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# Smart and Resilient Transformation of Manufacturing Firms

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**Abstract:** The smart and resilient transformation of manufacturing firms has flourished in the last decade. This paper investigates the smart and resilient transformation of manufacturing firms with the application of digital services. It uses a Serbian data set of 136 manufacturing firms from the Digital Servitization Survey from 2022 coordinated by IFIP WG5.7. The authors applied a different method approach through social network analysis, correlation analysis, and interviews with representatives from the manufacturing firms. The main results show that manufacturing firms that apply an adequate combination of services and digital technologies have the highest impact on the network of manufacturing firms. Moreover, the results show that applying digital technologies, such as additive manufacturing/3D printing, big data analytics, and digital twin, increases the gross annual turnover of manufacturing firms in the COVID-19 era. Finally, the results show that for a successful smart and resilient transformation, manufacturing firms need to develop a strategy and motivation oriented to profit to be resilient enough to withstand market change.

**Keywords:** smart manufacturing; resilient manufacturing; social network analysis; digital transformation; digital servitization



**Citation:** Sofic, A.; Rakic, S.; Pezzotta, G.; Markoski, B.; Arioli, V.; Marjanovic, U. Smart and Resilient Transformation of Manufacturing Firms. *Processes* **2022**, *10*, 2674. https://doi.org/10.3390/pr10122674

Received: 4 October 2022
Accepted: 6 December 2022
Published: 12 December 2022



## 1. Introduction

Industry 4.0 through digital technologies transforms traditional manufacturing systems into smart manufacturing systems [1]. The main technology push is in increasing mechanization and automation, digitalization, networking, and miniaturization [1]. On the other hand, industry is making progress with the non-technology factors supporting manufacturing systems' transformation [2]. Furthermore, with the development of the manufacturing processes, Industry 4.0 increased the implementation of digital services along with product offers [3]. Today, the growing appetite of manufacturing firms for swift revenue growth is clashing with limited demand. For instance, due to the maturity of the market, the global smartphone manufacturer Apple (Cupertino, CA, USA) is switching its strategy from a pure manufacturer to a digital service provider. From 2015 to 2021, the share from services doubled to 19% of Apple's total revenue [4]. Digital services became part of a new business model, supporting digital product–service systems to achieve a competitive advantage in the market [5]. The integration of products, services, and information creates a service-oriented architecture in manufacturing firms, which increases the reliability, adaptability, scalability, and flexibility of their systems [2]. To achieve readiness for a smart transformation, manufacturing firms first employ digital technologies in their product characteristics [6]. Digital technologies such as digital twins, the Internet of Things, 3D printing, etc., transform traditional products into digital products [7,8]. With this type of transformation, digital technologies trigger a service transformation [9]. To achieve innovation and competitor advantages, manufacturing firms need to create a new digital solutions, which need to be a mix of products, services, and digital technologies [6]. These characteristics of the systems enable manufacturing firms to survive in the competitive market in situations of global changes [10]. For example, the COVID-19 pandemic radically changed the value chains of the manufacturing systems [11]. The negative trends of COVID-19, such as quarantines, closed borders, and unemployment, cripple the manufacturing industry, which poses the question: "how to survive?" [12]. The production of new products was stopped in many countries and many manufacturing firms transformed their orientation from products to offering services [11]. The changes in the market created by COVID-19 open new solutions for resilient manufacturing supported by web-based product and service delivery [11]. The combination of products and digital services enables manufacturing systems to stay more resilient to macro and micro influences from the environment [12]. Moreover, previous experiences of global economic crises show that manufacturing firms push the focus on induction and the impetus of service to reinvigorate the industry [13]. However, there are negative examples of servitization (negative effects on the financial performance of manufacturing firms) [14]. The paradox of digitalization and servitization creates a "black box" for the resilience of manufacturing firms [15]. This paradox could be very dangerous in situations of global change when manufacturing firms cannot achieve their expected revenue growth via digital technologies and services [15]. According to the different influences on manufacturing firms, such as digital transformation, global change (e.g., COVID-19 or war in Ukraine), the servitization paradox, and economic crises, the main aim of this research is to shed light on which business models can enable a smart, sustainable, and resilient transformation of manufacturing systems. To investigate the smart and resilient transformation, the authors propose the following conceptual framework in Figure 1.

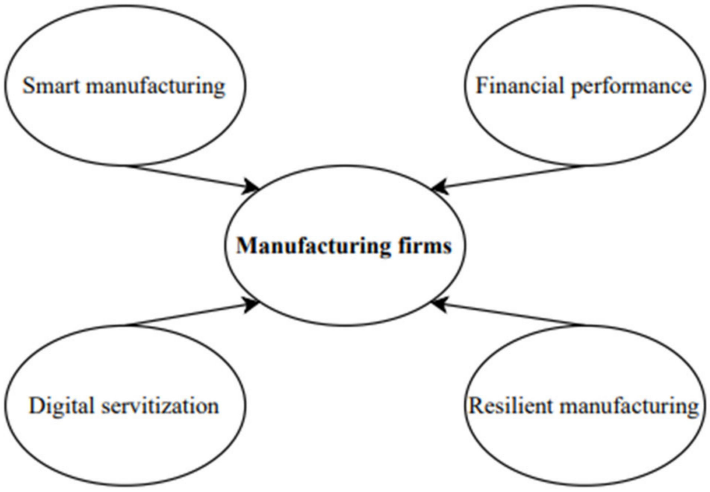


**Figure 1.** Conceptual framework.

Based on the previous literature and according to the aim and conceptual framework of this study, the authors proposed the following research questions:

RQ1: *Which digital technologies and services make the highest impact on the network of manufacturing firms?*

RQ2: *Which digital technologies and services comprise the gross annual turnover of manufacturing firms?*

RQ3: *What are the main reasons for the successful or unsuccessful smart transformations of manufacturing firms?*

The paper is structured as follows: Section 2 presents the main findings from the literature. Section 3 describes the mixed-method approach with the sample and data collection procedure. Section 4 presents the research results. Additionally, Section 5 depicts the practical and theoretical implications of the study. Finally, Section 6 summarizes the conclusions and further implications.

## 2. Literature Review

### 2.1. Smart Manufacturing

Industry 4.0 starts to create new business models with the involvement of digital technologies, organizational changes, and the creation of additional value for customers [16]. From an academic perspective, researchers have attempted to define the term "Industry 4.0" and its related business models. On the other hand, manufacturing firms try to understand how to transform traditional equipment to make smart manufacturing systems [16]. To achieve the goal of transformation, manufacturing firms need to understand some of the main digital technologies, such as the Internet of Things, cloud computing, big data, artificial intelligence, virtual or augmented reality, digital twins, and others [17,18]. However, to establish a sustainable smart transformation of manufacturing firms, it is not only necessary to understand digital technologies but how to involve and use only adequate technologies according to firm characteristics [19,20]. Only the combination of adequate digital technologies with firm culture, strategy, organization resources, and other non-technology factors can perform a successful digital transformation [21]. Production managers have a lot of challenges in the transformation process of firms according to the different technologies, organizational changes, and other influences from the environment. Data management tools could be a solution for them to solve a lot of these challenges in smart manufacturing [22,23]. Data management encourages the integration of digital technologies within traditional equipment to make smart production. Moreover, data management enables a better organization of firm resources to increase readiness for a digital transformation [24]. The main goal for manufacturing firms is to create a smart factory through digital manufacturing processes [20]. With the establishment of a smart factory, every digital technology could increase the value of manufacturing processes (e.g., Internet of Things increases knowledge about customer needs, big data increases flexibility and product quality, augmented or virtual reality increases the speed of prototyping, advanced manufacturing solutions reduces set-up costs, etc.) [25]. In this way, technologies support manufacturing firms to achieve better financial performance in the market. According to the benefits from one side and challenges from the other, this paper will investigate which digital technologies support smart manufacturing processes to achieve better financial performance using evidence from the transitional economy (i.e., Serbia).

### 2.2. Resilient Manufacturing

The resilience of the manufacturing system could be defined as the capacity of a system to withstand hard influence from the environment and its ability to mitigate influence and quickly return to the previous state [26]. The resilience of manufacturing systems is very well discussed from ecological and sustainable perspectives [27]. However, the engineering and financial resilience of manufacturing systems has not been sufficiently explored [27]. To encourage the resilience of production processes, manufacturing systems need to be more flexible and reconfigurable [26]. According to the requirements produced by rapid changes in the market, Industry 4.0 provides the possibility for manufacturing firms to quickly react to changes in the environment [28]. Furthermore, digital technologies affect the key functional requirements of resilient systems, such as quick actions, system and performance monitoring and adjustments, etc. [28]. On the other hand, COVID-19 changed the way manufacturing firms do their business and challenged them to solve new challenges in production organization, supply chains, and the market [29]. COVID-19 triggered the resilience of manufacturing systems. Moreover, evidence from the manufacturing firms shows that firms that employ adequate digital technologies make progress in the COVID-19 era [29]. Thus, digital technologies transform the threats from the environment into opportunities for growth and development [30]. Data analytics and the application of the Internet of Things and robotics in production processes along with e-commerce represent sustainable models to survive in a market undergoing rapid changes on a global level [30]. However, the research community have neglected to analyze how digital technologies affect the financial resilience of manufacturing systems. In this way, this research fills the literature gap by analyzing digital technologies, resilient manufacturing, and financial performance.

### 2.3. Digital Servitization

The term "servitization" was introduced by Vandermerwe and Rada in 1988 to describe an offer of service alongside products to achieve a competitive advantage in the market [31]. Servitization opens new research insights, which result in the existence of new business models based on product–service systems [32]. However, the main progress of servitization in theory and practice starts in 2008 during the period of worldwide economic crisis [28]. The reason for the increase in service implementation in manufacturing firms was the unstable market situation [33]. When people do not have enough money to buy new products, this results in firms transforming from a product orientation to a service orientation [33]. In this period, services became solutions for both sides—people and firms. On the one side, people repair and maintain their old products, and on the other side, firms offer services that support the lifecycle of their products [34]. This increase in servitization was a practical example of how manufacturing firms could increase their resilience to global market changes [35]. Furthermore, the Industry 4.0 concepts support the new transformation from traditional to digital servitization [36]. The integration of digital technologies in the offer of traditional services has a high impact on firm performance [37]. Moreover, with the influence of COVID-19 on the servitization process, manufacturing firms attempted to develop new digital services, which create a digital product–service system [38]. Digital product–service systems became one of the solutions for manufacturing firms to increase their resilience in the pandemic era [39]. Resilient manufacturing firms oriented to services achieve better results in the market by reducing production costs [39]. Furthermore, the combination of digital technologies with appropriate services could increase the resilience and financial performance of manufacturing firms.

### 2.4. Finanical Performance in Manufacturing Firms

The previous research uses financial indicators to measure firm performance. The main reason why authors use financial indicators to measure firm performance is the measurability and objectivity of the achieved results [37]. Zahringer uses financial aspects in their research, including costs and income to measure the effect of servitization on manufacturing performance [40]. Eggert and Marjanovic use a share of the revenue for the measurement of firm performance [41,42]. Visnjic uses the ratio between market capitalization and the book value of total assets in their results [43]. Vendrell-Herrero uses revenues and profit margin evolution to measure the implication of digital services [44]. Martin-Pena uses total sales to measure relations between digital technologies, servitization, and firm performance [45]. Kharlamov uses return on assets to measure the financial performance of manufacturing firms [46]. According to the previous research, authors proposed to measure gross annual turnover in the period of COVID-19 to present the financial results of manufacturing firms. Moreover, these results show which digital technologies along with product-related services provide long-term growth in gross annual turnover.

## 3. Methodology

### 3.1. Data Sample and Collection

The exploratory survey for this paper was conducted under the consortium of IFIP WG5.7 SIG on Service Systems Design, Engineering, and Management in 2022 [38]. The survey was conducted in six countries (i.e., Italy, Germany, Sweden, Mexico Switzerland, and Serbia). For this research, the authors used the Serbian dataset. The data sample consisted of 136 manufacturing firms (NACE Rev 2 codes from 10 to 33) with at least 20 employees. For the sampling method, the authors used Cohran's method [47] to determine sample size based on the industrial sector, firm size, and district in Serbia. Furthermore, for the data collection, authors used Dillman's method [48], and the survey was sent online with a response rate of 15%. The first iteration with respondents was a phone call or message on

LinkedIn with the production managers of the firms. After that, the online survey was sent to the email addresses of the respondents. The reminder was sent after 14 days via email to achieve a higher response rate. Table 1 depicts the distribution of firms by size.

**Table 1.** Distribution of firms by size.

| Size | Number of Employees | (%) |
| --- | --- | --- |
| Small | 20–49 | 39.0 |
| Medium | 50–249 | 40.0 |
| Large | >250 | 21.0 |

The sample shows that 39% of manufacturing firms are small, 40% of manufacturing are medium, and 21% are large firms. Table 2 depicts the distribution of firms by industry sector.

**Table 2.** Distribution of firms by industry sector.

| NACE | Industry Sector | (%) |
| --- | --- | --- |
| 10 | Food production | 27.0 |
| 25 | Production of fabricated metal products, except machinery and equipment | 10.0 |
| 28 | Production of machinery and equipment n.e.c. | 9.0 |
| 13 | Production of textile | 7.0 |
| 22 | Production of rubber and plastics | 7.0 |
| 27 | Production of electrical equipment | 7.0 |
| 29 | Production of motor vehicles, trailers, and semi-trailers | 6.0 |
| | Other sectors | 27.0 |

Sampled manufacturing firms belonged to food production (27%); production of fabricated metal products, except machinery and equipment (10%); production of machinery and equipment n.e.c. (9%); production of textile (7%); production of rubber and plastics (7%); production of electrical equipment (7%); production of motor vehicles, trailers, and semi-trailers (6%); and other sectors (27%).

### *3.2. Data Analysis*

Based on the previous literature, the authors performed social network analysis to ensure the relations between product-related services and digital technologies in the transformation of manufacturing firms. Social network analysis (SNA) measures the relation between product-related services (i.e., PRS1—spare parts, PRS2—repairs and maintenance, PRS3—training, PRS4—leasing and sharing, PRS5—pay-per-use and full-service contracts) and digital technologies (i.e., DT1—additive manufacturing/3D printing; DT2—cyber–physical systems, collaborative robots; DT3—artificial intelligence/machine learning; DT 4—big data analytics; DT 5—cloud computing; DT 6—cyber security; DT 7—Internet of Things; DT 8—virtual and augmented reality; DT 9—digital twin). The authors employed eigenvector and betweenness centrality to find which product-related services and digital technologies have the highest influence on the smart and resilience transformation of manufacturing firms. Like degree centrality, an eigenvector measures the influence of digital technologies and product-related services based on the number of links it has to manufacturing firms in the network. By calculating the extended connections of digital technologies and product-related services, an eigenvector can identify manufacturing firms with influence over the whole network, not just those directly connected to it. Betweenness centrality measures the number of times digital technologies and product-related lies on the shortest path between manufacturing firms. This measure shows which digital technologies and product-related services are "bridges" between manufacturing firms in a network by identifying all the shortest paths and then counting how many times each manufacturing firm falls on one. Moreover, the authors used correlation to show the relation between product-related services and digital technologies with the gross annual turnover from manufacturing firms in the era of COVID-19. This type of analysis is often used in manufacturing research, which measures the effects of digital technologies and product-related services on manufacturing financial performance. In previous research, authors used predictors for digital technologies, such as big data, augmented reality, remote control, etc., and product-related services such as training, maintenance, spare parts, etc. For the financial performance, authors used a share of revenues, profit, or gross annual turnover.

For the in-depth analysis, the authors performed interviews with representatives from all groups of firms. According to the previous research, which shows the difference in the technology intensity and application of digital servitization, authors conducted interviews with the representatives from manufacturing firms [32]. The structure of the interview was developed according to the previous research results and consultancy with the representatives from manufacturing firms. The firms were divided into three groups according to the technology intensity of the firms: low-tech, medium-tech, and high-tech firms. In the low-tech group, firm A belongs to leather production (unsuccessful example) and firm B is from paper production (successful example). In the medium-tech firms, firm C is from the production of coke and oil (unsuccessful example) and firm D belongs to the repair and installation of machines and equipment (successful example). Finally, in the high-tech firms, firm E is from the production of chemicals and chemical products (unsuccessful example) and firm F is from the production of computers, electronic, and optical products (successful example).

## 4. Results

Figure 2 presents the relations between product-related services and digital technologies in the manufacturing sector of Serbia.

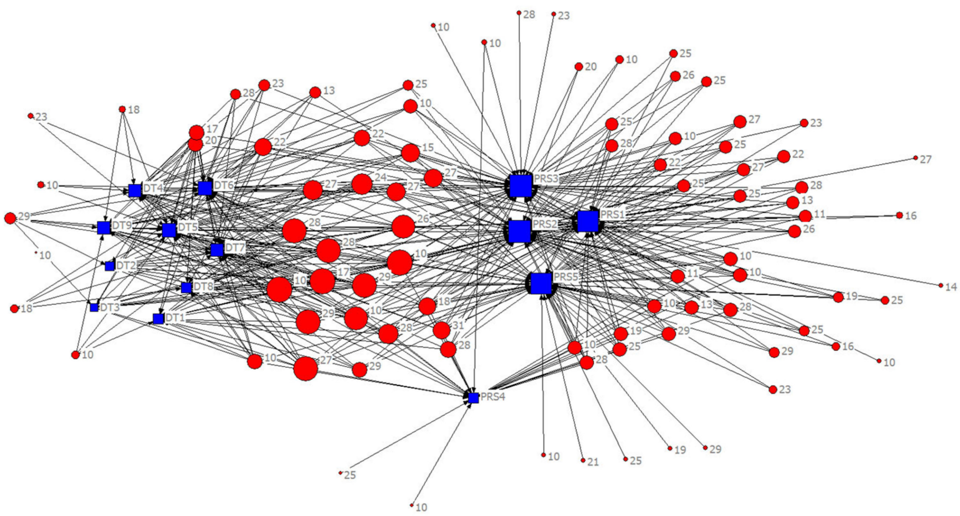


**Figure 2.** The network of manufacturing firms from Serbia.

Figure 2 shows which are the most influential services and digital technologies that enable the smart and resilient transformation of manufacturing firms. Figure 2 visualizes the difference between product-related services and digital technologies. The results show that manufacturing firms use product-related services more than digital technologies in their manufacturing. Moreover, this figure shows which firms are the main nodes in the manufacturing ecosystem of the Republic of Serbia. These firms are in the center of the network with the highest red circles. Moreover, Table 3 shows the eigenvector and betweenness centrality results from the SNA.

**Table 3.** Centrality analysis in the manufacturing network.

| Node | Eigenvector Centrality | Betweenness Centrality |
|---|---|---|
| PRS1 | 0.376 | 0.069 |
| PRS2 | 0.403 | 0.086 |
| PRS3 | 0.410 | 0.107 |
| PRS4 | 0.179 | 0.026 |
| PRS5 | 0.386 | 0.101 |
| DT1 | 0.165 | 0.005 |
| DT2 | 0.147 | 0.002 |
| DT3 | 0.127 | 0.002 |
| DT4 | 0.227 | 0.015 |
| DT5 | 0.231 | 0.022 |
| DT6 | 0.234 | 0.019 |
| DT7 | 0.228 | 0.013 |
| DT8 | 0.157 | 0.003 |
| DT9 | 0.213 | 0.010 |

The eigenvector centrality shows the most influential nodes in the manufacturing sector of Serbia. From the service perspective, the most influential nodes are product-related services, such as repairs, maintenance, and training, with an eigenvector value of more than 0.4. On the other hand, from the digital technologies perspective, the most influential nodes are big data analytics, cloud computing, cyber security, the Internet of Things, and digital twins, with an eigenvector value of more than 0.2. The betweenness centrality shows that services such as training, pay-per-use, and full-service contract are on the shortest path between other services and digital technologies. From the digital technologies perspective, betweenness centrality shows that cloud computing is on the shortest path between other services and digital technologies. Moreover, the results show that product-related services have a significantly shorter path between other nodes compared with digital technologies. To ensure the resilience of manufacturing firms, Tables 4 and 5 show the correlation between product-related services and gross annual turnover, and between digital technologies and gross annual turnover, respectively.

**Table 4.** Correlation between product-related services and gross annual turnover (GAT).

| | GAT |
|---|---|
| PRS1 | 0.132 * |
| PRS2 | 0.069 |
| PRS3 | 0.074 |
| PRS4 | 0.001 |
| PRS5 | 0.174 * |

* $p < 0.005$.

**Table 5.** Correlation between digital technologies and gross annual turnover (GAT).

| | GAT |
|---|---|
| DT1 | 0.169 * |
| DT2 | 0.140 |
| DT3 | 0.090 |
| DT4 | 0.152 * |
| DT5 | 0.003 |
| DT6 | 0.023 |
| DT7 | 0.044 |
| DT8 | 0.069 |
| DT9 | 0.168 * |

* $p < 0.005$.

The correlation analysis shows that services, such as spare parts, pay-per-use, and full-service contracts have significant and positive relations with gross annual turnover. Furthermore, the results show that digital technologies, such as additive manufacturing/3D printing, big data analytics, and digital twins also have significant and positive relations with gross annual turnover in the manufacturing sector of Serbia. All other services and technologies have positive, but not significant, relations with gross annual turnover. Tables 5–7 show the results from the interviews with the representatives from the manufacturing firms on the following five questions: (1) "What position do you hold in the company?"; (2) "Why do not you use some of the digital services mentioned in the survey?"; (3) "How do you apply digital services in the firm?"; (4) "Do you have a developed strategy for offering digital services?"; and (5) "What is the motivation for offering digital services?". Tables 6–8 present the interviews with the representatives from the firms.

**Table 6.** Interviews with representatives from low-tech firms.

| Answers/Firm | Firm A | Firm B |
|---|---|---|
| Answer 1 | CEO | Project manager |
| Answer 2 | Lack of knowledge | The product has no need for those services |
| Answer 3 | According to defined standards | To increase the value chain |
| Answer 4 | No developed awareness for service implementation | The service development strategy has been developed according to the smart transformation |
| Answer 5 | Better relations with customers | Competition advantage and resilience to market change |

**Table 7.** Interviews with representatives from medium-tech firms.

| Answers/Firm | Firm C | Firm D |
|---|---|---|
| Answer 1 | Sales manager | Sales manager |
| Answer 2 | Services that are not offered are proved to be unprofitable | They do not just use one service |
| Answer 3 | Services are offered depending on the market B2B or B2C | Services are implemented in accordance with user needs |
| Answer 4 | The strategy is in the development phase | The strategy is defined so that the company is oriented towards results |
| Answer 5 | Competition advantage and customer loyalty | Profit and competition advantage |

**Table 8.** Interviews with representatives from high-tech firms.

| Answers/Firm | Firm E | Firm F |
|---|---|---|
| Answer 1 | Production manager | CEO |
| Answer 2 | Lack of the awareness | Lack of resources |
| Answer 3 | They offer only product-related services that are closely related to product characteristics | Services are implemented to increase product value |
| Answer 4 | They do not have a developed strategy | The service development strategy is directed towards the satisfaction of customers |
| Answer 5 | Traditional relations with customers | Customer loyalty and resilience to the market change |

According to the answers from the three groups of firms (i.e., low-tech, med-tech, and high-tech), our findings show similar answers for the unsuccessful and successful examples in all three groups. The main findings from the unsuccessful examples show that these firms: ***lack knowledge and awareness***, ***do not have a strategy*** for the firm's transformation, and ***their main motivation is relations with customers***. On the other hand, the successful examples show that these firms: orient ***service offers to their customer's needs, have developed strategies*** oriented to digitalization, are ***mainly motivated by customer advantages***, ***resilience in the market***, change, and ***profit***.

## 5. Discussion

### 5.1. Theorethical Implications

From the theoretical perspective, these findings fill the literature gap about the resilience of manufacturing firms in transition economies [49]. Furthermore, our results show which manufacturing sector has the strongest position in the manufacturing ecosystem [50]. Our results confirm that manufacturing firms from the transitional economies have the biggest focus on product-related services, which are closely related to product characteristics [51]. On the other hand, our results confirm that digital technologies have a stronger connection with services that are not closely related to product characteristics [5]. Moreover, the result of this study shows that manufacturing firms that employ more digital technologies and product-related services have a better chance to survive challenges from the environment. These findings fill the gaps in the literature about environmental, sustainable, and engineering resilience with evidence about the construction of the gross annual turnover in the COVID-19 era [11,29,47]. Moreover, the results from the in-depth interviews show the main differences between successful and unsuccessful manufacturing firms undergoing digital transformation. Our results confirm the findings of previous research, which shows that the main difference between successful and unsuccessful firms is in the understanding of the importance of digital technologies and product-related services in establishing smart and resilient manufacturing [52,53]. For RQ1: "Which digital technologies and services make the highest impact on the network of manufacturing firms?", our results show that training as a service and cloud computing as a digital technology have the highest centrality values (eigenvector and betweenness). These results show that manufacturing firms using these services and digital technologies have the best connections in the manufacturing ecosystem. For RQ2: "Which digital technologies and services are construct of the gross annual turnover of manufacturing firms?", spare parts and full-service contracts, along with additive manufacturing/3D printing, big data analytics, and digital twins, result in an increase in the gross annual turnover of manufacturing firms in the COVID-19 era. Moreover, these findings show that manufacturing firms that employ some of these digital technologies and product-related services could easily achieve higher financial resilience. With a higher gross annual turnover, manufacturing firms could easily bypass impacts from the environment, such as economic crises, COVID-19, the war in Ukraine, etc. In this way, these technologies and services have a long-term effect that results in the increase in gross annual turnover. For RQ3: "What are the main reasons for the successful or unsuccessful smart transformation of manufacturing firms?", to give answers to this research question, we go with an in-depth interview to obtain knowledge from firm representatives according to the empirical results from this and previous research on similar topics. The results show that regardless of technology intensity, all successful manufacturing firms have developed strategies oriented to digitalization, a high level of awareness, and motivation to achieve customer needs and profit. On the other hand, all unsuccessful examples have a lack of awareness, services that are not offered or are proven to be unprofitable, and a lack of knowledge about the smart transformation.

### 5.2. Practical Implications

This study investigates findings from the manufacturing sector of developing countries (i.e., Serbia). The results show which product-related services and digital technologies are implemented in manufacturing firms. Furthermore, the results indicate the ecosystem of the manufacturing firms and the relations between them. With these results, production managers could compare their manufacturing firms according to the other firms in their sector or other firms with the same level of technology intensity. Moreover, these results could help production managers by showing that a combination of product-related services along with digital technologies could result in an increase in gross annual turnover in manufacturing firms. These findings are very important in this time of global changes, especially changes related to COVID-19 or the war in Ukraine. In this way, production managers could prepare their manufacturing firms to prepare for new environmental challenges. Finally, results from the interviews of the three groups of manufacturing firms (i.e., low-tech, med-tech, and high-tech) indicate practical implications as well. The interviews pointed out the main differences between successful and unsuccessful manufacturing firms. With this information, production managers could shape their business models to achieve smart and resilient manufacturing. From a non-technology perspective, manufacturing firms need to first create a strategy of digitalization to achieve a successful smart transformation. After that, they need to achieve a higher level of awareness and knowledge about digital technologies and services among their employees, especially production managers. From a technology perspective, they need to find appropriate digital technologies and product-related services that will enable long-term effects. In this study, the authors show that additive manufacturing/3D printing, big data analytics, digital twins, spare parts, pay-per-use, and full-service contracts have a positive effect on a firm's performance.

## 6. Conclusions

This study investigates the role of smart manufacturing, resilient manufacturing, digital servitization, and financial performance in the manufacturing ecosystem. Furthermore, this study involves a mixed-method approach, using SNA methods, correlation analysis, and interviews with representatives from the manufacturing sector. The implications of the research show how findings from this study could fill the literature gap and how this information could help production managers. Results for this study are obtained via the Digital Servitization Survey coordinated by IFIP WG5.7. Results from the survey indicate which manufacturing sector and which digital technologies and product-related services have the strongest position in the manufacturing ecosystem. Moreover, the results show which combination of digital technologies with product-related services make a positive effect on the increase in gross annual turnover in manufacturing firms. In-depth analysis via interviews with manufacturing representatives shows the main differences between manufacturing firms in the process of digital transformation. The results from this study confirm many previous results about smart and resilient manufacturing from developed countries. However, these results provide additional evidence to the information obtained from developing countries, which fills gaps in the literature. Additionally, this information could be useful for the manufacturing community because many manufacturing firms from developed countries have firms from developing countries in their value chains. Furthermore, the results show opportunities for manufacturing firms to improve their processes, making them more sustainable and resilient to the challenges of the environment.

The main limitation of this study is the dataset. This study only used a Serbian dataset. For future research, authors could use the results from a whole consortium to show a wider picture of smart and resilient manufacturing. Moreover, a further limitation of this study is that we only focus on the financial resilience of manufacturing firms. Future research needs to show environmental and engineering resilience along with financial resilience.

**Author Contributions:** Conceptualization, A.S., B.M., U.M. and S.R.; methodology, U.M., S.R., G.P., V.A. and A.S.; analyzed the data: S.R. and B.M.; investigation, U.M., A.S. and B.M.; writing—original draft preparation, A.S., S.R., G.P., V.A., B.M. and U.M.; writing—review and editing, S.R. and A.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

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