THE USE OF DIGITAL PRODUCT-SERVICE SYSTEMS IN MANUFACTURING FIRMS

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Original Scientific Paper

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Digital technologies change the way how manufacturing firms create offers for customers. These new technologies transform traditional Product-Service Systems into Digital Product-Service Systems. This paper investigates the use of digital technologies for the creation of new products and smart services in manufacturing firms. Additionally, this paper investigates the service orientation in Product-Service Systems. The data for this research were collected at the end of 2021 through the ASAP Service Management Forum in the manufacturing sector of the Republic of Serbia. The empirical results indicate that more than 60% of manufacturing firms use digital technologies for the creation of new products and less than 50% for the creation of new smart services. Moreover, results indicated that most services are product-oriented with 25% of share in a sample, followed by results-oriented services with 20% of share in a sample and use-oriented services with 11% of share in the total sample

Keywords: Product-service systems; Digital servitization; Manufacturing firms; ASAP SMF.

INTRODUCTION

The technology changes that came with the appearance of the Industry 4.0 revolution completely changed the value chains of firms from the manufacturing sector (Raiher et al., 2017; Rakic et al., 2021). The application of the Industry 4.0 concepts in the manufacturing sector has primarily changed production processes, and thus everything related to them (Alheriani et al., 2021; Frank et al., 2019). Accordingly, the process of providing services in production systems is also in a period of transformation from traditional to digital (Gebauer et al., 2021; Tronvoll et al., 2020). The application of new technologies is growing rapidly with the evolution of digitalization (Bressanelli et al., 2018; Popović & Rajović, 2021). The World Economic Forum has estimated that the potential benefits of digitalization for industry and society are about $ 100 trillion by 2025. A report published by the consulting firm McKinsey states that the digitalization of the value chain is a priority for 70% of firms from the most developed countries in the world (Zivlak N. et al., 2021). In addition to financial benefits, the application of digital technologies in the industry increases their efficiency and productivity and enables business optimization through data management of production processes (Gebauer et al., 2021; Sklyar et al., 2019). Previous research indicates that technology concepts are one of the main prerequisites for the successful implementation of both product-related services and digital services (Segarra-Ciprés et al., 2012). With the development of the application of services in production systems, there has been greater use of product-service systems from firms in the manufacturing sector (Clemente et al., 2018; Paschou et al., 2020). Product-service systems provide a wide range of services for customers,

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which build more complex relationships with customers that later result in new sales contracts (Haber & Fargnoli, 2017). Advanced services deepen the relationship with customers and enable a connection with the manufacturer throughout the product life cycle (Rapaccini et al., 2013). Previous studies mentioned greater customer loyalty, cost reduction, competitive diversity, and financial benefits as the main benefits of the product-service system (Moro et al., 2020). In addition to the benefits for the firms which use product-service systems, several benefits can be expressed for customers, the environment, and society as a whole (Sjödin et al., 2020). However, despite the many advantages of product-service systems, the complexity presented in the previous part of the work brings with it several barriers, such as large initial investments, lack of knowledge for implementation, and necessary changes in the organizational structure of the firm (Moro et al., 2020). These barriers have led to the need to break down product-service systems into individual components, to facilitate implementation and better market performance (Goedkoop, 1999). In order to decompose product-service systems, it is important to mention eight types and orientations of product-service systems according to Tucker's model (see Figure 1) (Tukker, 2004):

– Product-oriented product-service systems - in this system the traditional sale of products is realized, where the customer takes ownership of the product, the supplier of product-service systems offers and charges for related services.
– Use-oriented product-service systems - in this system, the product is owned by its manufacturer, who sells or rents the product.
– Result-oriented product-service systems - in this system the manufacturer sells the result or competence instead of the product.

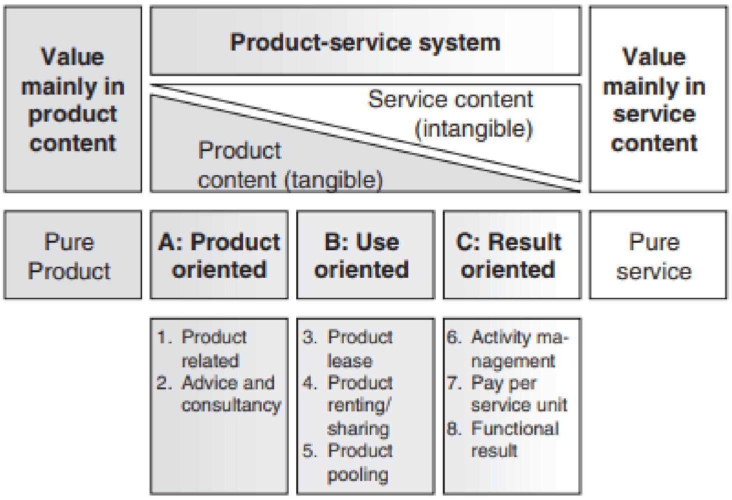

Figure 1: Transformation of Product-Service Systems (Tukker, 2004)

Following the presented literature and the division based on Tucker's model, this paper aims to show the level of application of digital product-services systems in manufacturing firms. The authors suggest the following research questions:

RQ1: What is the level of service use according to the orientation in the manufacturing firms?

RQ2: What is the level of the use of digital technologies for the creation of new products in manufacturing firms?

RQ3: What is the level of the use of digital technologies for the creation of new smart services in manufacturing firms?

The research article is structured as follows: Section 2 presents the literature review. Section 3 describes the sample, data collection, and analysis. Section 4 presents the empirical results and discussion of the research. In addition, section 5 summarizes depicts the conclusions with their limitations and suggestions for further research.

LITERATURE REVIEW

The concept of product-service systems was created on the basis of the proposal of the United Nations program for environmental protection in the late 90s of the last century (Baines & Lightfoot, 2013). The scientific community dealing with product-service systems originated mainly from Scandinavia and northern European countries in order to preserve and improve society, economic and environmental environment, as well as industrial sustainability (Baines & Lightfoot, 2013). Since then, many models and tools have been developed to help organizations more easily implement product-service systems in their firms (Clemente et al., 2018). Product-service systems are an integrated package of products and services, provided by manufacturing firms in order to achieve better results in the market (Goedkoop, 1999). Product-service systems enable manufacturing firms to create long-term relations with customers through the offers of products and services in one package (Rapaccini et al., 2013). Advanced services push the product-service systems from the creation of product-service packages to the creation of new smart solutions for customers (Marjanovic et al., 2020; West et al., 2021). Despite the great complexity of the implementation of product-service systems, a large number of firms from different industries decide to implement these systems, in order to make additional profits by selling products (Bressanelli et al., 2018). This is supported by a large number of studies from developed countries, which show the positive impact of product-service systems on the manufacturing firm performance (Frank et al., 2019; Haber & Fargnoli, 2017). Product-service systems reduce the responsibility of manufacturing firms for the customer during installation, maintenance, and disposal of products at the end of the life cycle (Sjödin et al., 2020). On the other hand, society have benefits from the product-service systems in two ways fewer natural resources are used, and new jobs are created in the field of product-service systems (Clemente et al., 2018). Accordingly, environmental benefits are reflected in renewable products as well as system life cycle planning (Haber & Fargnoli, 2017). Nevertheless, the implementation of product-service systems has a lot of internal and external barriers (Moro et al., 2020). The most distinguished internal barriers are "resistance to change by stakeholders", "difficulty in maintaining the system" and "difficulty in performing reverse logistics". The most distinguished external barriers are "resistance to established local habits", "resistance to consumption without possession" and "lower tangible value" (Moro et al., 2020). According to these barriers, manufacturing firms need to make new business models for the implementation of product-service systems which will result in lower implementation costs (Rapaccini et al., 2013). Previous studies show that digital services could be a solution for this challenge since the marginal cost of digital services is under the marginal cost of traditional services (Marjanovic et al., 2020). The marginal cost of digital services is near zero and they enable the implementation of digital product-service systems (Marjanovic et al., 2020). Science has recognized digital services as one of the main components of product-service systems in terms of innovation and digitalization of manufacturing firms (Lerch & Gotsch, 2015). Digital product services systems present digital technologies as a novel component in the creation of products and services which create intelligent and independent operating systems that deliver the highest level of availability for customers and lower initial investments for manufacturing firms (Lerch & Gotsch, 2015). In addition, it is important to note that research on the application of digital product-service systems has been done mainly in developed countries that have greater potential for their implementation (Lerch & Gotsch, 2015). In line with the lack of data from developing countries, this research examines the application of digital product-service systems in the Republic of Serbia. Previous research from developing countries has dealt with the application of traditional and digital services (Rakic, et al., 2021), or service business models, while digital product-service systems have been neglected (Zivlak et al., 2021). In accordance with the above, the main research gap is to understand the process of transformation from traditional to digital product-services systems in developing countries. Additionally, this research provides information about the creation of digital products and services.

METHODOLOGY

Data for this research were collected in the end of 2021 through the ASAP Service Management Forum in the manufacturing sector of the Republic of Serbia. This dataset is a pilot dataset of the Digital Servitization Survey, which is conducted in Italy, Germany, Sweden, Mexico Switzerland, and Serbia. The research obtained results from the 54 manufacturing firms with at least 20 employees. The full sample was provided by the Business Registers Agency of the Republic of Serbia. The research sample was obtained by Cohran's method of sampling. The sample is stratified in relation to the industrial sector and the size of the manufacturing firms. The data collection was done according to the adapted Dilman's method via e-mail. The largest industries in the sample are the

Manufacture of food products (NACE 10) with 22.2%, followed by the Manufacture of fabricated metal products, except machinery and equipment (NACE 25) with 13.9%, Manufacture of machinery and equipment n.e.c. (NACE 28) with 9.3%, and Manufacture of rubber and plastic products and Printing and reproduction of recorded media (NACE 18) with 7.4%. Table 1 depicts the sample by industry.

Table 1: Distribution of sample by industry

Manufacturing industry	Share on total sample
Manufacture of food products	22.2%
Manufacture of fabricated metal products, except machinery and equipment	13.9%
Manufacture of machinery and equipment n.e.c.	9.3%
Printing and reproduction of recorded media	7.4%
Manufacture of rubber and plastic products	7.4%
Manufacture of beverages	5.6%
Manufacture of wearing apparel	5.6%
Manufacture of electrical equipment	5.6%
Other	23%

44.4% of the firms in the sample are small(20 - 49 employees) and medium (50 - 250employees), while the other 11.1% of the firms have more than 250 employees. Table 2 shows the firm size.

Table 2: Distribution of sample by firm size

Firm size	%
20 to 49 employees	44.4
50 to 249 employees	44.4
250 and more employees	11.1

For data analysis, the descriptive statistic method was used by the authors. Data analyses are performed in the SPSS program. Tables 3, 4, and 5 perform results on the service orientation in product-service systems, and the use of digital technologies for the creation of new products and smart services. Additionally, according to the research model (see Figure 2), authors show relations between digital technologies and product-related services.

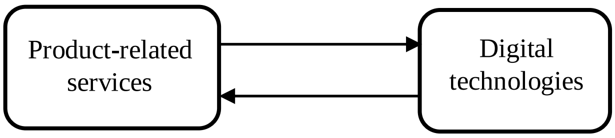

Figure 2: Research framework

The proposed research framework measures the relations between product-related services and digital technologies. The results of the correlation analysis are presented in Table 6.

RESULTS AND DISCUSSION

According to the research question "*What is the level of service use according to the orientation in the manufacturing firms?*", Table 3. shows the use of services in the manufacturing firms.

Table 3: The use of services in the manufacturing firms

Services	No offer (%)	Traditional offer (%)	Digital offer (%)
Spare parts	59.2	27.7	13.1
Repairs and Maintenance	62.9	25.9	11.2
Training and Consultancy	61.1	16.6	22.2
Leasing and Pooling	83.3	11.1	5.6
Pay-per-use and Full-Service contracts	68.5	20.4	11.1

The most often use services in the traditional offer are spare parts and repairs and maintenance which are offered by more than 25% of manufacturing firms. Pay-per-use and full-service contracts are offered approximately by 20% of manufacturing firms. In the end, services leasing and pooling are offered approximately by 11% of manufacturing firms. According to the Tucker classification, most services are product-oriented with 25% of share in a sample, followed by results-oriented services with 20% of share in a sample and use-oriented services with 11% of share in the total sample. All of them are more offered in traditional than in digital ways. Only service training is more offered in digital 22.2% than in traditional way 16.6%. According to the research question "*What is the level of the use of digital technologies for the creation of new products in the manufacturing* *firms?"* Table 4. shows the use of digital technologies for the creation of new products in the manufacturing firms.

Table 4: The use of digital technologies for the creation of new products

Statements	(%)
Strongly disagree	5.6
Disagree	7.4
Don't know	20.4
Agree	46.3
Strongly agree	20.4

66% of the manufacturing firms confirm that they use digital technologies for the creation of new products. On the other hand, 13% of manufacturing firms said that they don't use digital technologies for the creation of new products. The other 21% of manufacturing firms don't have information about the use of digital technologies for the creation of new products. According to the research question *"What is the level of the use of digital technologies for the creation of new smart services in the manufacturing firms?"*, Table 5. shows the use of digital technologies for the creation of smart services in the manufacturing firms.

Table 5: The use of digital technologies for the creation of smart services

Digital technology	Not used (%)	Evaluating the adoption (%)	Already adopted (%)
3D-Printing	75.0	16.6	8.4
Cyber-physical systems, collaborative robots	58.3	33.3	8.4
Artificial Intelligence/Machine Learning	66.6	33.4	0.0
Big Data Analytics	41.6	33.3	25.1
Cloud Computing	33.3	58.3	8.4
Cyber Security	41.6	33.3	25.1
(Industrial) Internet of Things	41.6	33.3	25.1
Virtual and Augmented Reality	58.3	33.3	8.4
Simulation of Connected Machines (e.g. Digital twin)	41.6	50.0	8.4

Table 6: The correlation between product-related services and digital technologies

	Spare parts	Repairs and Maintenance	Training and Consultancy	Leasing and Pooling	Pay-per-use and Full Service contracts
3D-Printing	**0.11**	**0.11**	**0.29**	-0.26	***0.11***
Cyber-physical systems, collaborative robots	-0.10	-0.10	**0.31**	-0.38	-0.10
Artificial Intelligence/Machine Learning	0.00	0.00	**0.12**	-0.32	0.00
Big Data Analytics	-0.29	-0.29	**0.03**	-0.53	-0.29
Cloud Computing	**0.41**	**0.41**	**0.24**	**0.32**	**0.41**
Cyber Security	**0.10**	**0.10**	**0.03**	-0.08	**0.10**
(Industrial) Internet of Things	**0.10**	**0.10**	**0.03**	-0.08	**0.10**
Virtual and Augmented Reality	-0.10	-0.10	-0.03	-0.38	-0.10
Simulation of Connected Machines (e.g. Digital twin)	-0.29	-0.29	**0.03**	-0.53	-0.29

The most adopted digital technologies for the creation of new smart services are Big Data Analytics, Cyber Security, and (Industrial) Internet of Things with 25% of the use in manufacturing firms. On the other hand, Artificial Intelligence and Machine Learning are not adopted for the creation of new smart services. All other digital technologies are adopted by approximately 8.5% of manufacturing firms. More than 50% of manufacturing firms evaluating the adoption of Cloud Computing and Simulation of Connected Machines for the creation of new smart services. 3D-Printing, Cyber-physical systems and Collaborative robots, Artificial Intelligence and

Machine Learning, and Virtual and Augmented Reality are not used by more than 50% of manufacturing firms for the creation of new smart services. Table 6 (see previous page) presented the correlation between product-related services and digital technologies.

The results of the correlation show that digital technologies have the strongest relations with the service such as Training and Consultancy. All the digital technologies have strong and positive relations with these services, except Virtual and Augmented Reality, which don't have positive relations with any product-related services. Cloud Computing is a digital technology that has a strong and positive relationship with all product-related services. According to these findings, the authors show that services Leasing and Pooling have positive relation only with Cloud Computing.

CONCLUSION

This research examines the role of digital product-service systems in manufacturing firms. Furthermore, this study shows which digital technologies support the creation of new products and smart services. Additionally, this research shows the service orientation (i.e. product, use, and results) in manufacturing firms. The empirical results indicate that more than 60% of manufacturing firms use digital technologies for the creation of new products and less than 50% for the creation of new smart services. From the theoretical perspective, this study compares the level of product-service systems according to the Tucker's model. Results confirm previous studies which show that manufacturing firms from developing countries offer more product-oriented services than use or results-oriented services. Furthermore, this study confirms that services that are not closely related to product characteristics have more opportunities to become digital services (e.g. training). From a practical perspective, this research presented data from the manufacturing firms of the developing countries during the Covid-19 pandemic. The results indicate that production managers more involved digital technologies in the creation of new products than in the creation of new smart services. However, the Big Data Analytics, Cyber Security, and (Industrial) Internet of Things are adopted in the creation of new smart services in more than 25% of manufacturing firms. Additionally, more than 50% of manufacturing firms evaluate the adoption of Cloud Computing and Simulation of Connected Machines for the creation of services. Additionally, the results of correlation show that digital technology based on Cloud Computing has a strong and positive relationship with all product-related services. On the other hand, the service such as Training and Consultancy has the strong and positive relations with all digital technologies, except Virtual and Augmented Reality. This information could help production managers to involve mentioned digital technologies in the co-creation of products and services to develop smart solutions for their customers. These digital solutions could support the transformation of traditional product-service systems to digital product-service systems. Thus, digital solutions could increase the number of services that are result and use-oriented to generate more profits from service offers. The findings indicate that manufacturing firms from developing countries have a lot of opportunities to increase the use of digital product-service systems. The limitations of this research are datasets from the Republic of Serbia. Future research needs to make a comparative analysis between all countries which are involved in ASAP Service Management Forum. Moreover, future research needs to measure the effects of digital technologies which are included in the creation of new products and smart services on the manufacturing firm performance. With this information, the production managers could create a list of digital technologies which support the creation of new products and services and result in maximum profits for the firm.

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UPOTREBA DIGITALNIH PROIZVODNO-USLUŽNIH SISTEMA U PROIZVODNIM FIRMAMA

Digitalne tehnologije menjaju način na koji proizvodne firme kreiraju paket svojih ponuda za krajnje korisnike. Nove tehnologije transformišu tradicionalne proizvodno-uslužne sisteme u digitalne proizvodno-uslužne sisteme. Ovaj rad istražuje upotrebu digitalnih tehnologija koje potpomažu kreiranju novih proizvoda i pametnih usluga. Pored toga, ovaj rad istražuje orijentaciju usluga unutar proizvodno-uslužnih sistema. Podaci za ovo istraživanje prikupljeni su krajem 2021. godine preko *ASAP Service Management Foruma* u proizvodnom sektoru Republike Srbije. Empirijski rezultati pokazuju da više od 60% proizvodnih firmi koristi digitalne tehnologije za kreiranje novih proizvoda, a manje od 50% njih koristi digitalne tehnologije za kreiranje novih pametnih usluga. Štaviše, rezultati su pokazali da je većina usluga orijentisana na proizvode sa 25% udela u uzorku, zatim slede usluge orijentisane na rezultate sa 20% udela u uzorku i usluge orijentisane n aupotrebu sa 11% udela u ukupnom uzorku.

Ključne reči: Proizvodno-uslužni sistemi; Digitalna primena usluga; Prerađivački sektor; ASAP SMF.