart street lighting with LED technology that dims when there are no pedestrians or vehicles, achieving significant energy savings.

Smart meters play a fundamental role in smart energy management, since they enable accurate measurement of electricity, gas and water consumption. Users can monitor their consumption in real time via mobile applications or web platforms, which helps them more easily identify unnecessary costs and use resources more rationally. In addition, many residential and commercial buildings are installing smart flow meters and thermostatic radiator valves. These devices automatically regulate the amount of thermal energy in each room depending on the temperature and the presence of the user, thus avoiding unnecessary heating of the space and achieving additional energy savings. In winter, heating and in summer, cooling of empty rooms are reduced, and based on the detection of user arrival, it is increased, thus achieving significant savings.

By applying these technologies, smart cities reduce energy consumption, maintenance costs and emissions of harmful gases, while contributing to sustainable development and environmental protection.

Smart water supply and sewage management

Smart water and sewerage infrastructure enables the application of modern information and communication technologies for the efficient management of water supply and wastewater disposal. The integration of sensors, devices and systems for remote monitoring and real-time data analysis enables continuous monitoring of the condition of the water and sewerage network, water quality, pressure levels and flow. Such systems enable rapid detection of leaks, failures and other anomalies, thereby reducing water losses, maintenance costs and the risk of supply interruptions. In addition, smart sewage infrastructure enables significantly more efficient management of wastewater and its quality, monitoring of network load, and timely response in the event of failure, flooding or congestion. In this way, the reliability, resilience and sustainability of critical municipal infrastructure are increased, while at the same time improving the quality of services for citizens and protecting the environment.

E-government in smart cities

E-government improves the accessibility, efficiency and transparency of public administration by using information and communication technologies. The digitalization of administrative procedures and public services for individuals and legal entities enables easier access to administrative procedures, while reducing time and financial costs. Various software applications are used that enable electronic communication between individuals and legal entities and public administration. For example, submission of requests for the issuance of documents, payment of taxes, fees and utility services, scheduling of appointments in state institutions, reporting of utility problems (breakdowns, illegal landfills, road damage, etc.), participation of citizens in decision-making through surveys and public hearings, monitoring of the status of requests and receiving notifications in real time, etc. The integration of e-government into the smart city concept contributes to the optimization of urban resource management, the improvement of the quality of public services and the strengthening of citizen participation in decision-making processes. In this way, e-government is not only a

technological innovation, but also an instrument of public sector modernization that fosters sustainable, inclusive and data-driven urban development.

Security in smart cities

Given that the functionality of a smart city is based on the application of information and communication technologies, security is one of the key aspects of the smart city concept, as it encompasses the protection of citizens, infrastructure, data and information systems. Smart cities use sensor networks, video surveillance systems, big data analytics and artificial intelligence for the timely identification of potential security risks, with a quick and efficient response by the competent services. The integration of various data sources enables continuous monitoring of the urban environment, improving emergency management and increasing the city's resilience to natural disasters, traffic incidents and other risks. At the same time, the development of such systems imposes the need for high standards of cybersecurity and protection of citizens' privacy, in order to ensure the safe and responsible use of collected data.

CONCLUSIONS

The smart city concept is based on the applications of information and communication technologies (ICT) to improve the management of urban resources and services, with the goal to improve the quality of life of numerous citizens and achieve sustainable development. This paper presented smart city through an analysis of its technologies, functionalities and challenges.

REFERENCES

United Nations: Department of Economic and Social Affairs, Population Division. (2019). *World Urbanization Prospects: The 2018 Revision*. New York: United Nations.

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology*, 22(1), 3–21. https://doi.org/10.1080/10630732.2014.942092

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart Cities in Europe. Journal of Urban Technology, 18(2), 65–82. https://doi.org/10.1080/10630732.2011.601117

Stephen M. Rinaldi, James P. Peerenboom, & Terrence K. Kelly (2001). Identifying, Understanding, and Analyzing Critical Infrastructure Interdependencies. *IEEE Control Systems Magazine*, 21(6), 11–25.

Lewis, T. G. (2014). *Critical Infrastructure Protection in Homeland Security: Defending a Networked Nation* (3rd ed.). Wiley.

RISK ANALYSIS OF MICROSERVICES ARCHITECTURE FOR A BANK'S INFORMATION SYSTEM

DOI: 10.5937/EMC26285M

Tamara Milić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: tamaraaamilic021@gmail.com
Biljana Radulović
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin Republic of Serbia
Igor Vecštejn
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Vuk Amižić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

ABSTRACT

Microservices architecture is a modern approach to information systems development that enables greater scalability, modularity, and more flexible maintenance of software solutions. However, due to the system's distributed structure, microservices also introduce certain risks related to component interdependence, coordination between teams, system performance, and the reliability of data exchange itself. Such risks are particularly significant in banking information systems, where transaction accuracy, service availability, and user trust are of paramount importance. This paper analyses the microservices architecture of a banking information system using the Bank of Anthos application as an example. A particular focus is placed on identifying the critical dependency points between frontend services, backend microservices, and databases. The results of the analysis show that risks in microservice architecture are not just a technical problem, but also a challenge from the perspective of management, organization, and coordination. The timely identification and control of such risks can contribute to greater system reliability, better user experience, and the preservation of banking services in the long term.

Keywords: Risk Management, Microservices, Microservice Architecture, Information System

INTRODUCTION

Data processing, in an attempt to obtain well-organized information, is a significant and time-consuming task for businesses, as large and growing amounts of data require further processing. However, advancements in computer systems have greatly contributed to the development of systems to simplify specific practices associated with data processing, particularly the collection, storage, processing, and analysis of data, as well as the extraction and distribution of information for specific purposes. Such systems are called Information Systems (IS), which play an important role within an organization with the aim of increasing the efficiency of management decision-making (Nikoloski, 2014; Taherdoost, 2021). In addition to the general purposes of an information system, its main advantages within an organization can be listed as accessing large amounts of data, making efficient decisions in an automated manner, reducing human error through the use of complex algorithms, and assisting in the development of new approaches to generating revenue and increasing the number of customers. An excellent example of the importance of an information system within an organization is the e-commerce company Amazon, whose business success is largely based on the implementation of a microservices architecture (Mutwiri, 2020; Taherdoost, 2021; Stricker et al., 2018). Although microservices architecture contributes to scalability and more efficient development of information systems, its structure requires a certain complexity, and therefore various risks can arise in the system's operation.

In addition to the wide range of benefits and success factors that an information system offers, there are also certain challenges that limit its implementation and can lead to potential risks affecting the organization's performance. These include: (i) the constant, day-to-day changes in technology, which require up-to-date users to be in a state of continuous learning, (ii) security issues related to suppliers, banking and the distribution of core data, intellectual property and company records, (iii) inefficient establishment of an information system due to the high costs and expenses associated with it. The sheer number of risks and risk factors associated with business and information systems establishes a driving force towards the development of an organizational framework for managing them and responding accordingly (Taherdoost, 2021).

MICROSERVICE ARCHITECTURE IN THE CONTEXT OF RISK MANAGEMENT

The emergence of microservices is closely linked to the early 2000s, when companies like Amazon began to transition from monolithic architectures to architectures based on loosely coupled services. Amazon, as one of the world's most well-known e-commerce companies, was (and remains) one of the pioneers in adopting this architectural style to accelerate software development (Peša, 2025). The application of Microservice Architecture (MSA) spans multiple industries, from technology to e-commerce and banking, as well as various development environments, from cloud computing to on-premise solutions (Lewis & Fowler, 2014; Amri et al., 2024). MSA breaks down a monolithic application into a set of smaller, discrete, and interconnected services (Amri et al., 2024; Newman, 2015). The microservices approach to software development offers an alternative to the conventional monolithic style. Although the advantages of microservices-based development over the monolithic style are clear, industry experts agree that neither style provides an absolute advantage in all situations. Proponents argue that the microservices approach to software development facilitates the mapping of organizational changes, which manifest from a more dynamic business environment, into corresponding IT/IS (Information Technology/Information Systems) changes. Each microservice corresponds to a single function around a business capability. Each one contains its own data resources and is deployed quickly. Examples range from paying bills online on a banking website to an alternative flight service on an airline's website. Although the benefits are clear, there are significant challenges to the adoption and maintenance of MS-based software development. Many of these challenges stem from the novelty of the approach and a lack of understanding of the technical and organizational parameters that affect MS-based development. If these challenges are not well understood, companies are unlikely to realize the full benefits of MSs and may be in an even worse position than before modernization (Vitharana & Daya, 2024). Consequently, under certain circumstances, the challenges can be risky for a company's business.

Risk classification

One of the challenges of microservices architecture is that teams developing different microservices become more isolated from the system, and collaboration between teams becomes a greater challenge (Söderqvist & Göthe, 2022; Jamshidi et al., 2018). Implementing corrective maintenance to resolve an issue spanning multiple microservices becomes a complicated procedure for teams, as it requires cross-team communication. Figure 1 illustrates the problem (Söderqvist & Göthe, 2022).

In Figure 1, all the lines connecting the different services represent the links between microservices, i.e., the points where they communicate and exchange data. The red lines indicate which microservices may be affected when a problem occurs in one microservice, as this problem can also lead to difficulties in other related microservices. If multiple microservices are affected, teams must collaborate to resolve the issue. The yellow dashed lines represent the collaboration between teams (Söderqvist & Göthe, 2022). The specific case illustrated in Figure 1 indicates the interconnection of microservices and communication between multiple teams within the company, which represents a risk concerning coordination and dependency between components.

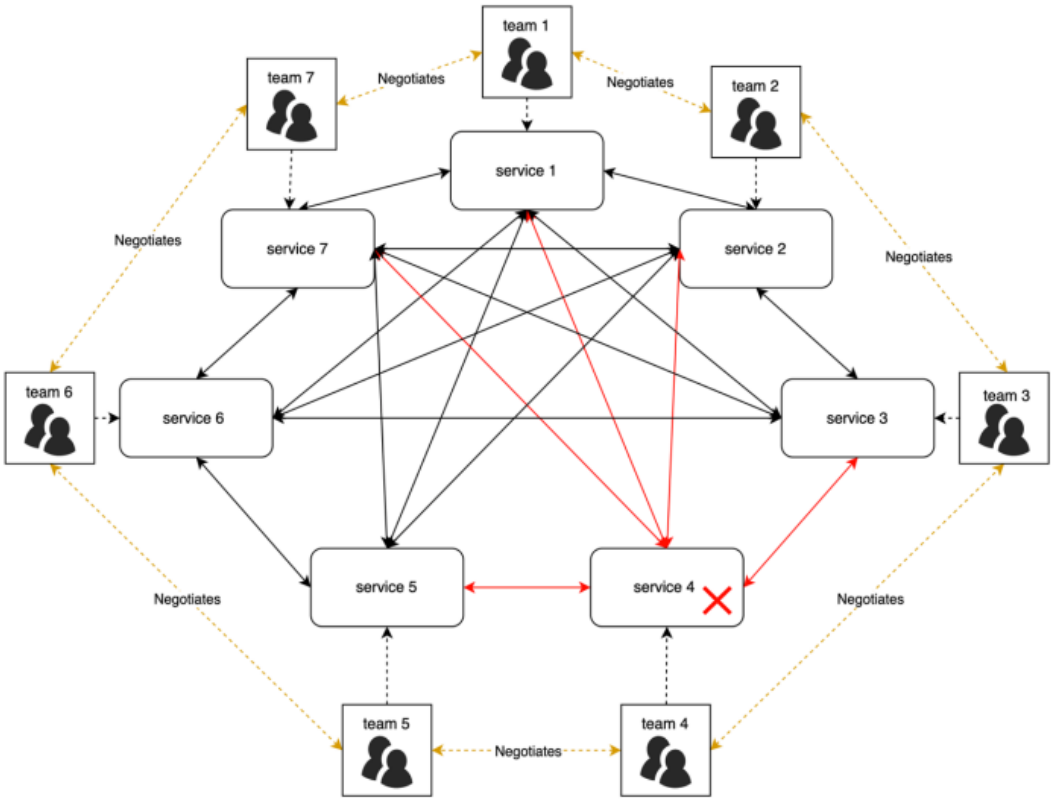


Figure 1: Illustration of microservice architecture with an issue (Söderqvist & Göthe, 2022)

A significant risk in microservices architecture is the risk caused by insufficient system performance. The fine-grained decomposition of microservices makes the system vulnerable to performance issues. Today's microservices systems consist of tens of thousands of microservices. Consequently, each microservice can suffer from performance issues due to many unpredictable problems, such as network failures, host issues. Furthermore, the control flow and data flow for processing a single request can traverse hundreds of microservices; a performance issue with any one of them will affect the entire request. Therefore, to ensure system performance and reliability, it is essential to monitor and efficiently diagnose performance issues in every microservice. If a system's performance degrades, the consequences can include general customer dissatisfaction, slower processing of business processes, and an increase in system maintenance costs. Figure 2 shows an example of a request flow in a microservices system. A simple request on the frontend can cause a problem in a lower-level microservice and further affect numerous higher-level microservices (Hou et al., 2021).

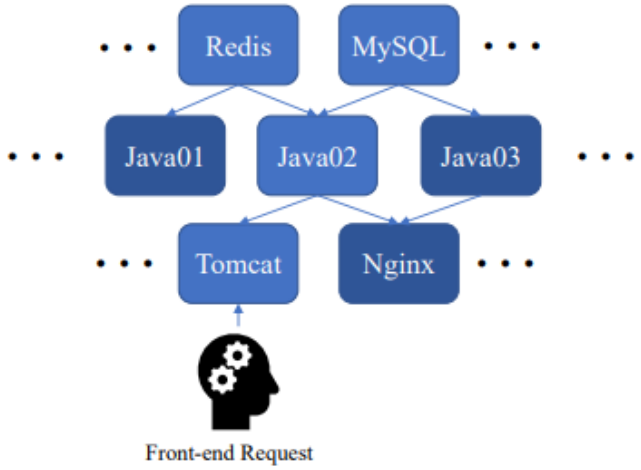


Figure 2: An overview of the request flow in a microservices architecture (Hou et al., 2021)

BANK INFORMATION SYSTEM

This section will present the adaptive microservices architecture diagram for the Bank of Anthos application. Bank of Anthos is an example of a multi-tier, HTTP-based web application that simulates a bank's payment processing network, allowing users to create artificial bank accounts and perform transactions. Google uses this application to demonstrate how developers can modernize business applications using cloud-native technologies and Kubernetes-based deployment. This application can run on any Kubernetes cluster (GoogleCloudPlatform, n.d.). Figure 3 represents the adapted Bank of Anthos application model used in this paper.

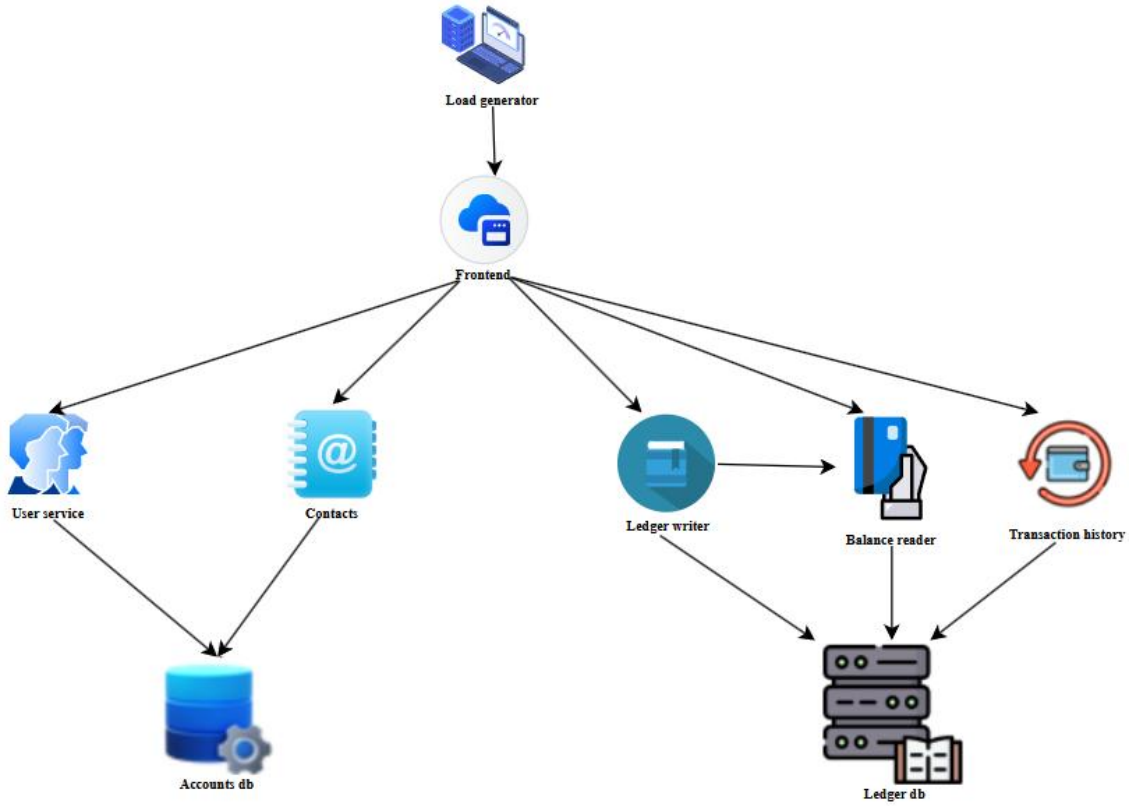


Figure 3: Bank of Anthos application diagram

Based on Figure 3, it can be observed that the presented diagram contains five backend microservices, namely: User Service, Contacts, General Ledger Entry Service, Balance reader, and Transaction History. The load generator tests the system by simulating the sending of a large number of requests. The frontend is also a microservice; it is the part of the application visible to users, serving for user login, viewing account balances, creating transactions, etc. The user service (user-service) is responsible for user authentication and authorization. Contacts provide an overview of all the contacts a user has, allowing them to add new ones, edit or delete existing ones. The accounts database (accounts-db) is an example of a relational database that contains the necessary information about users and user accounts. User service and contact data are stored in the accounts database. The ledger-writer service first validates the entered transactions and then saves them permanently. The general ledger entry service is connected to a balance reader, which allows the reader to see the current balance of a user's account. The transaction history provides data on previously executed transactions for a specific user, while the ledger database, as the main transaction database, stores all necessary transaction data. The data flow in the system circulates from the load generator to the frontend service by sending the appropriate requests. The frontend then sends a request to a specific microservice, depending on the activity the user is requesting. Requests concerning contacts and user data will be directed to the User service and Contacts microservices, which communicate with the Accounts database. Conversely, requests concerning the Ledger writer, Balance reader, and Transaction history will be directed to the microservices of the same name, which communicate with the Ledger database.

ANALYSIS AND DISCUSSION

The risk analysis in this paper was conducted based on an overview of communication flows and functional dependencies among microservices and components shared for data storage. Critical points are identified according to the following criteria: (1) whether the component participates in communication with multiple services, (2) whether its failure affects the functionality of the system, (3) whether the consequences of the failure may have an impact on user activities, service availability, or transaction data accuracy. Based on these criteria, three critical points were identified: (1) frontend - user-oriented communication layer, (2) Accounts DB - common database for user and contact data, and (3) Ledger DB - central component of the transaction system.

Figure 4 shows the risk analysis of coordination and dependencies among the current components in the system, based on the previously described application architecture.

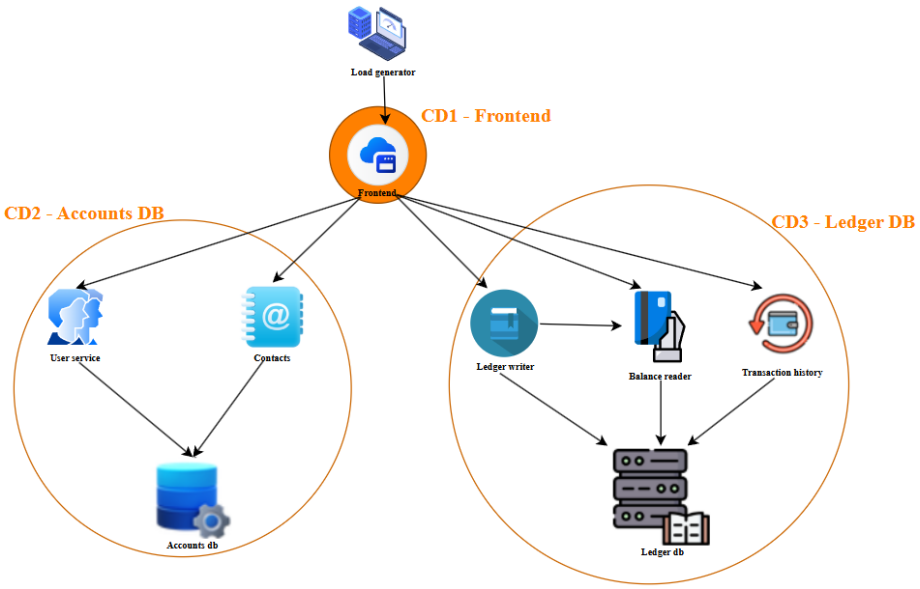


Figure 4: Analysis of coordination and dependency risks among components

Marked critical points indicate clusters of dependencies where component failure may affect related services, user-facing functions, or transaction-related operations.

- Critical dependency point (CD1 – Frontend) – The part of the application visible to the user is the frontend. When the user wants to view their account balance, the frontend sends a request to the corresponding backend microservice in the background. If a failure or delay occurs with the given backend microservice when forwarding the request, the user does not receive a correct response, or the response arrives with a delay. The consequences can include degraded user service, an increased number of user complaints, reduced service quality, slower application performance, and increased customer support costs.
- Critical dependency point (CD2 – Accounts DB) – The critical point consists of the User service, Contacts, and Accounts DB. When a user attempts to log in with a user account, the User service accesses the database to retrieve the necessary user information. This means that the user service and user contacts data are stored in the Accounts DB. Should a problem occur with the aforementioned database, the consequences are not limited to a single service but can affect both the User service and Contacts. This risk can result in login and authentication issues, user dissatisfaction, increased maintenance costs, and an increase in customer support requests.
- Critical dependency point (CD3 – Ledger DB) – This critical point represents the transactional part of the system and is composed of: Ledger writer, Balance reader, Transaction history, and Ledger DB. If an incorrect transaction entry is made by the Ledger writer, the Balance reader will display an inaccurate account balance, and the Transaction history will show incorrect transaction history. Furthermore, as all transaction data is stored in the Ledger DB, an error can

affect multiple microservices simultaneously. The consequences can include reputational risk for the bank, a loss of competitive advantage, a breach of customer trust, and jeopardized continuity of transactional processes.

CONCLUSION

The analysis of the microservice architecture of the Bank of Anthos application shows that risks arise not only from individual components but also from dependencies between services in the system, database, and user-oriented communication flows. The paper identified three critical dependency points: the frontend communication layer, Accounts DB, and Ledger DB. The frontend is critical because it mediates the process of forwarding user requests to backend services, which is why any failure or delay can affect service availability and lead to a poor user experience. Accounts DB represents a common data dependency for services related to users and contacts. Ledger DB represents a particularly sensitive point because it supports transaction writing, balance reading, and transaction history display, whereby inconsistencies may affect the accuracy of transaction data and user trust.

These results confirm that risk management in banking microservice architectures requires both technical and organizational control. From a technical perspective, it is necessary to monitor system service performance, database availability, and transaction data consistency. From an organizational perspective, it is necessary to define clear team responsibilities and coordination mechanisms in order to reduce the possibility of cascading system disruptions and preserve the reliability of the bank's services.

REFERENCES

Amri, M. G., Raharjo, T., Fitriani, A. N., & Hutasuhut, N. R. P. (2024). Critical success factors of microservices architecture implementation in the information system project. International Journal of Advanced Computer Science and Applications, 15 (10). https://doi.org/10.14569/IJACSA.2024.0151064.

GoogleCloudPlatform. (n.d.). Bank of Anthos. GitHub repository. Available at: https://github.com/GoogleCloudPlatform/bank-of-anthos/blob/main/README.md

Hou, C., Jia, T., Wu, Y., Li, Y., & Han, J. (2021). Diagnosing performance issues in microservices with heterogeneous data source. In 2021 IEEE International Conference on Parallel and Distributed Processing with Applications, Big Data and Cloud Computing, Sustainable Computing and Communications, Social Computing and Networking. Los Alamitos, CA: IEEE, 493-500. https://doi.org/10.1109/ISPA-BDCloud-SocialCom-SustainCom52081.2021.00074

Jamshidi, P., Pahl, C., Mendonça, N. C., Lewis, J., & Tilkov, S. (2018). Microservices: The journey so far and challenges ahead. IEEE Software, 35 (3), 24-35. https://doi.org/10.1109/MS.2018.2141039

Lewis, J., & Fowler, M. (2014). Microservices: A definition of this new architectural term. Available at: https://martinfowler.com/articles/microservices.html

Mutwiri, W. (2020). Amazon Business Information Systems: Data Acquisition and Management in Its Value Chain. Munich: GRIN Verlag

Newman, S. (2015). Building Microservices: Designing Fine-Grained Systems. Sebastopol, CA: O'Reilly Media

Nikoloski, K. (2014). The role of information technology in the business sector. International Journal of Science and Research, 3 (12), 303-309

Peša, M. (2025). Uzorci dizajna u mikroservisnoj arhitekturi (Doctoral dissertation, Sveučilište u Zagrebu, Sveučilište u Zagrebu Fakultet organizacije i informatike, Katedra za razvoj informacijskih sustava)

Söderqvist, E., & Göthe, D. (2022). Maintain multiple microservices without compromising the autonomy of Agile teams: Developing a strategy for increased productivity in maintenance of microservices.

Stricker, R., Müssig, D., & Lässig, J. (2018). Microservices for redevelopment of enterprise information systems and business processes optimization. In Proceedings of the 20th International Conference on Enterprise Information Systems, Vol. 2. Setúbal, Portugal: SCITEPRESS, 719-726. https://doi.org/10.5220/0006791607190726

Taherdoost, H. (2021). A review on risk management in information systems: Risk policy, control and fraud detection. Electronics, 10 (24), 3065. https://doi.org/10.3390/electronics10243065

Vitharana, P., & Daya, S. A. (2024). Challenges in adopting and sustaining microservice-based software development: Organizational challenges can be more difficult than technical ones. ACM Queue, 22 (1), 48-72. https://doi.org/10.1145/3649402

MAPPING BUSINESS PROCESS MODELS INTO SOFTWARE DESIGN DIAGRAMS

DOI: 10.5937/EMC26291R

Branislava Radu
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: branislava.radu@tfzr.rs
Ljubica Kazi
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

ABSTRACT

In contemporary information system development, mapping business processes into software architecture represents a key step in ensuring alignment between business requirements and technical implementation. Differences in notations and abstraction levels between business models, such as BPMN and technical models, such as UML and service-oriented architecture, often lead to communication issues, loss of semantics and difficulties in system realization. This paper analyzes various approaches to transforming business processes into architectural and software models with a particular focus on model-driven methods, service-oriented architecture and agile approaches.

Key words: Business processes, Mapping, Software architecture, UML

INTRODUCTION

In contemporary information systems, one of the key challenges is aligning business processes with software architecture. Organizations are increasingly striving for digitalization and automation of their operations, which requires the precise translation of business requirements into technical solutions. However, differences between business models and IT models, both in terms of notation and level of abstraction, often lead to communication issues between business analysts and software engineers, as well as to loss of information during system implementation. (Elvesæter et al., 2010).

Business processes represent a set of interconnected activities with a clearly defined flow, inputs and outputs and their modeling enables a better understanding of organizational functioning and improvement of operational efficiency (Geambașu, 2012). Effective management of these models helps organizations maintain competitiveness and continuously enhance their performance. Regular review and updating of processes ensure that the products and services delivered meet quality standards and user requirements (Aldin & De Cesare, 2009). Business Process Model and Notation (BPMN) is primarily intended for modeling business processes for business users, while UML diagrams are more technically oriented and intended for software developers.(Peixoto et al., 2008)

The aim of this paper is to demonstrate how business processes can be mapped into UML diagrams and software architectures. Special attention is given to software Service-Oriented Architecture (SOA), which divides functionalities into independent services connected within business process flows. This approach facilitates flexible implementation and service reuse, as well as better planning and management of software development. (Valipour et al., 2009) The main objective of these methods is to ensure continuity between the business and technical levels, reduce the possibility of errors and enable more efficient realization of information systems. A review of relevant literature provides a systematic insight into the mapping problem, highlights key practical challenges and points to possible improvements.

RESEARCH METHODOLOGY

For this research, a literature review was conducted with the aim of identifying and analyzing approaches to mapping business processes into software architecture and UML diagrams. The search was performed on Google Scholar using keywords such as: "business process model mapping to UML" and "business process model mapping to software architecture."

Through the literature analysis, a large number of studies were identified, from which 10 studies were selected as relevant for examining methods, rules and tools for transforming business processes based on their titles and abstracts. The selected studies were thoroughly reviewed and analyzed and their approaches were grouped into two main categories: the first relates to mapping business processes to software architecture, while the second covers mapping business processes into UML. This analysis provides insight into the different approaches and solutions explored in the literature.

MAPPING BUSINESS PROCESSES TO ARCHITECTURE

This section analyzes different approaches to mapping business process models to software architectures.

One of the key challenges in Service-Oriented Architectures (SOA) is aligning business and IT models, as business analysts often use Business Process Model and Notation (BPMN) to model business processes, while IT architects apply the Service-Oriented Architecture Modeling Language (SoaML) to describe service architectures. Different notations can hinder communication and system implementation. To overcome this issue, Elvesæter et al. (2010) propose a Model Driven Engineering (MDE) approach with multiple levels of abstraction. In this approach, a BPMN business process model is transformed into a logical SoaML service architecture and then into a concrete implementation. Tasks are translated into UML actions, subprocesses into the service architecture, participants and roles from pools and lanes and message exchanges into service ports, while service contracts are established through interaction analysis. Mapping is carried out using the CIMFlex Editor and Atlas Transformation Language (ATL), which allow automatic conversion from BPMN XML models to SoaML models, preserving continuity between business and technical levels. A practical example of a purchase process shows that activities become service logic and participants become service actors, improving alignment between the business and IT layers. Future work includes enhancing transformation rules and supporting BPMN 2.0.

Similarly, another study associates IT project failures with starting development from technology, without prior analysis of the business context. Instead, a reverse approach is proposed, where the design begins with the business model, which is then translated into system architecture. Meertens et al. (2012) use the Business Model Canvas (BMC) in combination with ArchiMate, supported by Osterwalder's Business Model Ontology (BMO) consisting of nine elements: value proposition, customers, channels, relationships, revenue, resources, activities, partnerships and costs, organized into four domains—product, customers, infrastructure and finances. Mapping connects BMC elements with ArchiMate elements (customer segments → actor/role, channels → interface, relationships → interaction, activities → process/function, resources → resource, partnerships → collaboration and revenue and costs → value) and their relationships, describing cooperation, dependencies and contributions to value creation. The value proposition, as the most complex element, is modeled as a combination of product, goal and customer value. The ArchiSurance case study demonstrates how the BMC model of an insurance company can be transformed into ArchiMate models, turning abstract concepts into processes, actors and resources, while addressing challenges such as overload and redundancy. This approach enables better system understanding, requirements tracking and change analysis, with potential for future automation and quantitative cost–benefit analysis.

Weiss (2010) focuses on the gap between business processes and IT implementation, emphasizing that different models complicate process realization in software. He proposes a method connecting Business Process Modeling (BPM) and services to facilitate the transition from business to technical

levels within SOA. The main contribution is a transformation method that semi-automatically converts BPMN diagrams into UML service models, including component, sequence and activity diagrams, enabling processes to be directly realized as service orchestrations. The BPMN diagram is formalized into a structure containing activities, events, gateway elements, control flows, messages and data with processes broken down into basic patterns—sequential, parallel, branching and loops—with transformation rules defined through an iterative Fold function. In the service model, primitive services represent core functionalities, while composite services orchestrate multiple services and processes, each functioning as a UML component with well-defined interfaces, behaviors and communication protocols. Transformation rules determine how BPMN elements become primitive or composite services across three aspects: structure, behavior and communication.

In the context of collaborative environments, Touzi et al. (2008) explore how business requirements from multiple organizations can be aligned with technical architectures using a Model-Driven Approach (MDA). Business requirements are first modeled at the Computation Independent Model (CIM) level and then transformed into a logical SOA model at the Platform Independent Model (PIM) level. Transformation occurs in two phases: first, the basic SOA elements are created through direct mapping from the BPMN model with pools and lanes represented as services and tasks linked to services and their activities. Data is transformed into business objects in the information view and the process structure organizes elements into three packages: services, information and process. The second phase involves linking rules, transforming the sequence flow into activity order and establishing connections between services, activities and data to preserve process logic. The implemented prototype uses Intalio Designer, Atlas Transformation Language (ATL) and TOPCASED to automate the transformation and visualize UML models.

Finally, applying business process modeling in agile software development shows that the traditional approach using user stories often loses connection with actual business activities. Kazi and Kazi (2025) propose the BPriS method, which converts a BPM model into a prioritized list of work items for sprint planning. The transformation goes through several stages: process decomposition, mapping to software functions, adding business objects, applying functional patterns, semantic grouping and prioritization based on value and dependencies. The result is a backlog that better connects business activities with IT functionalities, facilitates iteration planning and semantically organizes functions, although the method requires additional analysis as it is not fully automated.

MAPPING BUSINESS PROCESSES TO DIFFERENT SOFTWARE DESIGN - RELATED DIAGRAMS

This section analyzes different approaches to mapping business process models into software design diagrams, including use case diagram, class diagram, sequence diagram and activity diagram.

The development of methodologies for automatically translating business processes from BPMN notation into UML activity models represents a significant step toward better integration of business requirements and software design. Cibrán (2008) highlights the problem of BPMN models being poorly understood by IT architects, which hinders the direct connection between business processes and software models. As a solution, a Model-Driven Engineering (MDE) approach is proposed, where the BPMN diagram is used as input and the UML activity diagram as output with defined mapping rules implemented in the Atlas Transformation Language (ATL). Transformations include different types of mappings: one-to-one (Task → Action, Sub-process → StructuredActivityNode, Sequence Flow → Control Flow, Pool/Lane → ActivityPartition), one-to-many (message start event → InitialNode + AcceptCallAction), and many-to-one (multiple events → FlowFinalNode). Complex cases such as XOR and AND gateways are transformed into UML nodes—DecisionNode, MergeNode, Fork and Join—according to context. Automation ATL reduces manual translation and the risk of errors, enabling precise and consistent mapping of BPMN elements to UML, although some semantics may be lost due to UML's limited expressiveness compared to BPMN.

A similar problem is explored by Khlif et al. (2018), who propose the DESTINY methodology based on an MDA approach, allowing automatic generation of UML analysis models directly from BPMN diagrams at the CIM level. The method includes creating use case, sequence and class diagrams with transformation occurring in three phases: preparing the BPMN model by adding semantic context, defining mapping rules for elements to UML and automatically applying these rules. In this process, pools and lanes are translated into actors or classes, tasks become use cases or operations, data objects are transformed into UML classes and gateway elements become control structures in sequence diagrams. The process includes 1:n mapping, where a single BPMN element can generate multiple UML elements, while a pattern-based approach recognizes interaction patterns for automatic creation of use cases. Activity fragments are transformed into use cases and associations are established according to lanes and actors with defined rules for activities and gateways. This results in a complete, semantically rich UML analysis model, directly linked to business processes, allowing a more precise and realistic representation of the information system compared to methods focusing solely on structure.

Macek and Richta (2009) extend the transformation perspective by applying XML and XSLT standards to convert BPMN diagrams into UML activity diagrams (UML-AD), achieving platform independence and improving readability for users and analysts. The goal of the transformation is to preserve information about activity flows, actors and task names, enable reuse of existing BPMN diagrams in software development and improve communication with end users, as BPMN symbols often combine multiple pieces of information into a single element, making understanding difficult. UML-AD, on the other hand, provides clearer presentation and better tool support. The method is based on XML Metadata Interchange (XMI) representation of BPMN diagrams and XSLT transformation into UML-AD XMI with the input XMI describing the BPMN diagram and the output XMI generating the corresponding UML-AD diagram. Start events are translated into InitialNode, while loops and complex symbols are decomposed into multiple UML nodes—task, decision, edges. Due to the complexity of BPMN elements, the transformation often uses one-to-many mapping, which allows precise preservation of activity flows, control and conditions with improved readability, consistency and support for further use of diagrams in software development.

Rhazali et al. (2014) further develop the business process transformation approach using the MDA methodology, enabling the transition from the Computation Independent Model (CIM) to the Platform Independent Model (PIM) level, including the generation of UML use case and class diagrams. The MDA approach separates business description, software model and technical implementation, aiming for BPMN models to serve not only for process understanding but also as a foundation for automatic software development through clearly defined transformation rules. The process occurs in two steps: first, a simple BPMN model is created with clearly defined actors, subprocesses, tasks, activity flows and data; then, transformation rules are applied. Tasks are translated into use cases, actors remain actors, subprocesses are grouped into packages, execution order becomes include, conditions are transformed into extend and data is converted into UML classes. This approach enables a systematic and automated transition from CIM to PIM and precise generation of UML software models.

Previous studies mostly focused on static transformations of BPMN diagrams into UML models. Rabhi et al. (2022) build on these approaches but introduce agile principles and an iterative transformation method. Their work focuses on automatic and iterative transformation of business processes, where BPMN collaboration and process diagrams, identifying participants, subprocesses, tasks, decisions and output data, become UML use case diagrams through sprints. Activity flows are transformed into include relationships, decisions into extend relationships and participants into actors, enabling a flexible and controlled approach to complex processes. An e-commerce process case study demonstrates practical application, where subprocesses and tasks are gradually transferred to the PIM level through iterations. The iterative approach and defined transformation rules enable efficient automation and precise mapping of the business model into software design with future work envisaging transformation of PIM models into PSM and code generation for specific platforms.

CONCLUSION

The aim of this study is to explore methodologies for mapping business processes from BPMN models into UML diagrams and software architecture models. Special emphasis is placed on identifying challenges arising from differences in notations and levels of abstraction between business and IT models.

The analysis of the reviewed studies clearly shows that the problem of aligning business processes with IT architecture is multi-layered and requires a systematic approach. The main challenge lies in the differences between the notations used by business analysts and IT professionals: BPMN enables intuitive modeling of activity flows and interactions, while SoaML and UML are used for technical implementation of services and software models. Differences in complexity and semantics often lead to information loss or inaccurate transfer of business rules, while one-to-one, one-to-many, or many-to-one mappings can result in semantic loss and require additional decomposition of complex elements. The formalization of transformation rules and the application of MDE/MDA approaches, together with pattern-based methods, enable semi-automated transformation and pattern recognition, contributing to better consistency between the business and technical layers, although full automation still requires additional analysis and evaluation. Mapping business elements to technical models allows abstract business concepts to become concrete technical models with clearly defined relationships, but also highlights the problem of redundancy and model overload, suggesting the need for optimization and automated evaluation of transformations. At the same time, iterative approaches through sprints and prioritized backlogs enable flexible and controlled implementation, where the transformation of business activities directly influences the development of software functionalities, reducing the gap between the business and IT layers and allowing efficient iteration planning.

Future directions include improving automated mapping tools to minimize redundancy and reduce the risk of semantic loss, as well as introducing formal verification and defining quality metrics for transformations to ensure the accuracy and reliability of the resulting models. Special attention should be given to semantic alignment of terminology between the business process and the software solution, as well as to the integration of different software components within the execution of a single business process. Additional challenges relate to the scalability of solutions, especially for larger and more complex systems, where increased complexity and model overload make understanding, maintaining and managing transformations more difficult. Another significant challenge is ensuring the flexibility of proposed software solutions so that systems can adapt to technological changes and meet new organizational requirements. These development directions contribute to more efficient implementation, reduced errors and better alignment between the business and IT layers in modern information systems.

REFERENCES

Aldin, L., & De Cesare, S. (2009). A comparative analysis of business process modelling techniques. In *Proceedings of the 14th UK Academy for Information Systems (UKAIS) Annual Conference* (pp. 1–17), Oxford, United Kingdom.

Cibrán, M. A. (2008). *Translating BPMN models into UML activities*. Thales Research & Technology, ThereSIS Security & Information Systems.

Elvesæter, B., Panfilenko, D., Jacobi, S., & Hahn, C. (2010). Aligning business and IT models in service-oriented architectures using BPMN and SoaML. In *Proceedings of the First International Workshop on Model-Driven Interoperability* (pp. 61–68).

Geambașu, C. V. (2012). BPMN vs. UML activity diagram for business process modeling. *Journal of Accounting and Management Information Systems, 11*(4), 637–651.

Kazi, L., & Kazi, Z. (2025). BPriS: Disciplined agile delivery planning method based on work items list pattern applied to prioritized semantically coupled software functions derived from business process model and software functional pattern. *Applied Sciences, 15*(9), 5091.

Khlif, W., Ayed, N. E. B., & Ben-Abdallah, H. (2018). From a BPMN model to an aligned UML analysis model. In *Proceedings of the 13th International Conference on Software Technologies (ICSOFT 2018)* (pp. 657–665).

Macek, O., & Richta, K. (2009). The BPM to UML activity diagram transformation using XSLT. In *Dateso 2009 Proceedings* (pp. 119–129).

Meertens, L. O., Iacob, M. E., Nieuwenhuis, L. J., van Sinderen, M. J., Jonkers, H., & Quartel, D. (2012). Mapping the business model canvas to ArchiMate. In *Proceedings of the 27th Annual ACM Symposium on Applied Computing* (pp. 1694–1701).

Peixoto, D. C., Batista, V. A., Atayde, A. P., Borges, E. P., Resende, R. F., & Pádua, C. I. P. (2008). A comparison of BPMN and UML 2.0 activity diagrams. In *Proceedings of the Simpósio Brasileiro de Qualidade de Software (SBQS 2008)* (pp. 1–12).

Rabhi, O., Arrassen, I., & Erramdani, M. (2022). Automatic agile transformation with approach by modeling from BPMN collaboration diagram model to UML use case. In *Proceedings of the International Conference on Industrial Engineering and Operations Management (IEOM 2022), Istanbul, Turkey*.

Rhazali, Y., Hadi, Y., & Mouloudi, A. (2014). Transformation method CIM to PIM: From business processes models defined in BPMN to use case and class models defined in UML. In *International Conference on Multimedia Computing and Systems (ICMCS)*.

Touzi, J., Bénaben, F., & Pingaud, H. (2008). Prototype to support morphism between BPMN collaborative process model and collaborative SOA architecture model. In B. Vallespir, T. Alix, & D. Romero (Eds.), *Enterprise Interoperability III: New Challenges and Industrial Approaches* (pp. 145–157). Springer.

Valipour, M. H., AmirZafari, B., Maleki, K. N., & Daneshpour, N. (2009). A brief survey of software architecture concepts and service-oriented architecture. In *2009 2nd IEEE International Conference on Computer Science and Information Technology* (pp. 34–38). IEEE.

von Rosing, M., White, S., Cummins, F., & de Man, H. (2015). *Business process model and notation (BPMN)*. Morgan Kaufmann.

Weiss, P. (2010). Modeling of service-oriented architecture: Integration of business process and service modeling. *Information Sciences and Technologies Bulletin of the ACM Slovakia*, 2(2), 79–92.

TOOLS FOR AUTOMATED SOFTWARE CODE GENERATION WITH PROMPT ENGINEERING, EFFICIENCY AND THE EDUCATIONAL UTILIZATION POTENTIALS: A BRIEF REVIEW

DOI: 10.5937/EMC26297R

Branislava Radu
University of Novi Sad, Technical Faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia
E-mail: branislava.radu@tfzr.rs
Ljubica Kazi
University of Novi Sad, Technical Faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia

ABSTRACT

The development of generative artificial intelligence and large language models (LLMs) has enabled significant progress in automatic code generation and the application of AI systems in education and software engineering. This paper presents fundamental concepts of generative artificial intelligence, the importance of prompt engineering, prompting techniques and strategies for improving the quality of responses generated by large language models. Special attention is given to AI tools for code generation, their characteristics, operating principles and application in software development. The paper also analyzes studies that evaluate the performance, accuracy and quality of AI-generated code, as well as the potential applications of these tools in programming education. In addition to the advantages, challenges such as inaccurate responses, model bias, academic ethics and the need for human supervision are also discussed.

Key words: Generative AI, prompt engineering, large language models, AI code generation

INTRODUCTION

Generative artificial intelligence (Generative AI) and Large Language Models (LLMs) have become key technologies that are transforming the way digital content is created and used. Their ability to automatically generate text, images and source code has enabled greater work efficiency, automation of complex tasks, and the application of AI systems in education, medicine and finance (Yazdani et al., 2025; Aydın & Karaarslan, 2023). At the same time, these systems improve collaboration between humans and artificial intelligence, while also raising concerns related to bias, reliability and copyright issues (Feuerriegel et al., 2024). The development of generative AI has also led to the emergence of prompt engineering as an important approach for controlling the behavior of large language models. Prompt engineering involves carefully designing instructions in order to obtain higher-quality responses, using techniques such as zero-shot and few-shot prompting, as well as structured prompt templates (Sahoo et al., 2024; Cook, 2026).

This paper presents an overview and analysis of generative artificial intelligence and large language models, with a particular focus on prompt engineering, its techniques and prompt templates. Furthermore, the fundamental characteristics of generative AI systems and prompt engineering will be explained, together with their capabilities and limitations in practical applications. The paper will also present the architecture and workflow of AI systems for code generation, along with an overview of code generation tools. In addition, the efficiency and quality of AI-generated code will be analyzed through a comparison of different model performances. Finally, the application of these tools in programming education will be discussed, with particular attention given to their advantages and the challenges associated with their use.

GENERATIVE ARTIFICIAL INTELLIGENCE

Generative artificial intelligence (Generative AI) represents a field of artificial intelligence focused on generating new content based on data on which the model has previously been trained. Generative models are capable of creating original outputs such as text, images, videos, music and source code. These systems learn patterns and structures from large datasets and then use them to generate content similar to existing examples. Owing to their capability for automated content creation, generative AI systems are now widely applied in various fields, including education, medicine and finance(Aydın & Karaarslan, 2023).

The most significant approaches in the implementation of generative artificial intelligence include Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), diffusion models, models based on the transformer architecture and hybrid architectures. Transformers form the foundation of Large Language Models (LLMs), including GPT models and ChatGPT. (Feuerriegel et al., 2024, Bandi et al., 2023) Generative AI also requires adequate hardware support, including GPUs, TPUs, cameras and microphones, as well as software tools such as PyTorch and TensorFlow, together with a high-quality user experience characterized by accuracy, speed and performance (Bandi et al., 2023).

Recent research results related to generative AI are focused on evaluation of Generative AI tools. One of the results present conclusion that evaluation results differ depending on the application domain. For image generation, realism is evaluated; for text generation, accuracy and informativeness are assessed; for source code generation, functionality is examined; and for audio generation, the naturalness of audio signals is analyzed (Bandi et al., 2023). Although generative models have achieved significant progress and widespread adoption, they still face numerous challenges, including high demands for data and computational resources, training instability, difficulties in evaluating the quality and creativity of outputs and limited generalization capabilities (Bandi et al., 2023). Furthermore, models often rely on statistical patterns rather than causal relationships and may contain biases and hidden assumptions (Manduchi et al., 2024). In addition, important ethical challenges remain, including hallucinations, lack of transparency and the potential misuse of these systems through the generation of convincing but inaccurate information (Banh & Strobel, 2023).

PROMPT ENGINEERING

The development of large language models has led to the emergence of prompt engineering, a technique that leverages the capabilities of pre-trained Large Language Models (LLMs). It is based on designing instructions that guide the model's output without modifying its parameters. Prompts may take the form of natural language instructions that provide context and help the model generate appropriate responses. The quality of outputs generated by large language models depends on carefully designed prompts used to direct the model's behavior (Sahoo et al., 2024). Within prompt engineering, various techniques have been developed to help models produce more accurate and higher-quality responses. (Sahoo et al., 2024):

- Zero-shot prompting is a fundamental technique in which a pre-trained large language model is asked to solve a task without being provided with prior examples, relying solely on instructions and knowledge acquired during training. Performance can be further improved through various sub-techniques, including additional instructions provided in interaction with a user.
- Few-shot prompting involves including one or more input–output examples directly within the prompt, thereby demonstrating the expected method of solving the task and enabling in-context learning without additional training. The effectiveness of this technique depends on the careful selection, number, arrangement, and formatting of examples, while research shows that properly structured and representative examples can significantly improve response quality.

Quality of generative AI results is improved by utilization of prompt templates, with structured approach to prompting. They provide key components that enable more precise control over generated

responses (Cook, 2026): Persona – defines the role and style of the model, determining the perspective from which the model responds; Instructions – describes the task and the expected result, including specific actions, response style and priorities; Context – additional information about the topic, target audience and environment in which the response will be used. If the few-shot technique is applied, examples may also be included; Constraints – limitations and rules that the model must follow, such as text length, prohibited expressions and safety parameters; Output – format of the final response, which may be presented as a paragraph, table, FAQ section, structured data or another standardized format suitable for further use. Prompt engineering includes structured prompt patterns and sometimes particular patterns are named upon the particular prompt part or prompting interaction type that is emphasized: Persona Pattern (role assignment), Question Refinement Pattern (question clarification), Template Pattern (format-based interaction), Flipped Interaction Pattern (where the model asks questions), Cognitive Verifier and Reflection patterns that support problem decomposition and explanation of responses, Meta Language Creation Pattern, Output Automater Pattern, Alternative Approaches Pattern, Recipe Pattern (White et al., 2023)

Research related to prompt engineering and generative AI are related to improvement of AI generated results. In the implementation of Generative AI based on prompting, particularly important are reasoning methods such as Chain-of-Thought, Tree-of-Thoughts and Graph-of-Thoughts, which enable step-by-step and multi-path logical reasoning while generating the result. To improve accuracy, methods such as Retrieval-Augmented Generation (RAG), ReAct and Chain-of-Verification are also used, reducing errors and hallucinations through the combination of generation and information verification (Giray, 2023). Limitations of prompt engineering are addressed in the context of generated results quality, such as ambiguous prompts, bias, lack of context and potential ethical concerns, which may lead to inaccurate or overly generic responses (Sahoo et al., 2024; Giray, 2023).

GENERATIVE AI TOOLS FOR SOFTWARE CODE GENERATION

In the research of (Becker et al., 2023), comparative analysis of Generative AI tools for code generation and their characteristics is presented and key results are provided in Table 1.

Table 1: Examples of generative AI tools for software code generation and their characteristics (Becker et al., 2023)

Tool	Characteristics
OpenAI Codex	generates code from natural language descriptions; supports multiple programming languages (Python, JavaScript, Go, PHP, Ruby, Swift, TypeScript, etc.); capable of translating code between languages; explains code functionality; supports working with APIs.
GitHub Copilot	AI programming assistant based on the Codex model; marketed as an "AI pair programmer"; provides code suggestions during programming; designed to increase developer productivity; free for verified students and teachers.
DeepMind AlphaCode	Transformer-based model for program generation; trained on more than 715 GB of GitHub code; supports C++, C#, Go, Java, JavaScript, Lua, PHP, Python, Ruby, Rust, Scala and TypeScript; solves complex algorithmic problems; achieves performance comparable to competitive programmers.
Amazon CodeWhisperer	AI tool for code recommendation and generation; uses machine learning; generates code based on natural language comments and existing code; recommends cloud services and libraries; integrates with IDE environments; aims to increase developer productivity.

Efficiency of Generative AI Tools in Software Code Creation

Recent research results are related to development of methods and systems for evaluation of generated software code. (Yetiştiren et al., 2023) performed evaluation of large language models trained on code. (Yetiştiren et al., 2023) performed experimental study with a system that includes creating prompts based on problem formulation, utilizing automated code generation tools and verification of the generated code quality. GitHub Copilot and Amazon CodeWhisperer were used within the Visual Studio Code environment, while ChatGPT was accessed through the OpenAI web interface in a

browser. (Yetiştiren et al., 2023) Once the code is generated, test cases are executed to verify whether the solutions are correct and executable. Afterwards, SonarQube is used for code quality analysis, including the evaluation of security, reliability, maintainability, the number of bugs and code smell issues. (Yetiştiren et al., 2023)

Manik (2025) compares the performance of large language models (LLMs) utilized for Python programming, where their efficiency is evaluated through accuracy, code quality, execution speed and code conciseness. The tools were tested on standardized tasks, and the results showed differences in performance: DeepSeek achieved higher accuracy and more frequently produced correct solutions, while ChatGPT generated more readable and concise code, but with a higher number of initial errors. Muñoz et al. (2024), compared different AI tools with tasks of varying complexity, ranging from basic algorithms to complex systems such as CRUD applications and REST APIs. Analysis using SonarQube and Jenkins tools showed that no single tool is universally superior; instead, performance depends on the programming language and task type. Simpler tasks produced better results, particularly in Python, Go and Ruby, while Java, PHP and C# proved to be more problematic. In more complex tasks, differences between tools became more pronounced, with Bing and Replit standing out as more stable solutions, whereas some tools exhibited more errors and code quality issues.

Li et al. (2024) explains the causes of performance variations and shows that Copilot-generated code often contains inefficient functions, poorly designed loops, and suboptimal algorithms, affecting performance and resource consumption. The study also highlights that prompt engineering can improve results, particularly through the use of specific prompts, but that limitations still exist, especially regarding memory optimization and more complex tasks.

Software Code Generation Tools in the Educational Context

Educational utilization of generative AI tools for software code creation has been evaluated in recent research results. Becker et al. (2023) point to the broader educational implications of these tools, emphasizing that systems such as Codex, AlphaCode and CodeWhisperer provide advantages including faster access to solutions, easier understanding of code, and the development of critical thinking through analysis. At the same time, they shift the educational focus from writing code toward understanding and evaluating it. Sheard et al. (2024) analyze computer science teachers' perceptions of the use of large language models in education. Assessment of generative AI tools was focused on their ability for explaining concepts and providing interactive learning support. It has been concluded that these tools have limitations, such as dependence on prompt quality, unclear explanations and their "black-box" nature which complicates full understanding and raises reliability concerns in educational contexts.

Building on these findings, Agbo et al. (2025) show that Generative AI is most commonly used in programming education at the university level in areas such as algorithms and software engineering, using tools such as ChatGPT, GitHub Copilot, and Codex. Although Generative AI enables personalized learning, code generation and explanation, error identification, and the development of creativity, limitations still exist regarding accuracy, consistency and the quality of explanations, as well as the risk of dependency on AI systems. The study concludes that Generative AI significantly improves computer science education but requires controlled and responsible use in order to preserve fundamental skills and independent problem-solving abilities.

CONCLUSION

The aim of this paper was to analyze the role of generative artificial intelligence-based tools for automatic code generation with a particular focus on prompt engineering and its impact on the quality, accuracy and efficiency of generated code. In addition, the study aimed to present the fundamental characteristics of AI tools, provide an overview of modern code generation tools and examine their application in programming education.

The research results indicate that generative artificial intelligence and large language models significantly contribute to the automation of code generation processes, increased productivity and the improvement of learning processes. However, the efficiency of these tools depends on the application context, task type, prompting quality and programming language, which means that no universally most effective solution can be identified. The analysis shows that the quality of generated code largely depends on the model and the way prompts are formulated, with prompt engineering representing an important factor in improving performance. In addition to these technical aspects, challenges related to system reliability, ethical implications, academic integrity and the risk of excessive reliance on AI tools were also identified, indicating the necessity of continuous human supervision and evaluation of generated results.In the educational context, the application of these tools contributes to improving the learning process through personalized support, faster understanding of programming concepts and the development of analytical skills. At the same time, challenges remain, including the reduced development of fundamental programming competencies, the possibility of academic dishonesty and difficulties in knowledge assessment due to the “black-box” nature of the models.

Future directions of development involve improving the accuracy and reliability of models through advanced prompt engineering techniques, hybrid approaches that combine code generation and verification, as well as the development of models with improved understanding of the semantic aspects of problems. Furthermore, it is necessary to establish standardized methods for evaluating the quality of AI-generated code and appropriate verification mechanisms, together with the definition of ethical and pedagogical guidelines for their application in education.

REFERENCES

Agbo, F. J., Olivia, C., Oguibe, G., Sanusi, I. T., & Sani, G. (2025). Computing education using generative artificial intelligence tools: A systematic literature review. Computers and Education Open, 9, 100266. https://doi.org/10.1016/j.caeo.2025.100266

Aydın, Ö., & Karaarslan, E. (2023). Is ChatGPT leading generative AI? What is beyond expectations?. Academic Platform Journal of Engineering and Smart Systems, 11(3), 118–134. https://doi.org/10.21541/apjess.1293702

Bandi, A., Adapa, P. V. S. R., & Kuchi, Y. E. V. P. K. (2023). The power of generative ai: A review of requirements, models, input–output formats, evaluation metrics, and challenges. Future Internet, 15(8), 260. https://doi.org/10.3390/fi15080260

Becker, B. A., Denny, P., Finnie-Ansley, J., Luxton-Reilly, A., Prather, J., & Santos, E. A. (2023). Programming is hard-or at least it used to be: Educational opportunities and challenges of ai code generation. In Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 1, 500–506. https://doi.org/10.1145/3545945.3569759

Banh, L., & Strobel, G. (2023). Generative artificial intelligence. Electronic Markets, 33(1), 63. https://doi.org/10.1007/s12525-023-00680-1

Cook, D. A. (2026). The PICCO Framework for Large Language Model Prompting: A Taxonomy and Reference Architecture for Prompt Structure. arXiv preprint arXiv:2604.14197.

Feuerriegel, S., Hartmann, J., Janiesch, C., & Zschech, P. (2024). Generative AI: S. Feuerriegel et al. Business & Information Systems Engineering, 66(1), 111–126. https://doi.org/10.1007/s12599-023-00834-7

Giray, L. (2023). Prompt engineering with ChatGPT: a guide for academic writers. Annals of Biomedical Engineering, 51(12), 2629–2633. Springer Nature.

Li, S., Cheng, Y., Chen, J., Xuan, J., He, S., & Shang, W. (2024). Assessing the performance of ai-generated code: A case study on github copilot. In 2024 IEEE 35th International Symposium on Software Reliability Engineering (ISSRE), 216–227. IEEE.

Manik, M. M. H. (2025). ChatGPT vs. DeepSeek: A comparative study on AI-based code generation. arXiv preprint arXiv:2502.18467.

Manduchi, L., Meister, C., Pandey, K., Bamler, R., Cotterell, R., Däubener, S., … & Fortuin, V. (2024). On the challenges and opportunities in generative ai. arXiv preprint arXiv:2403.00025.

Muñoz, M. A. F., De La Torre, J. C. J., López, S. P., Herrera, S., & Uribe, C. A. C. (2024). Comparative study of ai code generation tools: quality assessment and performance analysis. LatIA, (2), 21. https://doi.org/10.62486/latia2024104

Sahoo, P., Singh, A. K., Saha, S., Jain, V., Mondal, S., & Chadha, A. (2024). A systematic survey of prompt engineering in large language models: Techniques and applications. arXiv preprint arXiv:2402.07927.

Sheard, J., Denny, P., Hellas, A., Leinonen, J., Malmi, L., & Simon. (2024). Instructor perceptions of ai code generation tools-a multi-institutional interview study. In Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1, 1223–1229. https://doi.org/10.1145/3626252.3630880

White, J., Fu, Q., Hays, S., Sandborn, M., Olea, C., Gilbert, H., … & Schmidt, D. C. (2023). A prompt pattern catalog to enhance prompt engineering with chatgpt. arXiv preprint arXiv:2302.11382.

Yetiştiren, B., Özsoy, I., Ayerdem, M., & Tüzün, E. (2023). Evaluating the code quality of ai-assisted code generation tools: An empirical study on github copilot, amazon codewhisperer, and chatgpt. arXiv preprint arXiv:2304.10778.

Yazdani, S., Singh, A., Saxena, N., Wang, Z., Palikhe, A., Pan, D., … & Zhang, W. (2025). Generative AI in depth: A survey of recent advances, model variants, and real-world applications. Journal of Big Data, 12(1), 230. https://doi.org/10.1186/s40537-025-01247-x

IMPACT OF TECHNOLOGICAL DRIVERS ON JOB TRANSFORMATION WITH IMPLICATIONS FOR RESKILLING AND UPSKILLING

DOI: 10.5937/EMC26303S

Jelena Slavić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: jelena.slavic@tfzr.rs
Željko Stojanov
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

ABSTRACT:

Industry 4.0 and the transition to Industry 5.0 are significantly changing the nature of work, introducing new technologies. The main aim of the paper is to examine the impact of technological drivers on job transformations, with a focus on the implications of reskilling and upskilling. The paper applies a literature review approach, developing a conceptual framework that shows the key links among technological factors, job change factors, and outcomes. The results indicate that technological drivers lead to job redesign, job creation, job displacement, job threat, and worker distrust, leading to the need for employee reskilling and upskilling. This is of great importance for organizations and their employees, in order to understand job transformations due to the impact of technologies, and to improve the skills and competencies of their employees.

Key words: Industry 4.0, Technological drivers, Job transformation, Reskilling, Upskilling

INTRODUCTION

Following the major industrial revolutions, Industry 4.0 (I4.0) is leading to the complete digitalization of industries and significant technological changes. The rapid development of technologies in I4.0 is changing the labor market as well as organizations and their employees. I4.0 introduces completely new technologies such as artificial intelligence (AI), Internet of Things (IoT), cognitive computing, virtual reality, big data, 3D printing, cloud computing and robotics (Adjei & King, 2024). In addition to I4.0, there is also an increasing transition to Industry 5.0 (I5.0), which focuses on putting humans at the center and achieving sustainable development. I5.0 is an industry that is resilient, sustainable, and human-centric oriented, complementing the goals of I4.0 while emphasizing the contribution of business to promoting worker well-being and facilitating the transition to sustainable growth (Sarkar et al., 2024). Contemporary technologies are changing and improving ways of working and doing business, but they are also causing changes in organizations regarding employees. Today, industries must strive to achieve a symbiosis between humans and AI, robotics, and other technologies that support employee work. From an organizational perspective, human-robot collaboration is expected to redefine the organization of work in the manufacturing environments, but the human role remains essential, as upskilling and craftsmanship reflect judgment, adaptability and attention to detail that automation alone cannot replicate (Callari et al., 2025). Human-robot collaboration aims to eliminate repetitive tasks in production by replacing them with machine-controlled operations, thereby encouraging more creative thinking (Pacheco et al., 2024). The integration of human intelligence with advanced technologies increases productivity and promotes development (Rahaman et al., 2025).

Recent studies show that contemporary technology has serious impacts on the labour market, leading to changes in jobs and the creation of new jobs. Also, they are enabling companies to significantly optimize production processes and improve resource efficiency. (Bouyahrouzi et al., 2025). They can also cause negative outcomes, such as insecurity among employees and a fear of losing their jobs, which can even lead to the gradual displacement of certain professions and jobs. The full automation of factories and the

introduction of technological innovations affect various factors that lead to job-related changes. New technologies create a demand for new skills and competencies, driving the need for employee reskilling and upskilling. Upskilling and reskilling can help employees acquire new skills and knowledge, increasing their employability and earning potential (Chuang et al., 2024). According to the World Economic Forum (2025), by 2030, 170 million new jobs are expected to be created, while the displacement of existing jobs will total about 92 million. The fastest-growing roles by 2030 are mainly driven by technological developments such as AI, robotics, and digital technologies. Existing literature shows that artificial intelligence, digital skills in ICT, and big data analytics are the top drivers, with artificial intelligence playing a crucial role, especially in the manufacturing and services sectors (Miah et al., 2024).

Although current research indicates that technological changes affect jobs and employees, these effects are mostly observed separately, focusing on individual changes in the job or on employees' skills and job losses. The aim of this paper is to examine the relationships among technological drivers, job change factors, and job change outcomes, as well as the implications for reskilling and upskilling. Job changes include not only job displacement or job creation, but also the impact on employees and possible positive outcomes. As a result of this analysis, a conceptual framework was developed.

LITERATURE REVIEW METHOD

The study uses a literature review methodology, a systematic way of collecting and synthesizing previous research, with the aim of providing an overview of a particular question or research problem (Snyder, 2019). The literature review search is conducted in the following databases: ScienceDirect, Emerald, MDPI, IEEE, ACM, Springer and Wiley. The appropriate databases were selected for their relevance to I4.0, technology and research on the reskilling and upskilling. It covers the last 10 years of published papers to ensure the study remains relevant and in focus amid rapid technological development. The next step in conducting the review is filtering articles based on title, abstract, and keywords, and then reading full-text articles. After final selection, 10 papers were chosen as relevant for further analysis (Figure 1).

Given the large number of studies on I4.0 and modern technology, to develop a conceptual model, a literature review was conducted to examine existing research and connect technological drivers, job change factors, and outcomes. In addition, the role and impacts of reskilling and upskilling were analyzed.

The criteria for literature selection were based on the Inclusion/Exclusion (I/E) criteria: (1) review of title, abstract and keywords, (2) papers published in English, (3) journal/conference publications, and (4) focused on reskilling and upskilling. To conduct an adequate literature review, the keywords related to review as Industry 4.0, job transformation, reskilling, and upskilling were defined. In Table 1. selected primary studies are presented. The selected studies were analyzed to determine the relationship between technological drivers and job change factors with implications for reskilling and upskilling. Based on synthesis of the reviewed studies, a conceptual framework was developed to present the relationship between technological drivers and job change factors and outcomes.

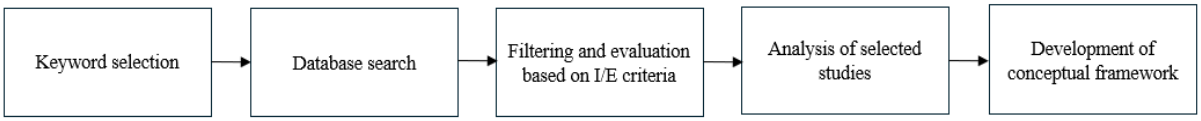


Figure 1: Method of conducting literature review

Review of selected studies

The most significant sources of change today in organizations and in work environments are technological drivers. Technological drivers are most often artificial intelligence, robotics, and digital technologies that have major contributions. Due to technology adoption and its future implications in the industrial society, there is significant speed of technological job control and the possible effects on workers' future employment (Chigbu & Nekhwevha, 2021). In addition to the above, the human-technology relationship, or the introduction of collaborative robots into human work, is further changing business across industries. Cobots, along with humans, constitute a large and important part of modern industries. Authors state that

redefinition of job structure is required in the high-tech sectors and automation does not replace people but require a higher level of skills (Ikata & Kent, 2022).

Table 1: Overview of selected primary studies

PS	Citation	References
PS1	Cingillioglu & Schoettner, 2025	Cingillioglu, I., & Schoettner, M. (2025). Adapting to AI-mediated workplaces: how STEM trainees navigate new challenges and opportunities. Information Technology & People, 38(8), 251-275.
PS2	Chigbu & Nekhwevha, 2021	Chigbu, B. I., & Nekhwevha, F. H. (2021). The future of work and uncertain labour alternatives as we live through the industrial age of possible singularity: Evidence from South Africa. Technology in Society, 67, 101715.
PS3	Chuang et al., 2024	Chuang, S., Shahhosseini, M., Javaid, M., & Wang, G. G. (2024). Machine learning and AI technology-induced skill gaps and opportunities for continuous development of middle-skilled employees. Journal of Work-Applied Management, (ahead-of-print).
PS4	Egasmara et al., 2025	Egasmara, F., Rahayu, A., Wibowo, L. A., Rofaida, R., Sofia, A., & Fauziyah, A. (2025). Workforce planning optimization utilising AI to improve firm performance: a systematic literature review using VOSviewer. Journal of Work-Applied Management, 1-13.
PS5	Ikata & Kent, 2022	Emma-Ikata, D., & Doyle-Kent, M. (2022). Industry 5.0 readiness–"Optimization of the relationship between humans and robots in manufacturing companies in Southeast of Ireland". IFAC-PapersOnLine, 55(39), 419-424.
PS6	Jamal et al., 2023	Jamal, A. F., El Nemar, S., & Sakka, G. (2025). The relationship between job redesigning, reskilling and upskilling on organizational agility. EuroMed Journal of Business, 20(2), 474-492.
PS7	Shimray & Subaveerapandiyan, 2025	Shimray, S. R., & Subaveerapandiyan, A. (2025). AI and workforce dynamics: a bibliometric analysis of job creation, displacement and reskilling. Global Knowledge, Memory and Communication.
PS8	Zirar et al., 2023	Zirar, A., Ali, S. I., & Islam, N. (2023). Worker and workplace Artificial Intelligence (AI) coexistence: Emerging themes and research agenda. Technovation, 124, 102747.
PS9	Zhanseitov et al., 2025	Zhanseitov, A., Akybayeva, G., Mambetova, S., Kazbekov, T., & Berdimurat, N. (2025). The impact of artificial intelligence on the labour market and HRM. Procedia Computer Science, 272, 489-495.
PS10	Wanasinghe et al., 2023	Wanasinghe, T. R., Gosine, R. G., Petersen, B. K., & Warrian, P. J. (2023). Digitalization and the future of employment: A case study on the Canadian offshore oil and gas drilling occupations. IEEE Transactions on Automation Science and Engineering, 21(2), 1661-1681.

Contemporary technologies create new jobs and change existing ones, leading to the need for new knowledge, skills, and competencies. Emerging job roles are concentrated in knowledge-intensive sectors, while displacement risks are more directed in low-skilled, routinized occupations (Shimray & Subaveerapandiyan, 2025). Jobs created by AI and machine learning technologies reshape job structures by creating new roles, displacing middle-skilled workers, and redesigning existing jobs. An important mechanism for the transformation of job responsibilities is job redesign, requiring employees to learn new skills, indicating that the organizational technological development positively affects job redesign (Jamal et al., 2023). The characteristics of AI are changing workplaces (information sharing, interactions, and ownership structures), and a model by Cingillioglu & Schoettner (2025) illustrates the connections among the findings and highlights the cascading pathways that connect AI technologies to new challenges in professional adaptation. People need to keep up with changes and technology trends, in case of a mismatch, many may lose on digital transformation.

Artificial intelligence is causing tectonic shifts across industries, perhaps more than any other technology. AI is creating new jobs to a large extent, but also a large part of people, 70% of whom, after a survey, stated that AI leads to job displacement in traditional industries (Zhanseitov et al., 2025).
Some studies outline a plan to predict how jobs and workplaces will change, merge, and some will disappear completely, underscoring the importance of implementing reskilling through various training programs (Wanasinghe et al., 2023). This technological impact often implies strategies such as reskilling

and upskilling. Workers should be reskilled and upskilled with a strategic career development plan rather than being replaced by AI and robots (Chuang et al., 2024). Reskilling and upskilling are central to mitigating all these effects. (Shimray & Subaveerapandiyan, 2025). This suggests that, in addition to job changes driven by technology, employees' career paths are also influenced by these changes.

The workforce's readiness also depends on both the country's location and its financial situation. A large part of the automotive industry workforce in Africa is expressing great concern about job security due to technological changes. Although reskilling and upskilling are widely recognized as key responses to skill gaps, some studies indicate that they are not sufficient to fully address job insecurity caused by technological change (Chigbu & Nekhwevha, 2021).

In the expansion of artificial intelligence, AI leads to changes in jobs, and there is an emergence of distrust among employees and fear for the survival of their jobs. Artificial intelligence offers greater opportunities to highly qualified workers, while low-skilled or unskilled workers express significant distrust of AI (Zirar et al., 2023). It is necessary to improve the skills of employees if organizations or employees themselves work on it. Employee resistance stems from job security and fear of displacement, which require transparent communication, proactive reskilling initiatives, and strong organizational change management to ensure that AI adoption enhances organizational efficiency (Egasmara et al., 2025). Rather than fostering fear or optimism about technological change, policies should aim to adapt labour markets to coexist with automation with supporting the transition to non-routine cognitive jobs through reskilling and upskilling initiatives is essential (Park et al., 2026). These findings indicate that artificial intelligence plays a crucial role as technological driver and has a significant impact on the job changes and their outcomes in the I4.0/5.0 environment.

Despite job distrust concerns, a recent study (Ikata & Kent, 2022) found that human-centric technologies have a positive impact on the workforce. Research showed that 81.8% of the workforce believes their future work prospects can be improved with Cobot training, while 60% do not believe humans will be irrelevant in manufacturing. Based on the literature review, it is evident that the creation of new jobs, the redesign of existing jobs, job displacement, and job threat or distrust are largely influenced by modern technologies. Largely artificial intelligence, automation and robotics imply these changes. In addition, technologies such as cobots lead to a positive impact on job changes. All the changes that occur mostly define reskilling and upskilling as some kind of solution that organizations need to implement for their employees.

FINDINGS

Through literature review of primary studies, findings highlight that technological impact on jobs is significant and inevitable. Through the analysis of studies, two categories, containing several individual concepts, were identified: technological drivers and job change factors, and outcomes with implications on reskilling and upskilling. By connecting relationships between their individual concepts, a conceptual framework was developed. The proposed conceptual framework is only based on literature review of selected studies, rather than on empirical evidence.

In the main conceptual framework presented in Figure 2, the key factors are separated into technological drivers, job change factors and outcomes. They are distinguished into individual elements that indicate the entities' belonging, while arrows indicate the effect that technology has on job change factors. Job changes factors and outcomes, depending on the employee’s perspective, can be positive and negative, where job creation and redesign are mostly associated with positive effects (marked green), while job displacement and distrust are presented as negative (highlighted grey).

The findings suggest that digital technologies and AI relation with job redesign positively affect the reskilling and upskilling program with increasing organization agility and profit, and AI environments reshape interaction, learning, autonomy, task ownership, and professional development (PS6, PS1). Digitalization and automation are changing jobs through job merging and the application of necessary skills, where reskilling is the main key (PS10).

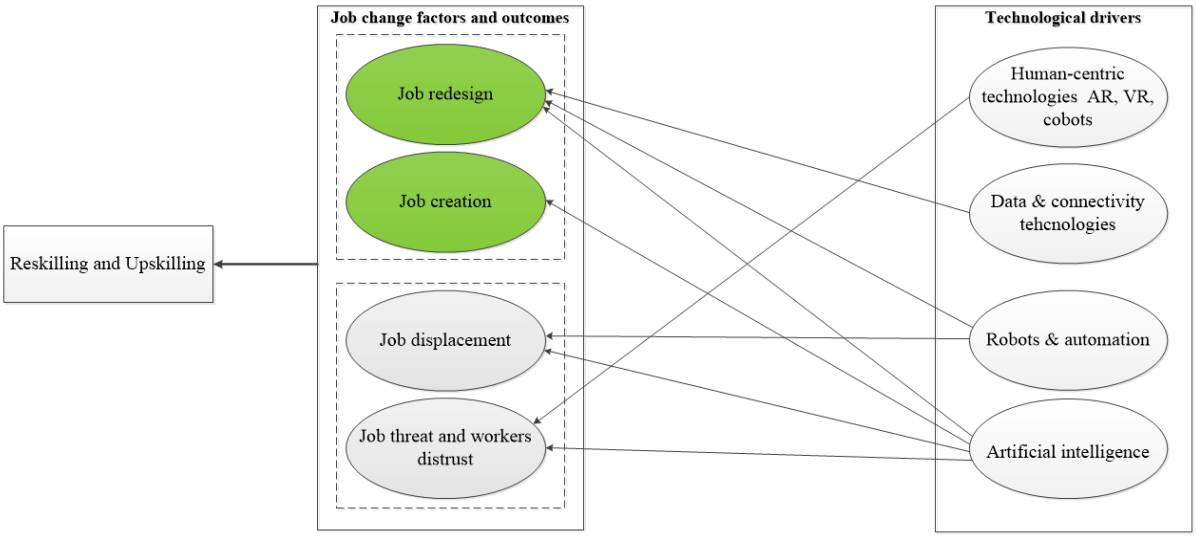


Figure 2: Technological impact on job transformation

Job creation – AI relationship indicates that the biggest technological driver for creating new jobs is AI and machine learning. Also, it can be concluded that job changes impacted by technology are also based on employee's skill level, and there is increased demand for high-skilled employees. Reskilling and upskilling of mid-level employees for jobs that require higher skills, created by advanced technology are crucial (PS3)

The reviewed studies highlight the job displacement – AI relationship, showing that AI has significant impact on job displacement as well as has a dual impact on job creation and job displacement, affecting low-skilled workers and automating routine tasks, creating the need for reskilling and upskilling (PS9, PS7). On the other hand, automation's impact on job displacement implies low motivation for reskilling, retraining, and upskilling, given the rate at which robots are being adopted and how smarter they are becoming with newer models designed to automate tasks (PS2).

Also studies illustrates that automation and AI cause distrust and fear of job displacement (PS8, PS4). Further, in Figure 2, the findings point that there is one relationship between job distrust and human-centric technology that yields positive outcomes, with cobots having a significant impact on employees and no fear of replacing people with technology (PS5).

The findings indicate that majority of job changes are caused by artificial intelligence and it is the most dominant technological driver. The literature suggests that technology have impact on job transformations, as creation of new jobs, redesign of existing ones, as well as triggering job distrust and causing employees to view technology as a threat with the need of reskilling and upskilling.

The role of the conceptual framework is the integration of key concepts, technological drivers and job change factors in I4.0/5.0 into one model. The model also presents the possible positive and negative outcomes of the impact of contemporary technologies on job transformation and workforce adaptation. Hence, the need for reskilling and upskilling can contribute to organizations in improving employees ' skills and competencies, as well as their operations.

CONCLUSION

In today's environment, it is inevitable that technologies will bring about changes in various aspects, including changing jobs and the work environment. For all those operating with contemporary technology they need to improve their employees' skills and knowledge, through reskilling or upskilling, as well as to keep investing in new technologies. Organizational agility and the willingness of employees to adapt to and embrace changes without fear and distrust are also needed. As the main contribution of the paper, the conceptual framework is developed based on the literature review which links the technological impact on job factors and defines the need for reskilling and upskilling. It was also emphasized that the main and dominant technological driver is artificial intelligence.

Future research is aimed at examining the impact of technological developments on employee skills and organizational enablers, to better understand and identify the need for reskilling and upskilling in the I4.0 environment.

REFERENCES:

Bouyahrouzi, E. M., Benmimoun, R., El Kihel, Y., & Bajjou, M. S. (2025). Integrating industry 4.0 technologies and maintenance 4.0 for sustainable manufacturing: a systematic literature review. The International Journal of Advanced Manufacturing Technology, 140(1), 35-61.

Callari, T. C., Curzi, Y., & Lohse, N. (2025). Realising human-robot collaboration in manufacturing? A journey towards industry 5.0 amid organisational paradoxical tensions. Technological Forecasting and Social Change, 219, 124249.

Chigbu, B. I., & Nekhwevha, F. H. (2021). The future of work and uncertain labour alternatives as we live through the industrial age of possible singularity: Evidence from South Africa. Technology in Society, 67, 101715.

Chuang, S., Shahhosseini, M., Javaid, M., & Wang, G. G. (2024). Machine learning and AI technology-induced skill gaps and opportunities for continuous development of middle-skilled employees. Journal of Work-Applied Management, (ahead-of-print).

Cingillioglu, I., & Schoettner, M. (2025). Adapting to AI-mediated workplaces: how STEM trainees navigate new challenges and opportunities. Information Technology & People, 38(8), 251-275.

Darko Adjei, N., & King, L. (2024). Academic libraries readiness in the Fourth Industrial Revolution: a comparative study between Ghana and South Africa. Library Management, 45(8-9), 581-596.

Egasmara, F., Rahayu, A., Wibowo, L. A., Rofaida, R., Sofia, A., & Fauziyah, A. (2025). Workforce planning optimization utilising AI to improve firm performance: a systematic literature review using VOSviewer. Journal of Work-Applied Management, 1-13.

Emma-Ikata, D., & Doyle-Kent, M. (2022). Industry 5.0 readiness–"Optimization of the relationship between humans and robots in manufacturing companies in Southeast of Ireland". IFAC-PapersOnLine, 55(39), 419-424.

Jamal, A. F., El Nemar, S., & Sakka, G. (2025). The relationship between job redesigning, reskilling and upskilling on organizational agility. EuroMed Journal of Business, 20(2), 474-492.

Miah, M. T., Erdei-Gally, S., Dancs, A., & Fekete-Farkas, M. (2024). A systematic review of Industry 4.0 technology on workforce employability and skills: Driving success factors and challenges in South Asia. Economies, 12(2), 35.

Pacheco, D. A. D. J., & Iwaszczenko, B. (2024). Unravelling human-centric tensions towards Industry 5.0: Literature review, resolution strategies and research agenda. Digital Business, 4(2), 100090.

Park, J., & Kim, D. (2025). The vulnerable future of manual jobs? Automation probabilities and regional patterns in the US under the Industry 4.0 transformation. *Sustainable Cities and Society*, 107038.

Rahaman, M. T., Pranta, A. D., & Ahmed, S. (2025). Transitioning from industry 4.0 to industry 5.0 for sustainable and additive manufacturing of clothing: framework, case studies, recent advances, and future prospects. Materials Circular Economy, 7(1), 20.

Sarkar, B. D., Shardeo, V., Dwivedi, A., & Pamucar, D. (2024). Digital transition from industry 4.0 to industry 5.0 in smart manufacturing: A framework for sustainable future. Technology in Society, 78, 102649.

Shimray, S. R., & Subaveerapandiyan, A. (2025). AI and workforce dynamics: a bibliometric analysis of job creation, displacement and reskilling. Global Knowledge, Memory and Communication.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of business research*, *104*, 333-339.

Wanasinghe, T. R., Gosine, R. G., Petersen, B. K., & Warrian, P. J. (2023). Digitalization and the future of employment: A case study on the Canadian offshore oil and gas drilling occupations. IEEE Transactions on Automation Science and Engineering, 21(2), 1661-1681.

World Economic Forum. (2025*). The future of jobs report 2025*. World Economic Forum.

Zhanseitov, A., Akybayeva, G., Mambetova, S., Kazbekov, T., & Berdimurat, N. (2025). The impact of artificial intelligence on the labour market and HRM. Procedia Computer Science, 272, 489-495.

Zirar, A., Ali, S. I., & Islam, N. (2023). Worker and workplace Artificial Intelligence (AI) coexistence: Emerging themes and research agenda. Technovation, 124, 102747.

TEACHERS' PERCEPTIONS OF AI TOOL ADOPTION IN SERBIAN SCHOOLS: IMPLICATIONS FOR EDUCATIONAL MANAGEMENT

DOI: 10.5937/EMC26309V

Ivana Vasić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: ivana.vasic@tfzr.rs
Ivana Berković
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Veselinka Lejić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia

ABSTRACT

This study examines primary and secondary school teachers' perceptions in the Republic of Serbia regarding the use of artificial intelligence (AI)–based tools in lesson planning and instruction. The aim of the study was to examine teachers' level of knowledge and experience, their evaluation of the usefulness of AI tools, as well as the factors influencing their motivation and frequency of use in educational practice. The research was conducted on a sample of 167 teachers using a survey questionnaire. The results indicate that teachers generally hold positive views about the potential of AI tools, particularly in terms of facilitating teachers' work, improving lesson planning, and supporting the individualization of learning. A statistically significant relationship was found between prior experience with digital tools and the perceived usefulness of AI, as well as between perceived benefits and motivation to use these tools. However, no significant relationship was found between attending training and the frequency of AI tool usage. The findings highlight the need for a more systematic approach to professional development in the field of artificial intelligence applications in education.

Key words: AI tools, artificial intelligence, education, lesson planning, digital competencies

INTRODUCTION

The growing integration of artificial intelligence (AI) in education is transforming teaching and learning processes, particularly in lesson planning and instructional design in primary and secondary schools. In the Republic of Serbia, unlike in countries where numerous systematic studies have been conducted, research on the application of AI in education remains limited, with most existing studies carried out within projects, pilot studies, or conference papers.

The aim of this paper is to examine primary and secondary school teachers' knowledge and understanding of the application of artificial intelligence in lesson planning and instruction, as well as their perceptions of its usefulness, motivational factors, and barriers to the use of these tools.

THEORETICAL BACKGROUND / LITERATURE REVIEW

Development of Artificial Intelligence

Generative artificial intelligence became widely recognized in late 2022 following the emergence of ChatGPT, an application that, within a very short period, became the fastest-growing application in history. Thanks to its ability to simulate human capabilities and generate various types of content—such as text, images, video, music, and software code—GenAI has attracted significant public attention (Miao & Holmes, 2023). AI systems, based on deep learning and Natural Language Processing (NLP), can communicate with users, understand their needs, analyze choices, and suggest appropriate actions without human intervention (Minić & Deretić, 2024). Large Language Models

(LLMs) are a type of AI designed to understand and generate human-like text, trained on vast datasets to recognize patterns in natural language (Brand et al., 2025).

Teachers' Perceptions and Acceptance of Artificial Intelligence in Education

The results of a study conducted in Malta in 2023, involving 86 mathematics teachers, indicate, similarly to Gill et al. (2024), that mathematics teachers perceive ChatGPT as a tool that can increase student engagement in learning and provide support to students of different levels of knowledge and abilities (Busuttil & Calleja, 2025). However, there is a need for schools and educational institutions to urgently improve teaching and assessment methods in a way that incorporates artificial intelligence, rather than avoiding it. The results of a study conducted in China in 2024, involving 318 primary and secondary school teachers, show that teachers' AI literacy directly influences their perceptions of the usefulness of artificial intelligence for society (PAIS) and their self-efficacy in learning AI, with both factors affecting their behavioral intentions to learn artificial intelligence (Du et al., 2024). Previous studies have also confirmed the impact of self-efficacy on learning intentions (Evans et al., 2020; Kumar et al., 2020). A study conducted in Iran in 2024 examined teachers' attitudes toward artificial intelligence in education and revealed a complex perspective that includes both the benefits and challenges of its implementation. Teachers recognized the potential of AI to enhance personalized learning, improve administrative efficiency, and support innovative teaching approaches, while also expressing concerns related to ethics, infrastructure, and the need for professional development (Aghaziarati et al., 2024).

According to Zhai (Zhai, 2024), teachers' attitudes, knowledge, technology acceptance, and practices represent interrelated factors that determine the successful implementation of GenAI, while the role of teachers evolves from users to collaborators and innovators in its application.

Artificial Intelligence in Education

The application of artificial intelligence in education significantly contributes to improving teaching methods and learning processes. The use of intelligent tutoring systems and automated assessment tools is transforming the interaction between teachers and students, as well as the way educational content is acquired. AI technologies enable the automation of administrative tasks, grading, and data processing, thereby reducing teachers' workload and increasing the efficiency of the educational process (Amin et al., 2025; Belloula, 2025; Erbas & Maksuti, 2024).

Teacher Training

In the current Catalogue of Professional Development Programs* of the Institute for the Improvement of Education and Upbringing, there are 23 accredited professional development programs related to the application of artificial intelligence in the educational process. In addition to these trainings, there are also various informal and non-accredited but high-quality courses available in the Serbian language, as well as training programs offered on platforms such as Udemy, Coursera, edX, and IBM SkillsBuild.

REVIEW OF AI TOOLS FOR LESSON PLANNING AND INSTRUCTION

Many instructional techniques have a proven positive effect on learning, but they are often difficult to implement in practice due to teachers' time constraints. With the support of artificial intelligence, their application becomes simpler and more accessible. Particularly significant are: generating diverse examples, providing multiple explanations, creating practice tests, assessing students' knowledge, and facilitating the acquisition of new concepts (Mollick & Mollick, 2023). Lesson planning is often challenging due to diverse student needs and varying levels of knowledge. Generative AI tools, along with specialized educational AI applications, support lesson planning, content generation, and instructional differentiation while helping teachers save time.

Tools based on generative artificial intelligence can help teachers quickly develop lesson plans by offering suggestions for teaching activities, assessment methods, instructional content, discussion prompts, and homework ideas (Trust et al., 2025).

RESEARCH METHODOLOGY

The research is empirical in nature and was conducted as a descriptive-analytical, quantitative, and cross-sectional study. The aim of the research was to examine teachers' attitudes and perceptions regarding the application of artificial intelligence in the teaching process, as well as to analyze the factors that influence the frequency and manner of its use in educational practice.

The sample consisted of 167 teachers from primary and secondary schools across different regions of the Republic of Serbia. A convenience sampling technique was used, with data collected through an online questionnaire distributed via Facebook groups intended for educators, which introduces potential self-selection bias. The sample included teachers of various school subjects and with different levels of teaching experience. It is possible that the sample includes a higher proportion of teachers with a higher level of digital literacy or a stronger interest in artificial intelligence, which may have contributed to more optimistic results regarding the use of AI and attitudes toward it. Therefore, the results should be interpreted with caution and cannot be fully generalized to all teachers in the Republic of Serbia.

The questionnaire consisted of 21 items, of which one was an open-ended question, 10 were constructed using a Likert scale, while the remaining questions were closed-ended with predefined response options. Cronbach's alpha was calculated to assess the internal consistency of the Likert-scale items measuring teachers' perceptions of AI tool adoption in education. The analysis included 10 Likert-type items, yielding a good reliability coefficient ($\alpha = 0.892$), indicating high internal consistency of the scale.

Research problem

Although AI tools have the potential to improve lesson planning and teaching, there is insufficient information about teachers' perceptions in primary and secondary schools and about the ways in which they use or plan to use these tools.

The research problem is reflected in the lack of knowledge about the extent to which teachers are familiar with and understand the possibilities of applying AI in teaching, how they evaluate the usefulness of these tools, and what motivates or concerns them. Furthermore, it is not sufficiently known to what extent teachers actually use available AI tools, how effective these tools are, and what challenges exist in their practical application. Special attention is also given to the level of teacher training for working with AI tools.

Subject of the research

The subject of the research includes teachers' perceptions in primary and secondary schools regarding the use of artificial intelligence in teaching, as well as an overview of available AI tools that support lesson planning and teaching delivery, along with their practical application in the educational process.

The aim of this research is to examine how teachers in primary and secondary schools perceive the use of artificial intelligence in teaching, to assess their level of knowledge and experience in working with AI tools, and to provide an overview of available AI tools that support lesson planning and teaching delivery, including the possibilities of their practical application.

Research questions

RQ1**:** Is there a statistically significant relationship between prior experience with digital tools and the perceived usefulness of artificial intelligence in teaching?
RQ2: Is there a statistically significant relationship between attending training on AI tools and the frequency of their use in teaching practice?
RQ3: Is there a statistically significant relationship between the perceived direct benefits of AI tools and teachers' motivation to use them in teaching?

RESULTS AND DISCUSSION

Descriptive statistics

A total of 167 teachers participated in the study, of which 63.5% mainly work in primary schools and 36.5% in secondary schools. Regarding years of teaching experience, 12% of respondents have less than 5 years of experience, 17.4% have between 5 and 10 years, 31.1% have between 11 and 20 years, and 39.5% have more than 20 years of teaching experience. A total of 92.2% of respondents reported using AI in teaching, while 7.8% do not use it. Furthermore, 29.3% of respondents stated that they had participated in some form of training, while the remaining respondents had not.

The results show that teachers, on average, positively evaluate the usefulness of AI tools in the teaching process. The highest mean value was recorded for the statement that AI tools facilitate teachers' work ($M = 4.06$), followed by the statement that they can contribute to better individualization of teaching ($M = 4.04$) and improve lesson planning ($M = 3.95$). Slightly lower, but still positive values relate to the perception that AI tools can increase student motivation ($M = 3.69$). Teachers' self-assessment of their knowledge of AI tools indicates a moderate level ($M = 3.29$). The results obtained through descriptive analysis show that 39.5% of respondents assess their knowledge of AI tools as good, while 18.6% of respondents consider their knowledge to be poor. The largest proportion of respondents (41.9%) expressed a neutral attitude, indicating uncertainty in assessing their own competencies in this area.

When comparing the opinions of teachers working in primary schools with those working in secondary schools, no statistically significant relationship was found in the given sample between the type of school in which respondents work and their self-assessment of knowledge of AI tools ($r = 0.080$, $p = 0.306$).

Relationships Between Key Variables

The results of Pearson's correlation indicate a statistically significant positive relationship between teachers' prior experience with digital tools and their perception of the usefulness of artificial intelligence in teaching. A strong correlation was found between prior experience and the belief that AI tools facilitate teachers' work ($r = 0.664$, $p < 0.01$), as well as a moderate correlation with the perception of improved lesson planning quality ($r = 0.554$, $p < 0.01$) and increased student motivation ($r = 0.507$, $p < 0.01$). This supports the first research question and confirms the relationship between the two stated factors. The findings show that teachers with more experience in using digital tools in teaching are more likely to recognize the benefits of using AI tools.

The obtained chi-square test results ($\chi^2 = 1.10$, $p = 0.294$) do not indicate a statistically significant association between training attendance and the use of AI tools in teaching. This may suggest the importance of other factors, such as personal motivation, interest, and prior experience.

The results of the correlation analysis indicate a statistically significant positive relationship between teachers' motivation to use AI tools and their perception of direct benefits in the teaching process. A strong correlation was found between motivation for using AI tools in lesson planning and motivation for using them in teaching delivery ($r = 0.766$, $p < 0.01$). Furthermore, a significant relationship was observed between motivation and the perception that AI tools facilitate teachers' work ($r = 0.629$, $p < 0.01$ for planning; $r = 0.532$, $p < 0.01$ for teaching delivery). These findings suggest that when teachers

recognize the direct benefits of using AI tools, their motivation increases significantly, supporting the third research question. Teachers most frequently reported using ChatGPT, Gemini, and Copilot for lesson preparation, while Canva AI, NotebookLM, and MagicSchool are used during the teaching process. Responses to the question about the future application of these tools varied—from highly positive and encouraging ones, such as "As a valuable resource for applying various content" and "I believe it will make teachers' work easier and allow them to devote more time to students," to expressed doubts about the quality of implementation, along with reported technical difficulties and a lack of necessary resources.

The study found that a high percentage of teachers reported using digital tools in teaching (92.2%), which may not fully reflect the actual situation in Serbia. A substantial proportion of respondents also stated that they regularly or occasionally use AI tools for lesson preparation or delivery; however, this finding should be interpreted with caution due to the data collection method. The use of online professional teacher groups for survey distribution likely introduced self-selection bias, attracting respondents who are already more digitally engaged and familiar with artificial intelligence tools. As a result, the sample may overrepresent teachers with higher levels of digital literacy and more positive attitudes toward AI, which could have contributed to more favorable results. In addition, the relatively small and non-random sample limits the generalizability of the findings. Therefore, future studies should employ systematic sampling approaches across different regions and school types in order to obtain more representative data.

The findings suggest that currently available training programs may not be sufficient on their own to significantly increase the frequency of AI tool use. This may indicate the limited effectiveness of existing forms of professional development or the perception that one-off training sessions are insufficient for the sustainable implementation of new technologies in practice. In this context, a more significant role could be played by continuous support, mentoring, and collaboration with more experienced colleagues in the process of integrating AI tools into teaching practice. These findings suggest that digital literacy and work experience play a more significant role in the adoption and use of AI tools in teaching practice than formal training.

Implications for educational management

The key role of school principals is reflected in recognizing the importance and potential of the proper and ethically acceptable application of artificial intelligence. By providing additional support to interested and motivated teachers, it is possible to highlight the significance and possibilities of its implementation in the educational process. Furthermore, it is necessary to recognize the need for continuous professional development, as the field of artificial intelligence is highly dynamic and subject to rapid changes.

The research results may serve as a starting point for involving teachers in a mentoring process. Through mentoring and differentiated training, it would be possible to adapt the content to teachers with different levels of knowledge and experience in the use of AI tools. Regarding systemic solutions, it is recommended that artificial intelligence be incorporated into the school development plan. In addition, it is necessary to develop guidelines for the ethical and pedagogically justified use of AI in education.

CONCLUSION

A common finding of this study, as well as the studies cited in the text, is teachers' confirmation that prior experience with digital tools influences their attitude toward the use of AI in teaching, as well as their motivation to learn new technologies. They also believe that its application in teaching can contribute to better individualization of instruction. The main barriers to the effective implementation of AI in teaching are reported to be a lack of training and technical limitations, which is consistent with the findings of the referenced studies. Additionally, 9% of respondents identified ethical dilemmas as a limiting factor, which is also one of the key issues in research on the application of AI

in all fields of work, especially in education.Although the topic is highly relevant, there is still a limited number of studies in the Republic of Serbia that address teachers' perceptions, patterns of use, and the effects of artificial intelligence in the teaching process. The significance of this paper lies in the fact that it may serve as a starting point for future, more comprehensive research with a larger and more representative sample of respondents. Furthermore, it would be important for future studies to include students as well, in order to examine their attitudes and motivations for using AI tools in learning.

REFERENCES

Aghaziarati, A., Nejatifar, S., & Abedi, A. (2024). Artificial intelligence in education: Investigating teacher attitudes. *AI and Tech in Behavioral and Social Sciences, 2*(2), 1–16. https://doi.org/10.61838/kman.aitech.2.2.1973

Amin, M. R. M., Ismail, I., & Sivakumaran, V. M. (2025). Revolutionizing education with artificial intelligence (AI): Challenges and implications for open and distance learning (ODL). *Social Sciences & Humanities Open, 11*, 101308. https://doi.org/10.1016/j.ssaho.2025.101308

Belloula, S. (2025). Empowering educators: Leveraging AI to revolutionize lesson planning. *International Journal of Research in Education and Science, 11*(2), 264–280. https://doi.org/10.46328/ijres.1295

Brand, J., Israeli, A., & Ngwe, D. (2025, October 6). *Using LLMs for market research* (Harvard Business School Marketing Unit Working Paper No. 23-062). Harvard Business School. https://www.hbs.edu/ris/Publication%20Files/23-062_b8fbedcd-ade4-49d6-8bb7-d216650ff3bd.pdf

Busuttil, L., & Calleja, J. (2025). Teachers' beliefs and practices about the potential of ChatGPT in teaching mathematics in secondary schools. *Digital Experiences in Mathematics Education, 11*, 140–166. https://doi.org/10.1007/s40751-024-00168-3

Du, H., Sun, Y., Jiang, H., Islam, A. Y. M. A., & Gu, X. (2024). Exploring the effects of AI literacy in teacher learning: An empirical study. *Humanities and Social Sciences Communications, 11*(1), 559. https://doi.org/10.1057/s41599-024-03101-6

Erbas, I., & Maksuti, E. (2024). The impact of artificial intelligence on education. *International Journal of Innovative Research in Multidisciplinary Education, 3*(4), 463–471. https://doi.org/10.58806/ijirme.2024.v3i4n01

Evans, C. A., Chen, R., & Hudes, R. P. (2020). Understanding determinants for STEM major choice among students beginning community college. *Community College Review, 48*(3), 227–251. https://doi.org/10.1177/0091552120917214

Gill, S., Xu, M., Patros, P., Wu, H., Kaur, R., Kaur, K., Fuller, S., Singh, M., Arora, P., Parlikad, A., Stankovski, V., Abraham, A., Ghosh, S., Lutfiyya, H., Kanhere, S., Bahsoon, R., Rana, O., Dustdar, S., Sakellariou, R., … Buyya, R. (2024). Transformative effects of ChatGPT on modern education: Emerging era of AI chatbots. *Internet of Things and Cyber-Physical Systems, 4*, 19–23. https://doi.org/10.1016/j.iotcps.2023.06.002

Kumar, J. A., Bervell, B., Annamalai, N., & Osman, S. (2020). Behavioral intention to use mobile learning: Evaluating the role of self-efficacy, subjective norm, and WhatsApp use habit. *IEEE Access, 8*, 208058–208074. https://doi.org/10.1109/ACCESS.2020.3037925

Minić, S. G., & Deretić, N. N. (2024). Primena veštačke inteligencije u obrazovanju – četbot ChatGPT. *Obrazovanje i vaspitanje, 19*(22), 61–72. https://doi.org/10.5937/obrvas19-54678

Miao, F., & Holmes, W. (2023). *Guidance for generative AI in education and research*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000386693

Mollick, R., & Mollick, L. (2023, March 16). *Using AI to implement effective teaching strategies in classrooms: Five strategies, including prompts*. Wharton School of the University of Pennsylvania & Wharton Interactive. https://ssrn.com/abstract=4391243

Trust, T., Maloy, R., Xu, C., & Pelletier, K. (2025). Civic education in the age of AI: Should we trust AI generated lesson plans? *Contemporary Issues in Technology and Teacher Education, 25*(3), 418–442.

Zavod za unapređivanje obrazovanja i vaspitanja. (2025). *Katalog programa stručnog usavršavanja za školsku 2025/2026, 2026/2027 i 2027/2028 godinu*. https://zuov.gov.rs/katalog-programa-strucnog-usavrsavanja-za-skolsku-2025-2026-2026-2027-i-2027-2028-godinu/

Zhai, X. (2024). *Transforming teachers' roles and agencies in the era of generative AI: Perceptions, acceptance, knowledge, and practices*. arXiv. https://arxiv.org/abs/2410.03018

ONBOARDING AS KNOWLEDGE MANAGEMENT IN REMOTE SOFTWARE TEAMS: A LITERATURE REVIEW

DOI: 10.5937/EMC26315V

Igor Vecstejn
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: igor.vecstejn@tfzr.rs
Tamara Milić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Vuk Amižić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Ninoslava Tihi
Academy of Applied Studies, Novi Sad, Republic of Serbia
Mohammad Anisseh
Department of Industrial Management, Imam Khomeini International University, Iran

ABSTRACT

This structured literature review examines software developer onboarding as a knowledge management (KM) process in remote, distributed, hybrid, and OSS teams. The set of 15 primary studies (2019-2025) synthesizes socio-technical practices aimed at accelerating the inclusion of new employees. The most common are case studies and mixed methods. Papers are mainly conference papers, with an increase in papers in journals. Outcome indicators are rarely and unevenly defined, so cross-study comparisons are limited. The onboarding process can be seen as an integration of explicit and tacit knowledge, and recommendations for practices can be derived from it, as well as guidelines for further research.

Key words: Onboarding, Knowledge Management, Software Engineering, Remote Teams, Literature Review.

INTRODUCTION

Remote working conditions, as well as the hybrid mode of work, have reduced ambient learning and spontaneous knowledge exchange, which makes it much more difficult for new employees in software teams to access contexts, coordination and feedback, which is confirmed by surveys conducted during the COVID-19 pandemic (Ford et al., 2021). Since software engineering (SE) is a highly knowledge-intensive field, a successful onboarding process requires careful planning and balancing of explicit knowledge through internal artifacts, documentation, and tacit knowledge (practices, communities, etc.). This is also indicated by the systematic review KM in SE, emphasizing that the balance is often lost when the focus is solely on documentation (Bjørnson & Dingsøyr, 2008).

In organizational psychology, onboarding is often viewed as a process related to organizational socialization during which a new employee acquires new skills, knowledge, and behaviors necessary to successfully perform a job (Bauer & Erdogan, 2011). Meta-analyses of social tactics confirm a stable connection when it comes to the adaptation of new employees, where faster work performance is achieved, greater job satisfaction and thus the probability of leaving the current job is reduced (Saks et al., 2007).

In software engineering, a multi-case study of globally distributed projects identifies onboarding process challenges such as access to code and software tools, mentoring support, and team integration and highlights practices that facilitate them (Britto et al.,2018). Survey-model work links the success of the onboarding process with fit in the organization and the intention to leave of professional developers (Sharma & Stol, 2020). Lessons learned from Open-Source Software (OSS) communities

offer lessons such as systematic reviews of barriers to new hires that highlight documentation issues, finding initial tasks, and building social connections (Steinmacher et al.,2015), while empirical work around the Good First Issue (GFI) label shows that starting points facilitate entry into the process (Alderliesten & Zaidman, 2021). More recent work also presents automated recommendations of such tasks, which accelerates the involvement of new employees in real projects (Xiao et al, 2022). These lessons, together with the challenges faced by employees in the company, as well as the measures taken in remote projects (Britto et al., 2020, Rodeghero et al., 2021), provide a framework for observing the onboarding process as a knowledge management mechanism in distributed software teams.

RELATED WORK

Previous reviews show that knowledge management in software engineering has often emphasized explicit knowledge, storage, and retrieval mechanisms, while tacit knowledge, learning, and knowledge transfer have received less systematic attention (Bjørnson & Dingsøyr, 2008). This distinction is important for onboarding because newcomers need both accessible artifacts and access to team routines, mentoring, contextual knowledge, and informal coordination mechanisms.

In distributed and agile software development, knowledge sharing is additionally affected by time-zone differences, cultural distance, tool mediation, and reduced face-to-face interaction (Zahedi et al., 2016, Yanzer Cabral et al., 2014). Prior work on social tools in software development also shows that collaborative platforms can support knowledge discovery and transfer, although their integration into everyday development work remains insufficiently explored (Sarka & Ipsen, 2017).

METHODOLOGY

In this research paper, a structured literature review was conducted with a focus on onboarding as KM in remote, distributed, hybrid or OSS software teams. The goal of the research is to identify and map primary studies that explicitly deal with the topic of onboarding and KM practice (e.g. Documentation, handbook, mentoring, buddy program, Community of Practice).Certain literature review procedures were used in this research from (Kitchenham et al., 2009). Although this research does not represent a comprehensive systematic literature review, certain methodologies are presented in chapter 22 of the book (Kitchenham et al., 2009) and were applied as guidelines in the literature review process, which is also visually represented in Figure 1. Yellow blocks indicate the main stages of the review process, while gray blocks provide supplementary information about data sources, database-specific counts, and excluded records.For the consistency of the search of scientific papers, four main conceptual groups and their synonyms were selected, which were combined with the Boolean operators AND and OR and applied in the search fields:

- Keyword 1 (KW1) – “Onboarding”
- Keyword 2 (KW2) – “Software” OR "Developer"
- Keyword 3 (KW3) – “Remote” OR "Virtual" OR "Distributed" OR “Hybrid” OR “OSS”
- Keyword 4 (KW4) – “Knowledge Management” OR “Documentation” OR “Mentoring”

These four primary keywords represent basic terms that guide the search for relevant literature sources. Combining these four keywords forms the following search string:

KW1 AND KW2 AND KW3 AND KW4

This literature search string was applied across databases covering software engineering and computer science such as Springer, IEEE Xplore, Elsevier (ScienceDirect), Wiley, ACM Digital Library and Google Scholar. In this way, the risk of missing relevant papers due to differences in indexing between the selected databases was reduced:

- The papers for this Literature Review were selected based on specific inclusion criteria: (I1) Works published in the period from 2019-2025; (I2) Domain Software Engineering; (I3) Explicit link between Onboarding and Knowledge Management; (I4) Context Remote, Virtual,

Distributed, Hybrid or OSS; (I5) Peer-reviewed journal or full conference paper; (I6) Published in English language

– In order to ensure the relevance and quality of the selected literature sources for this Literature Review, certain exclusion criteria were applied: (E1) Non-peer-reviewed papers; (E2) Duplicates; (E3) Full-text unavailable; (E4) Outside the scope of Software Engineering or Onboarding (E5) Papers not published in English

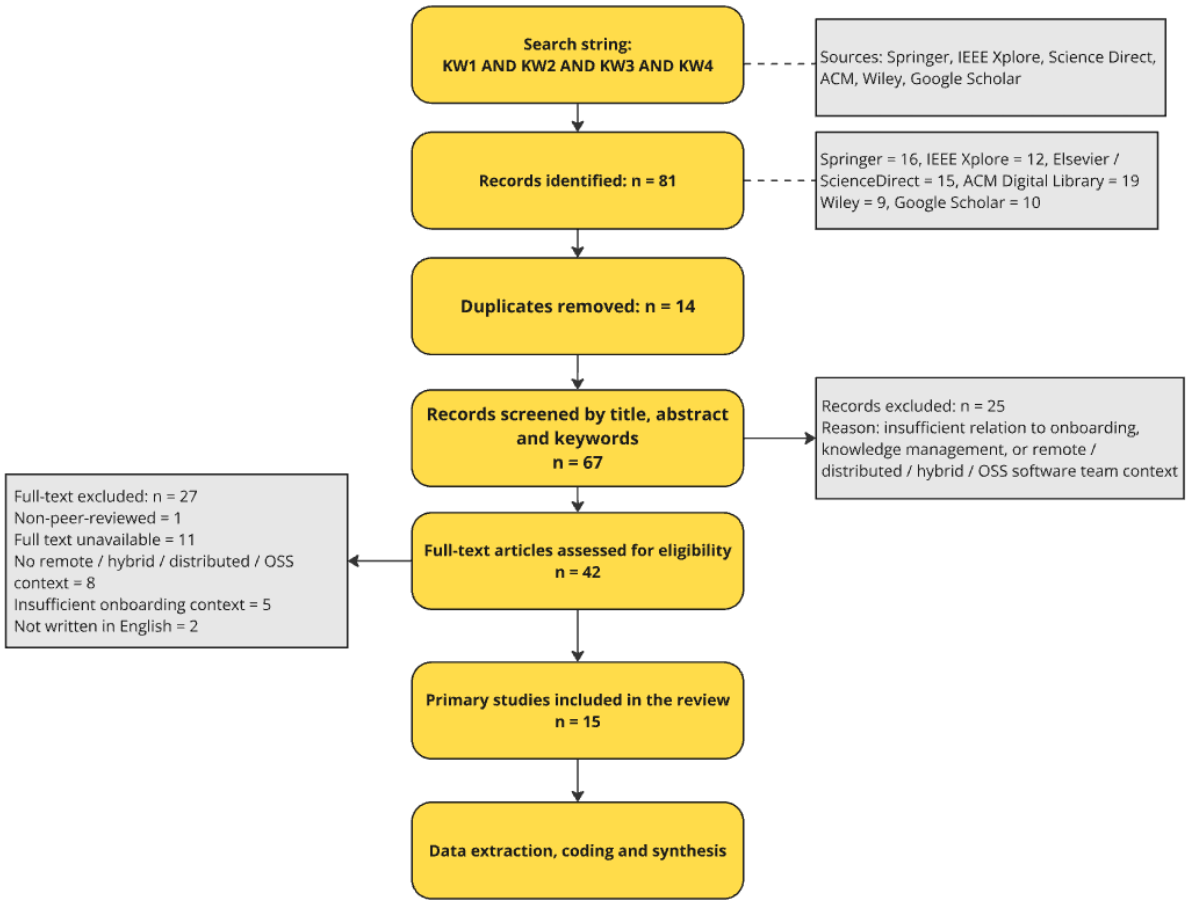


Figure 1: Figure 1: Flow of the structured literature review process

The application of the described procedures resulted in the following flow: 81 papers were identified from six sources for the period from 2019-2025. From Springer 16 papers, from IEEE Xplore 12 papers, Elsevier 15 papers, ACM 19 papers, Wiley 9 papers and Google Scholar 10 papers. By removing 14 duplicates (E2), 67 papers remained that had to go through the screening process for title, abstract and keyword. At this stage, 25 papers were excluded due to the insufficient context of onboarding and knowledge management in the context of remote work (E4), and 42 papers went into the process of detailed analysis of the entire text.

After reading the entire text, 1 paper was additionally excluded because it was not peer reviewed (E1), 11 papers due to insufficient access (E3), 8 papers did not contain a remote, hybrid or OSS context (E4), 5 papers did not contain a good onboarding context (E4), 2 papers were not in English (E5). Based on the full analysis, 15 papers were selected as primary studies (PS) that met all criteria and are listed in Table 1.

Table 1: Primary studies included in the review

Primary studies	References	Year
PS1	Britto, R., Smite, D., Damm, L. O., & Börstler, J. (2020). Evaluating and strategizing the onboarding of software developers in large-scale globally distributed projects. Journal of Systems and Software, 169, 110699.	2020
PS2	Moe, N. B., Stray, V., & Goplen, M. R. (2020). Studying onboarding in distributed software teams: a case study and guidelines. In Proceedings of the 24th International Conference on Evaluation and Assessment in Software Engineering (pp. 150-159).	2020
PS3	Rodeghero, P., Zimmermann, T., Houck, B., & Ford, D. (2021). Please turn your cameras on: Remote onboarding of software developers during a pandemic. In 2021 IEEE/ACM 43rd International Conference on Software Engineering: Software Engineering in Practice (ICSE-SEIP) (pp. 41-50). IEEE.	2021
PS4	Enberg, T., Alander, S., & Paasivaara, M. (2024). Onboarding for an agile software development company. In International Conference on Agile Software Development (pp. 144-162). Cham: Springer Nature Switzerland.	2024
PS5	Turzo, A. K., Sultana, S., & Bosu, A. (2025). From First Patch to Long-Term Contributor: Evaluating Onboarding Recommendations for OSS Newcomers. IEEE Transactions on Software Engineering.	2025
PS6	Akdur, G., Aydin, M. N., & Akdur, G. (2024). Understanding virtual onboarding dynamics and developer turnover intention in the era of pandemic. Journal of Systems and Software, 216, 112136.	2024
PS7	Smite, D., & Moe, N. B. (2023). The role of responsiveness to change in large onboarding campaigns. In International conference on agile software development (pp. 132-148). Cham: Springer Nature Switzerland.	2023
PS8	Tobisch, F., Schmidt, J., & Matthes, F. (2024). Investigating communities of practice in large-scale agile software development: an interview study. In International Conference on Agile Software Development (pp. 3-19). Cham: Springer Nature Switzerland.	2024
PS9	Perpétua, S. P., Peternelli, M. D. O., Portela, C. D. S., & Souza, M. R. D. A. (2024). Exploring the Practitioners Perspective on Remote Onboarding in Software Development Organizations. In Proceedings of the XXIII Brazilian Symposium on Software Quality (pp. 275-285).	2024
PS10	Subramanian, V. N. (2020). An empirical study of the first contributions of developers to open source projects on GitHub. In Proceedings of the ACM/IEEE 42nd International Conference on Software Engineering: Companion Proceedings (pp. 116-118).	2020
PS11	Rehman, I., Wang, D., Kula, R. G., Ishio, T., & Matsumoto, K. (2022). Newcomer oss-candidates: Characterizing contributions of novice developers to github. Empirical Software Engineering, 27(5), 109.	2022
PS12	Fronchetti, F., Shepherd, D. C., Wiese, I., Treude, C., Gerosa, M. A., & Steinmacher, I. (2023). Do contributing files provide information about oss newcomers' onboarding barriers?. In Proceedings of the 31st ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering (pp. 16-28).	2023
PS13	Santos, F., Trinkenreich, B., Pimentel, J. F., Wiese, I., Steinmacher, I., Sarma, A., & Gerosa, M. A. (2022). How to choose a task? mismatches in perspectives of newcomers and existing contributors. In Proceedings of the 16th ACM/IEEE International Symposium on Empirical Software Engineering and Measurement (pp. 114-124).	2022
PS14	Xiao, W., He, H., Xu, W., Tan, X., Dong, J., & Zhou, M. (2022). Recommending good first issues in github oss projects. In Proceedings of the 44th international conference on software engineering (pp. 1830-1842).	2022
PS15	Alderliesten, J. W. D., & Zaidman, A. (2021). An initial exploration of the "good first issue" label for newcomer developers. In 2021 IEEE/ACM 13th International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE) (pp. 117-118). IEEE.	2021

RESULTS

This study considers the onboarding process in remote, distributed and hybrid software teams as a KM mechanism, social mechanisms and initial tasks that serve to enter this process. This section presents a descriptive mapping of the 15 primary studies through three views: (1) annual distribution of papers; (2) coverage of key knowledge management practices across team contexts; and (3) distribution of

research designs. The results are based on the structured search and selection process described in the Methodology section and on the primary studies shown in Table 1. Figure 2 shows the distribution of primary studies in the period 2019-2025.

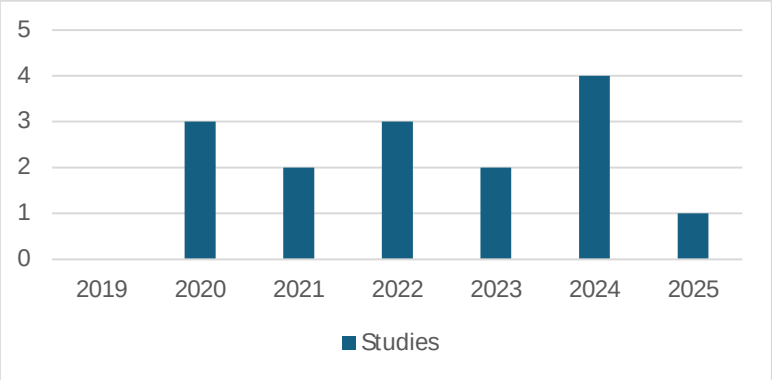


Figure 2: Annual distribution of included primary studies (2019–2025)

Figure 2 shows an increase in publications after 2020, which indicates growing attention to onboarding in remote and distributed software work. Figure 3 maps how often KM practices are identified in onboarding processes and by team context where they are all present (remote, distributed, hybrid, OSS).

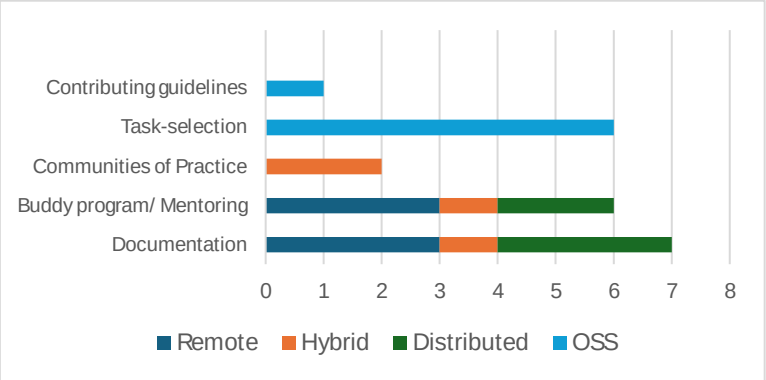


Figure 3: Coverage of KM practices across team contexts

Documentation, handbooks, mentoring, and buddy programs appear most frequently in the reviewed studies, particularly in remote and distributed settings, which is typical when it comes to remote environments. Communities of Practice (CoP) are mostly expressed when it comes to larger organizations, while curation is particularly visible in the context of OSS.

Regarding research design, case studies and mixed-method studies dominate the corpus, while interviews, surveys, quantitative observational studies, and design-science studies appear less frequently. This distribution reflects the context-dependent nature of onboarding research but also indicates a need for more evaluative and metric-oriented studies on onboarding outcomes.

LIMITATIONS

In accordance with the recommendations for Literature Review in Software Engineering (Zhou et al., 2016), the authors recognize threats to validity related to: (1) Search string construction and database selection; (2) Assessment of the quality of selected works and construction of inclusion and exclusion criteria; (3) Limited access to certain works that are available exclusively through subscription services. Details of the planning and execution of the works are given in section 3, which ensures the transparency of the findings to the primary studies and thereby increases the reliability of the presented conclusions. External validity is consciously limited to the domain of onboarding in KM in

remote, distributed and hybrid teams. Generalization beyond this domain was not intended, but the review process itself can be applied to other areas of software engineering.

CONCLUSION

This structured literature review examined onboarding in remote, distributed, hybrid, and OSS software teams as a knowledge management process. The mapping of 15 primary studies from 2019 to 2025 suggests increasing research interest in onboarding as a KM-related process and indicates that effective onboarding practices often combine explicit artifacts, such as documentation and handbooks, with social mechanisms for tacit knowledge transfer, such as mentoring, buddy systems, and communities of practice. The findings should be interpreted as a focused mapping of recurring practices rather than as statistically generalizable evidence across all software team contexts. Future research should include dual screening and coding, broader multilingual search, and a more explicit quality assessment procedure adapted to different study types.

REFERENCES

Ford, D., Storey, M. A., Zimmermann, T., Bird, C., Jaffe, S., Maddila, C., ... & Nagappan, N. (2021). A tale of two cities: Software developers working from home during the covid-19 pandemic. ACM Transactions on Software Engineering and Methodology (TOSEM), 31(2), 1-37.

Bjørnson, F. O., & Dingsøyr, T. (2008). Knowledge management in software engineering: A systematic review of studied concepts, findings and research methods used. Information and software technology, 50(11), 1055-1068.

Bauer, T. N., & Erdogan, B. (2011). Organizational socialization: The effective onboarding of new employees.

Saks, A. M., Uggerslev, K. L., & Fassina, N. E. (2007). Socialization tactics and newcomer adjustment: A meta-analytic review and test of a model. Journal of vocational behavior, 70(3), 413-446.

Britto, R., Cruzes, D. S., Smite, D., & Sablis, A. (2018). Onboarding software developers and teams in three globally distributed legacy projects: A multi-case study. Journal of Software: Evolution and Process, 30(4), e1921.

Sharma, G. G., & Stol, K. J. (2020). Exploring onboarding success, organizational fit, and turnover intention of software professionals. Journal of Systems and Software, 159, 110442.

Steinmacher, I., Silva, M. A. G., Gerosa, M. A., & Redmiles, D. F. (2015). A systematic literature review on the barriers faced by newcomers to open source software projects. Information and Software Technology, 59, 67-85.

Alderliesten, J. W. D., & Zaidman, A. (2021). An initial exploration of the "good first issue" label for newcomer developers. In 2021 IEEE/ACM 13th International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE) (pp. 117-118). IEEE.

Xiao, W., He, H., Xu, W., Tan, X., Dong, J., & Zhou, M. (2022). Recommending good first issues in github oss projects. In Proceedings of the 44th international conference on software engineering (pp. 1830-1842).

Britto, R., Smite, D., Damm, L. O., & Börstler, J. (2020). Evaluating and strategizing the onboarding of software developers in large-scale globally distributed projects. Journal of Systems and Software, 169, 110699.

Rodeghero, P., Zimmermann, T., Houck, B., & Ford, D. (2021, May). Please turn your cameras on: Remote onboarding of software developers during a pandemic. In 2021 IEEE/ACM 43rd International Conference on Software Engineering: Software Engineering in Practice (ICSE-SEIP) (pp. 41-50). IEEE.

Zahedi, M., Shahin, M., & Babar, M. A. (2016). A systematic review of knowledge sharing challenges and practices in global software development. International Journal of Information Management, 36(6), 995-1019.

Sarka, P., & Ipsen, C. (2017). Knowledge sharing via social media in software development: a systematic literature review. Knowledge Management Research & Practice, 15(4), 594-609.

Yanzer Cabral, A. R., Ribeiro, M. B., & Noll, R. P. (2014). Knowledge management in agile software projects: A systematic review. Journal of Information & Knowledge Management, 13(01), 1450010.

Kitchenham, B., Brereton, O. P., Budgen, D., Turner, M., Bailey, J., & Linkman, S. (2009). Systematic literature reviews in software engineering–a systematic literature review. Information and software technology, 51(1), 7-15.

Zhou, X., Jin, Y., Zhang, H., Li, S., & Huang, X. (2016). A map of threats to validity of systematic literature reviews in software engineering. In 2016 23rd Asia-Pacific Software Engineering Conference (APSEC) (pp. 153-160). IEEE.

MANAGING DIGITAL COMPETENCIES TO IMPROVE THE QUALITY OF INFORMATICS TEACHING IN PRIMARY SCHOOLS

DOI: 10.5937/EMC26321V

Ana-Marija Vukić
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
E-mail: anamvukic@gmail.com
Biljana Radulovic
University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia
Dragana Sajfert
ITS Information Tehnology School, Zemun - Belgrade, Republic of Serbia

ABSTRACT

The development of digital society has changed the role of teachers and increased the importance of digital competencies in primary education. This paper examines how primary school teachers use digital technologies in teaching practice, administrative work, cooperation with colleagues, and communication with parents. The study is conceptually based on selected areas of the DigCompEdu framework, especially professional engagement, digital resources, teaching and learning, assessment, and empowering learners. Data were collected through an online questionnaire completed by 88 primary school teachers from Belgrade. The research has a descriptive character and focuses on the frequency and purpose of technology use in educational practice. The results show that most teachers regularly use digital technologies in teaching activities. Digital tools are most often used for assigning student tasks, preparing and delivering learning content, motivating students to develop digital competencies, and supporting assessment. The findings also show that teachers use digital tools for cooperation with colleagues and communication with parents, although traditional communication channels remain important. The paper concludes that digital competencies represent an important condition for improving informatics teaching practice, but further research with a larger sample and more detailed statistical procedures is needed to examine deeper relationships between teacher competencies, teaching quality, and student learning outcomes.

Keywords: digital competencies; teachers; primary education; informatics teaching; digital technologies

INTRODUCTION

Teachers must possess a high level of digital competence, meaning they are able to effectively use digital tools and technologies in their teaching practice. Digital competencies include digital literacy, experience in using educational software and platforms, and the ability to seamlessly integrate information and communication technologies (ICT) into the organization of educational activities.

Primary school teachers should also have pedagogical digital competencies, which involve the integration of digital tools into pedagogical practice and training students to use technology for learning (Starkey, 2019). The most common practice for digital integration is the use of digital storytelling, which has been shown to improve language development, creativity, and digital literacy (Hwang et al., 2023).

This study uses the European Framework for the Digital Competence of Educators, DigCompEdu, as a conceptual basis for examining teachers' use of digital technologies in primary school practice. The paper does not aim to validate the full DigCompEdu framework. Instead, selected areas of the framework are used to structure the research focus and interpret teachers' reported practices. These areas include the use of digital tools in teaching, assessment, collaboration with colleagues, communication with parents, and support for student learning. In this way, the study provides descriptive insight into how teachers apply digital technologies in everyday educational activities and how these practices may contribute to the quality of informatics teaching in primary schools.

LITERATURE REVIEW

Contemporary society requires teachers with digital competencies in order to effectively apply digital technologies in the teaching and learning process (Reisoğlu & Çebi, 2020). Digital technologies have the potential to improve learning outcomes and encourage new teaching strategies that support the development of students' critical skills. However, there is still a lack of consensus regarding the appropriate age and approach for introducing digital technology concepts in primary schools (Springer et al., 2022).Key stakeholders are informatics teachers and their teaching competencies. The rapid development of information technologies presents significant challenges for teachers in terms of their professional training and appropriate curricula (Urem, Ban & Jureković, 2018).

Possessing a high level of digital competence enables teachers to use digital tools and resources to improve their teaching practices. They can create interactive and engaging learning materials, access various online educational resources, and facilitate collaborative learning through digital platforms. The use of digital technologies not only increases student engagement but also promotes critical thinking, creativity, and problem-solving skills.

The reviewed literature shows that teachers' digital competencies cannot be observed only through technical skills. They also include the ability to select appropriate digital tools, adapt them to students' needs, use them for assessment and feedback, and communicate effectively in a digital environment. For this reason, the DigCompEdu framework is useful for organizing research on teachers' digital practices. In the context of this paper, the framework supports the classification of questionnaire items into several practical areas: teaching activities, student assessment, cooperation with colleagues, administrative work, and communication with parents. This approach allows the research to remain focused on observable teaching practices, while avoiding claims that go beyond the descriptive nature of the collected data.

METHODOLOGICAL CONCEPT OF THE STUDY

The study examines how primary school teachers use digital technologies in their professional practice, with special attention to informatics teaching and related educational activities. The research was conducted as a descriptive survey study. Data were collected through an online questionnaire completed by 88 primary school teachers from Belgrade. The questionnaire was designed to identify the frequency, purpose, and areas of digital technology use in teaching, assessment, cooperation with colleagues, administrative work, and communication with parents. The study does not test causal relationships. Instead, it provides an overview of teachers' reported digital practices and discusses their relevance for improving the quality of informatics teaching in primary schools.

Research Problem and Subject

The research problem refers to the need to better understand how teachers use digital technologies in primary school teaching practice and how these practices are connected with the development of students' digital competencies. Although digital technologies are increasingly present in schools, their educational value depends on teachers' ability to integrate them into teaching, assessment, communication, and student support. Therefore, the subject of this research is the use of digital competencies and digital technologies by primary school teachers in everyday educational practice. The study focuses on teachers' reported activities, including the use of digital tools for learning content, student tasks, assessment, cooperation with colleagues, and communication with parents.

Research Objectives

The main objective of the study is to examine how primary school teachers use digital technologies in teaching and related professional activities. More specifically, the research aims to identify how often teachers use digital technologies, for which teaching purposes they use them, which digital tools they apply in cooperation with colleagues, and which communication channels they use with parents. The study also aims to discuss how these practices relate to the development of teachers' digital competencies and the improvement of informatics teaching quality. Since the research is based on descriptive survey data, the objective is not to prove causal effects, but to provide a clearer empirical overview of current digital practices among the surveyed teachers.

Expected Results and Hypotheses

Based on the research objective and the descriptive character of the study, the following research questions were formulated:

RQ1: How frequently do primary school teachers use digital technologies in teaching activities?
RQ2: For which purposes do teachers most often use digital technologies in teaching practice?
RQ3: Which digital tools do teachers use for cooperation with other teachers and administrative activities?
RQ4: Which communication channels do teachers use when communicating with parents?

In addition to these research questions, one general hypothesis was formulated:

H1: Primary school teachers use digital technologies in several areas of professional practice, including teaching activities, assessment, cooperation with colleagues, and communication with parents.

This formulation is aligned with the descriptive nature of the empirical analysis. The hypothesis is examined through frequency distributions and percentage shares obtained from the questionnaire responses.

Research Methods

The research was conducted using the survey method. Data were collected through an online questionnaire created for the purposes of this study. The questionnaire included items related to demographic characteristics, work experience, subject area, frequency of using digital technologies, purposes of using digital technologies in teaching, tools used for cooperation with other teachers, and communication channels used with parents. The questionnaire structure was conceptually informed by selected elements of the DigCompEdu framework. The area of professional engagement was reflected in items related to cooperation with colleagues and communication with parents. The area of digital resources and teaching was reflected in items related to the use of digital technologies for preparing and delivering learning content. The area of assessment was reflected in items related to the use of technologies for evaluating students' knowledge and skills, providing feedback, and monitoring progress. The area of empowering learners was reflected in items related to motivating students, supporting personalized learning, and encouraging the development of students' digital competencies. Since the study presents descriptive survey findings, data analysis was based on frequencies and percentages. The results are presented through figures and short interpretative comments. No causal analysis was conducted, and the findings should therefore be interpreted as indicators of teachers' reported practices rather than as evidence of direct effects between variables.

It should be noted that the study has several methodological limitations. The sample includes 88 teachers from Belgrade, which limits the possibility of generalizing the results to all primary school teachers. The data are based on teachers' self-reported answers, which may include subjective assessment and socially desirable responses. In addition, the study uses descriptive statistical analysis, so the findings should be interpreted as an overview of current practices rather than as proof of causal relationships. These limitations are important for understanding the analytical reach of the study and for defining directions for further research.

RESEARCH RESULTS AND DISCUSSION

This section presents descriptive results obtained from the questionnaire. The results are organized according to the main research questions and show the structure of respondents, their work experience, subject areas, frequency of using digital technologies, purposes of technology use in teaching, tools used for cooperation with colleagues, and communication channels with parents. The interpretation is limited to the observed frequency distributions and percentage shares. Therefore, the discussion focuses on identifying dominant patterns in teachers' reported digital practices.

The sample was predominantly composed of female teachers, who accounted for 75% of the respondents (66 teachers), while male teachers represented 25% of the sample (22 respondents). Respondents represented a relatively balanced distribution across different levels of professional experience. The largest group consisted of teachers with 21–30 years of experience (27.27%, 24 respondents), followed by those with 0–5 years (25%, 22 respondents) and 11–20 years of experience (23.86%, 21 respondents). Teachers with 6–10 years of experience accounted for 13.64% (12 respondents), while those with more than 30 years of professional experience represented the smallest group (10.23%, 9 respondents).

As shown in Figure 1, the sample was dominated by teachers of informatics, information technology, and mathematics, who accounted for 52.27% of respondents (46 teachers). Teachers of humanities represented 18.18% of the sample (16 respondents), followed by primary school teachers of other subjects with 15.91% (14 respondents). Teachers of natural sciences accounted for 11.36% (10 respondents), while art teachers represented the smallest group, comprising 2.27% of respondents (2 teachers).

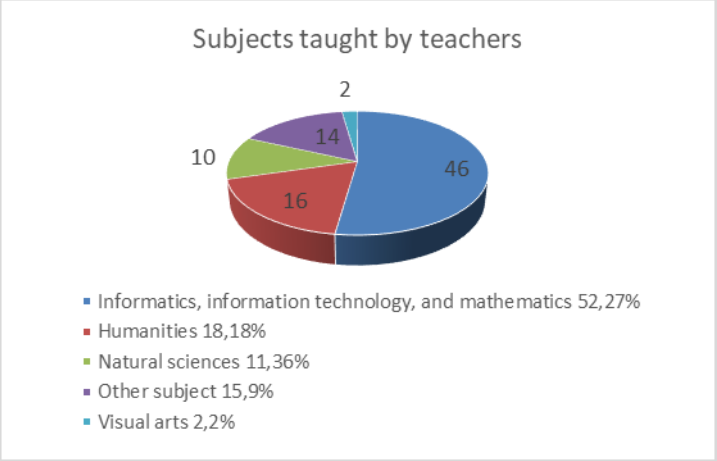


Figure 1: Subjects taught by teachers

Figure 2 shows the frequency of digital technology use in teaching activities. Respondents who always use digital technologies represent the largest share (54.55%, 48 teachers), followed by those who often use them (39.77%, 35 teachers). Only 2 teachers reported that they never use digital technologies (2.27%), while 3 respondents indicated that they rarely use them (3.41%).

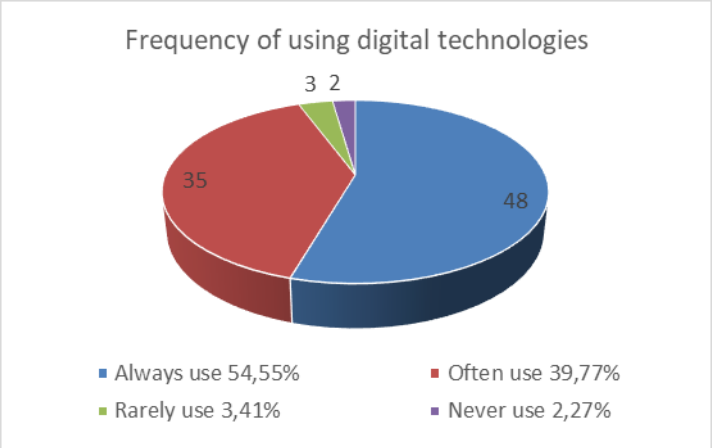


Figure 2: Frequency of using digital technologies

The largest share of teachers use digital technologies by assigning tasks that require students to apply information technologies (46.59%, 41 respondents), as shown in Figure 5. The development of students' digital competencies represents the second most common purpose of technology use (28.41%, 25 respondents). For 12.50% of teachers (11 respondents), digital technologies are primarily used for assessing students' knowledge and skills. Less frequently reported purposes include providing effective feedback (4.55%, 4 respondents), monitoring student progress (4.55%, 4 respondents), and enabling personalized learning (3.41%, 3 respondents).

The results presented in Figure 3 show that teachers most often use digital technologies for activities directly connected with teaching and student tasks. This indicates that digital tools are primarily understood as practical support for learning content delivery and student engagement. A smaller share of teachers reported using technologies for feedback, monitoring progress, and personalized learning. This finding suggests that digital technologies are still used more often for basic instructional support than for more advanced pedagogical functions. From the perspective of the DigCompEdu framework, this may indicate that further professional development should focus not only on the use of digital tools, but also on their application in assessment, feedback, student progress monitoring, and individualized support.

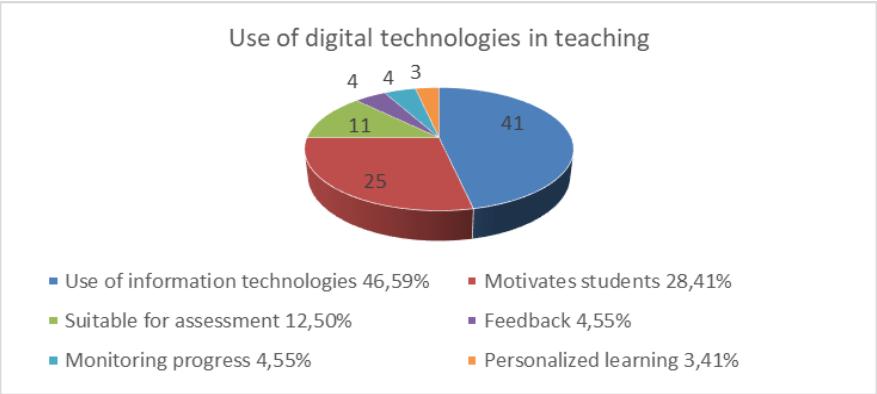


Figure 3: Purpose of using digital technologies in teaching activities

Figure 4 shows that online collaboration platforms that enable teachers to work on shared documents and access them from different devices and locations are the most frequently used digital tools, reported by 46.59% of respondents (41 teachers). Electronic calendars are used by 23.86% of teachers (21 respondents), primarily to facilitate the synchronization of administrative and teaching activities. Project management tools are utilized by 17.05% of respondents (15 teachers), indicating a moderate level of adoption for planning and coordinating tasks. Only 11.50% of teachers (11 respondents) reported not using modern digital technologies in their daily professional activities.

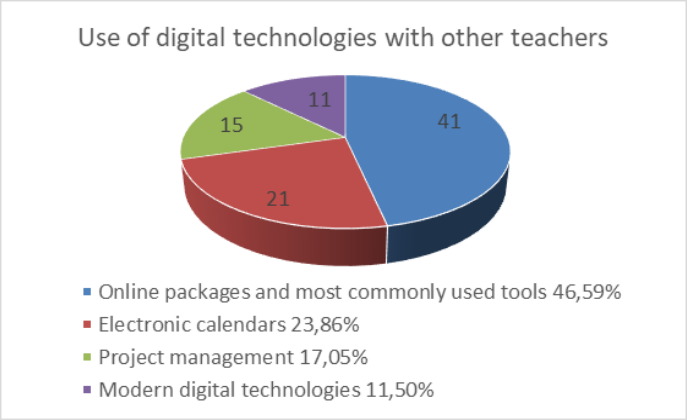


Figure 4: Digital tools used by teachers for collaboration with other teachers

The results related to cooperation with other teachers show that online packages and shared digital documents are the most frequently used tools. This finding indicates that digital technologies support professional engagement and cooperation among teachers, especially in activities that require joint preparation, document exchange, and access to teaching materials from different devices. However, the lower use of project management tools suggests that more structured forms of digital collaboration are less developed. This result points to the need for additional training focused on the use of digital tools for planning, coordination, and teamwork in school practice. The results show that the most common traditional channel of communication with parents is by phone, used by 38.63% of teachers (34 teachers). Electronic platforms with access for parents are used by 26.14% of teachers (23 teachers), followed by e-mail correspondence (12.50%), used by 11 teachers. Only a small number of teachers have the necessary skills to maintain their own websites (9.09%, 8 teachers) and blogs (6.82%, 6 teachers) for communication and information sharing with parents. Instant messaging applications (chat) are used as a preferred communication channel by 6.82% of teachers (6 teachers). The results show that communication with parents still relies strongly on traditional channels, especially telephone communication. At the same time, the use of electronic platforms and e-mail indicates that digital communication is becoming part of everyday school practice. The relatively limited use of websites, blogs, and instant messaging applications suggests that teachers may need additional support in developing more diverse and systematic forms of digital communication with parents. These findings are important because communication with parents is part of teachers' broader professional digital competence and can influence the transparency, continuity, and quality of educational support.

CONCLUSION

The results of this study show that digital technologies are present in the everyday professional practice of the surveyed primary school teachers. Most respondents reported that they always or often use digital

technologies in teaching activities. This confirms that digital tools have become an important part of teaching practice, especially in the preparation and delivery of learning content, assigning student tasks, and encouraging students to develop digital competencies. The findings also show that teachers use digital technologies for assessment, feedback, monitoring student progress, cooperation with colleagues, and communication with parents. However, these areas are less represented than the basic use of technologies for teaching tasks and content delivery. This indicates that there is still space for improving more advanced forms of digital pedagogical practice. In particular, teachers may benefit from additional training related to digital assessment, personalized learning, systematic feedback, and structured cooperation through digital tools.

The formulated hypothesis stated that primary school teachers use digital technologies in several areas of professional practice, including teaching activities, assessment, cooperation with colleagues, and communication with parents. Based on the descriptive results, this hypothesis can be accepted. The results show that teachers use digital technologies in all observed areas, although the intensity and purpose of use differ across activities. The study contributes to a better understanding of teachers' digital practices in primary education. Its contribution is mainly descriptive, since it presents empirical insight into the ways teachers use digital technologies in school practice. The findings should not be interpreted as evidence of causal relationships between digital competencies and teaching quality. Instead, they point to areas in which teachers already apply digital tools and areas in which further professional development is needed. The main limitations of the research are related to the sample size, the focus on teachers from Belgrade, and the use of self-reported questionnaire data. Future research should include a larger and more diverse sample of teachers from different regions. It should also include more detailed statistical procedures and, where possible, combine survey data with classroom observation or interviews. Such an approach would allow a deeper understanding of how teachers' digital competencies influence the quality of informatics teaching and students' digital learning outcomes.

Recommendations for Further Research

Future research should include a larger number of respondents from different schools, cities, and regions in order to provide a broader view of teachers' digital competencies in primary education. Further studies should also examine barriers that limit the more advanced use of digital technologies, especially in the areas of assessment, personalized learning, feedback, and cooperation with parents. In addition, future research should apply more detailed statistical analyses and include instruments that can more directly measure the dimensions of the DigCompEdu framework. This would make it possible to examine relationships between different areas of teachers' digital competence and the quality of informatics teaching in a more precise way.

REFERENCE

Hwang, G.-J., Zou, D., & Wu, Y.-X. (2023). Correction to: Learning by storytelling and critiquing: A peer assessment-enhanced digital storytelling approach to promoting young students' information literacy, self-efficacy, and critical thinking awareness. *Educational Technology Research and Development, 71*, 1079–1103. https://doi.org/10.1007/s11423-023-10204-5

Reisoğlu, İ., & Çebi, A. (2020). How can the digital competences of pre-service teachers be developed? Examining a case study through the lens of DigComp and DigCompEdu. *Computers & Education, 156*, 103940. https://doi.org/10.1016/j.compedu.2020.103940

Starkey, L. (2019). A review of research exploring teacher preparation for the digital age. *Cambridge Journal of Education, 50*(1), 37–56. https://doi.org/10.1080/0305764X.2019.1625867

Stringer, L. R., Lee, K. M., Sturm, S., & Giacaman, N. (2022). A systematic review of primary school teachers' experiences with digital technologies curricula. *Education and Information Technologies, 27*(9), 12585–12607. https://doi.org/10.1007/s10639-022-11127-z

Urem Frane, B., Ban, E., & Jureković, D. (2018). Enhancing digital competence of Croatian teachers of informatics – Oracle Academy use case. In *Proceedings of the 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO 2018)*. https://doi.org/10.23919/MIPRO.2018.8400114

Author Index

A

Afshari, Ali Reza, Islamic Azad University, Department of Construction Management, Shirvan Branch, Shirvan, Iran 113, 262

Alsharif, Abdulghder, University of Belgrade, Faculty of Mechanical Engineering Belgrade, Republic of Serbia 99

Akiner, İlknur, Akdeniz University, Faculty of Architecture, Department of Architecture, Antalya, Türkiye 56

Akiner, Muhammed Ernur, Akdeniz University, Vocational School of Technical Sciences, Department of Environmental Protection Technologies, Antalya, Turkey 49

Akiner, Nurdan, Akdeniz University, Faculty of Communication, Department of Radio-Television & Cinema, Antalya, Türkiye 171

Amižić, Vuk, University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 285, 315

Andrašić, Jelena, University of Novi Sad, Faculty of Economics, Subotica, Republic of Serbia 267

Anisseh, Mohammad, Imam Khomeini International University, Department of Industrial Management, Qazvin, Iran 229, 315

B

Bakator, Mihalj, University of Novi Sad, Technical Faculty “Mihajlo Pupin” in Zrenjanin, Republic of Serbia 3, 197

Berković, Ivana, University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 309

Bjelajac, Dajana, Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia 77

Bogdanov, Milica, University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 120, 126

Bubalo Živković, Milka, Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia 77

Bugarski, Marija, University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 179

Bulajić, Borko, University of Novi Sad, Faculty of technical sciences, Novi Sad, Republic of Serbia 83

C, Ć, Č

Cvjetković, Milovan, Higher educational institution "Economics Academy", Brčko District, Bosnia and Herzegovina 138

Ćoćkalo, Dragan, University of Novi Sad, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 3, 113

Ćoćkalo-Hronjec, Melita, High school "Laza Kostić", Novi Sad, Republic of Serbia 138

Čepić, Zoran, University of Novi Sad, Faculty of Technical Sciences, Republic of Serbia 10

Čomić, Brankica, University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina 132

D, Đ

Denčić, Ivana, University of Novi Sad, Technical Faculty “Mihajlo Pupin” in Zrenjanin, Republic of Serbia 16, 275

Desnica, Eleonora, University of Novi Sad, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 83

Dimovski, Stefan, Ministry of Defense, Skopje, Republic of North Macedonia 28

Djokic, Ines, University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia 185

Djokic, Nenad, University of Novi Sad, Faculty of Economics in Subotica, Republic of Serbia 185, 241

Dubinkina, Ulyana, Voronezh State University, Voronezh, Russian Federation 22

Dukić Mijatović, Marijana, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Republic of Serbia 236

Dunić, Mirjana, Technical Faculty "Mihajlo Pupin", University of Novi Sad, Zrenjanin, Republic of Serbia 157

Đurđev, Mića, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 106

Đurić, Dragana, Higher School of Business Studies, Novi Sad, Republic of Serbia 157

G

Gluvakov, Verica, University of Novi Sad, Technical faculty „Mihajlo Pupin", Zrenjanin, Republic of Serbia 3, 106

Grubišić, Igor, Harvard University, Faculty of Arts and Sciences, Cambridge, Massachusetts, USA 16

Guteša, Aneta, University of Ljubljana, Faculty of Arts, Ljubljana, Slovenia 126, 191

I

Inđić, Milica, University of Novi Sad, Faculty of Economics, Republic of Serbia 267

Ivanišević, Andrea, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Republic of Serbia 236

J

Jerković, Nikola, University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia 144

Jokanović Đajić, Mirjana, University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina 132

Jovanić, Dušan, Technical College of Applied Sciences, Zrenjanin, Republic of Serbia 65, 71

K

Kalaš, Branimir, University of Novi Sad, Faculty of Economics, Subotica, Republic of Serbia 185, 241

Kavalić, Mila, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 3, 106

Kazi, Ljubica, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 291, 297

Kepenek, Büşra Selin, Akdeniz University, Institute of Natural and Applied Sciences, Department of Architecture, Antalya, Türkiye 56

Kihler, Marko, Union University Law School, Belgrade, Republic of Serbia 163

Kovač, Dragana, University of Novi Sad, Technical faculty „Mihajlo Pupin", Zrenjanin, Republic of Serbia 138

Krivokuća, Mila, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 245, 251

Kupusinac, Aleksandar, University of Novi Sad, Faculty of Technical Sciences; Novi Sad, Republic of Serbia 281

L, Lj

Lakatuš, Peko, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 197, 202

Lejić, Veselinka, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 309

Ljubojev, Nadežda, University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia 144

Lukić, Tamara, Faculty of Sciences, University of Novi Sad, Novi Sad, Republic of Serbia 77

M

Malešev, Ljubiša, University of Novi Sad, Technical faculty "Mihajlo Pupin" Zrenjanin, Republic of Serbia 144

Maleva, Irina, Voronezh State University, Voronezh, Russian Federation 22

Marcikić Horvat, Aleksandra, University of Novi Sad, Faculty of Economics Subotica, Republic of Serbia 236

Marić, Dubravko, College of Sports and Health, Belgrade, Republic of Serbia 262

Marković, Vladimir, University of Novi Sad, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 257

Milicevic, Nikola, University of Novi Sad, Faculty of Economics, Subotica, Republic of Serbia 185

Milić, Tamara, University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Republic of Serbia 285, 315

Milošev, Vladimir, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 262

Miljanović, Mirjana, University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina 132

Mihajlović, Marija, Ministry of Construction, Transport and Infrastructure, Belgrade, Republic of Serbia 208, 214

Mitrašević, Mirela, University of East Sarajevo, Faculty of Business Economics Bijeljina, Bosnia and Herzegovina 267

Mladenović, Valentina, Technical College of Applied Sciences, Zrenjanin, Republic of Serbia 65, 71

Momčilović, Oliver, University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Republic of Serbia 87

N

Nikitina, Larisa, Voronezh State University, Department of Economics and Organization Management, Voronezh, Russian Federation 22

Nikolić, Milan, University of Novi Sad, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 3,

Nikolić, Natalija, University of Novi Sad, Faculty of Sciences, Novi Sad, Republic of Serbia 77

P

Palinkaš, Ivan, University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Republic of Serbia 83

Pap, Leontina, University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Republic of Serbia 151

Pavlović, Marko, Academy of Applied Studies – Polytechnic, Belgrade, Republic of Serbia 157

Pekez, Jasmina, University of Novi Sad, Technical faculty „Mihajlo Pupin“, Zrenjanin, Republic of Serbia 83, 144

Perišić Jokić, Martina, University of Belgrade, Faculty of Mechanical Engineering Belgrade, Republic of Serbia 99

Petrović, Julka, Public Utility Company "Novosadska toplana", Novi Sad, Republic of Serbia 10

Perić, Marija, Academy of Applied Studies – Polytechnic, Belgrade, Republic of Serbia 157

Pjanić, Miloš, University of Novi Sad, Faculty of Economics, Subotica, Republic of Serbia 267

Poštin, Jasmina, University Union “Nikola Tesla” Faculty of management, Sremski Karlovci, Republic of Serbia 120, 126

Pajin, Biljana, University of Novi Sad, Faculty of Technology, Novi Sad, Republic of Serbia 236

R

Radosavac, Adriana, University Business Academy in Novi Sad, Faculty of Applied Management, Economics and Finance, Belgrade, Republic of Serbia 87

Radovanović, Ljiljana, University of Novi Sad, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 83

Radu, Branislava, University of Novi Sad, Technical Faculty “Mihajlo Pupin“, Zrenjanin, Republic of Serbia 291, 297

Radulović, Biljana, University of Novi Sad, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia 285, 321

Ravlić, Sanela, University of Slavonski Brod, Department of Social Sciences and Humanities, Slavonski Brod, Republic of Croatia 28

S, Š

Sajed, Rohullah, Takhar University, Faculty of Economics, Department of Management and Business Administration, Takhar, Afghanistan 229

Sajfert, Dragana, ITS Information Tehnology School, Zemun-Belgrade, Republic of Serbia 163, 321

Savić, Iva, University of Belgrade, Faculty of Mechanical Engineering Belgrade, Republic of Serbia 99

Sedlak, Otilija, University of Novi Sad, Faculty of Economics Subotica, Republic of Serbia 236

Simić, Miodrag, Institute of Social Sciences, Belgrade, Republic of Serbia 157

Slavić, Jelena, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 303

Spaić, Obrad, University of East Sarajevo, Faculty of Production and Management, Bosnia and Herzegovina 132

Spasojević Brkić, Vesna, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Republic of Serbia 99

Stanisavljev, Sanja, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 3, 106

Stanojeska, Marija, UACS, School of Computer Science and Information Technology, Skopje, Republic of North Macedonia 28

Stojanov, Željko, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 303

Stošić Mihajlović, Ljiljana, Academy of Applied Technical and Preschool Studies, Niš - Vranje Department, Republic of Serbia 208, 214

Szabó, László, Budapest University of Economics and Business, Faculty of Marketing and Business Communication, Budapest, Hungary 94

Šarenac, Uroš, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 202

T

Terek Stojanović, Edit, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 3, 106

Tihi, Ninoslava, Academy of Applied Studies, Novi Sad, Republic of Serbia 315

Todorovic, Jun, Purdue University Fort Wayne, The United States 41

Todorovic, Zelimir, Purdue University Fort Wayne, The United States 41

Tomić, Branislav, Bombardier Aerospace, Canada 99

U

Ugrinov, Stefan, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 3, 106

V

Vasić, Ivana, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 309

Vašaš Kuručev, Dijana, University of Novi Sad, Technical Faculty "Mihajlo Pupin" in Zrenjanin, Republic of Serbia 126, 191

Vecstejn, Igor, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 285, 315

Vorkapić, Miloš, University of Belgrade, Institute of Chemistry, Technology and Metallurgy, Belgrade, Republic of Serbia 197

Vujić, Bogdana, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 83

Vukić, Ana-Marija, University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Republic of Serbia 163, 321

Z

Završnik, Bruno, University of Maribor, Faculty of Economics and Business, Slovenia 220





EMC 2026

16th International Symposium "Engineering Management and Competitiveness" 2026

ISBN 978-86-7672-396-6