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Servitization 4.0 as a Trigger for Sustainable Business: Evidence from Automotive Digital Supply Chain

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Abstract: The COVID-19 pandemic strengthens the use of digital services in the supply chains of manufacturers and suppliers in the automotive industry. Furthermore, the digitalization of the production process changed how manufacturing firms manage their value chains in the era of Industry 4.0. The automotive sector represents the ecosystem with rapid digital transformation, which provides a strong relationship between manufacturing firms in supply chains. However, there are many gaps in understanding how digital technologies and services could better shape relations between manufacturers and suppliers in the automotive industry. Accordingly, this study investigates the relations in deliveries of digital services in supply chains of the automotive industry. The data set was obtained through annual reports of the automotive firms, both from suppliers and manufacturers, between 2018 and 2020. From the network perspective, throughout the years, authors have used Social Network Analysis (SNA) method. SNA evaluates the relationship between actors (i.e., manufacturers and suppliers) in the use of services in their business models. The research results demonstrate how suppliers influence car manufacturers to deliver digital services to their customers. Finally, this study provides information that the combination of digital technologies with product-related services enables a stronger relationship between manufacturers and suppliers in the manufacturing ecosystem. These relations support the manufacturing ecosystem to survive the influence of different environments.

Keywords: digital servitization; digital technologies; digital supply chain; automotive industry; Industry 4.0; social network analysis

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1. Introduction

Despite the fact that digital transformation is one of the leading terms of today, for a complete understanding of this field, it is necessary to cross theory and practice. Although there is a large amount of literature on digital transformation [1], scholars have not yet reached a consensus on the definition of "digital transformation" [2]. Existing studies have defined digital transformation mainly from the perspectives of technology and value. Some scholars have also defined digital transformation from the perspective of strategic change [3]. The term "digital transformation" refers to a company-wide shift that results in the development of new business models [4]. Through business models, digital transformation applies digital components to establish a new value chain [5]. The function of digital servitization is a relevant subject for research in digital transformation [6]. The use of digital technology can hasten the transition from product to service-based business models [6]. The bulk of the studies examined pertain to digital transformation in a larger sense, concentrating on the creation of value using various digital technologies. The main drivers for digital transformation are technologies such as IoT, Big Data, AI, and Cloud. Digital transformation, on the other hand, might be considered an essential component of many company tasks, such as sales, marketing, and supply chains [7]. From all the above, it is clear that companies implementing digital transformation must be able to undergo major changes. It is important to understand the potential of digital technologies and how digital transformation is changing competitive scenarios [8]. Digital transformation affects all sectors, in particular the automotive industry. Automotive supply chains are international and, consequently, very complicated. They have a large network of relationships between manufacturers, suppliers, and customers worldwide [9]. Thus, firms that do not employ creative consumer solutions cannot compete in the market. Strategy cycles in the automotive industry are shortening due to differentiation and rapidly changing customer demands [10]. Furthermore, the continually changing reality of the COVID-19 outbreak compels firms to quickly modify their approaches in order to maintain their businesses. Long lockdowns in China occurred during the COVID-19 pandemic, resulting in a scarcity of spare parts for its European partners [11]. According to these issues, 95% of all German automotive businesses are relocating their staff to temporary positions [12]. As a result of the delays, material concerns, and a lack of transportation choices, this issue impacted the worldwide automobile supply chains as well [11]. Based on these concerns, digital technologies provide new ways to address human resource and supply chain issues. For example, some digital services, such as online collaboration platforms, were frequently utilized to resolve concerns with face-to-face meetings [13]. In light of these considerations, three main questions arise.

RQ1: Which digital technologies encourage the relations between automotive manufacturers and suppliers?

RQ2: Which product-related services encourage the relations between automotive manufacturers and suppliers?

RQ3: How does the COVID-19 pandemic affect relations between manufacturers and suppliers in the use of digital technologies and product-related services?

To answer these research questions, the paper provides a business model in the automotive industry from suppliers through manufacturers and to customers. The structure of the paper is as follows. The theoretical foundation for the investigation is presented in the next part. The third section describes the research methodology. In the findings section, results followed by the discussion are presented. Finally, the main implications of the research are derived, including the concluding remarks and propositions for further research directions.

2. Research Context

2.1. Industry 4.0

Industry 4.0 was created in 2011 in Germany to concentrate attention on the influence of technology in future production systems [14]. Various Industry 4.0 concepts have lately surfaced. The term "fourth industrial revolution" [15,16] has been used to characterize new production systems supported by digital technologies and networking [17]. The previous research provided a theoretical framework for comprehending Industry 4.0. Accordingly, the notion of Industry 4.0 encompasses several business characteristics that are supported by evolving technologies [18].

These aspects are underpinned by basic technologies such as cloud computing, big data, and IoT. In this view, the digital transformation of firms is viewed as the transition process from traditional to smart business [17]. Although the phrase or notion of Industry 4.0 is widely used, coherence in what it represents is sometimes lacking. Furthermore, related technologies have not yet been unified; thus, a full and mutually exclusive classification is still lacking.

Russmann et al. (2015) analyze Industry 4.0 through nine technologies that will be used in this paper [14,19]. Below is a brief overview of each technology and its use and utility if applied to services [14,20]:

- Big Data Analytics—the full analysis of accessible data in order to make better real-time decisions. When applied to a service, it allows for the creation of a more in-depth understanding of client behavior and preferences.

- Collaborative Robots—robots are used by manufacturers in a variety of sectors to perform complicated tasks. They are self-sufficient, adaptable, and cooperative. They take the role of people in totally rule-based work processes.
- Artificial Intelligence—businesses work on computer simulations of human intelligence processes using technology.
- Internet of Things (IoT)—an interconnected network of machines and products. Multidimensional communication between networked things.
- Cyber Security—entails safe, dependable communications as well as advanced machine and user identification and access control.
- Cloud Computing—communication in real time for manufacturing systems. Increased distant data sharing by the corporation reduces response times from all networked data consumers to a few milliseconds.
- 3D Printing—allows firms to develop and manufacture specific components.
- Augmented and Virtual Reality—a range of services are supported by augmented-reality-based systems, including the selection of components at a warehouse and the transmission of repair instructions via mobile devices.
- Digital Twin—computer models that depict the condition of the network at any given time, in real time.

Industry 4.0 technologies enable businesses to better comprehend what value represents to consumers by collecting a large quantity of data on their behavior and product consumption [17,21]. Large quantities of data, paired with rising computing capacity, are causing profound changes in industrial firms [22]. The phenomenal progress and acceptance of digital technologies have greatly altered customers' perceptions of product innovation and delivery speed [23]. In this scenario, product manufacturers must adapt to the demand-pull measure of service innovation, while simultaneously investing heavily in advanced technologies and connectivity to be more competitive [17]. Industry 4.0 enabling technologies provide mitigation potential for the multiple hazards that the automobile industry encountered during the COVID-19 epidemic. Climate change, increasing urbanization, digitization, and electrification, on the other hand, modify social requirements and customer preferences toward vehicle mobility [24]. The combination of digitization and services allows car manufacturers to form a green value chain with suppliers in order to obtain better market outcomes. Furthermore, these technologies can help businesses reduce the risk of trouble so that they can keep operating. This is especially true in the event of a pandemic, when a lack of employees is one of the many crucial elements possibly damaging operations, particularly supply chain activities [9].

2.2. Digital Servitization

Industry 4.0 and servitization are some of the most current innovations that are changing industrial businesses [25–27]. Industry 4.0 is typically associated with bringing value to the production process, whereas servitization is primarily concerned with providing value to customers [17]. Both Industry 4.0 and servitization arose from distinct study areas, the former from engineering and the latter from management science [15]. The notion of servitization was first established in 1988 in response to the requirement to assure and provide integrated products and services in order to provide additional value [28]. Today, servitization refers to a phenomenon that involves technology [29] that assists or improves the service delivered [30]. The adoption of IoT technology enables manufacturers to provide new kinds of services, enhancing servitization through digitalization [31], introducing the idea of "digital servitization". This is described as the creation of new services or the enhancement of current ones by employing digital technologies. These may be used to allow advanced business models and develop information from data in order to obtain a competitive advantage [7]. One of the most difficult servitization challenges is selecting the new value proposition, which has a significant influence on the whole value architecture of the business model [32].

Pournader et al. (2020) defined the COVID 19 epidemic as a "crisis-as-process" rather than a "crisis-as-event" [33]. Accordingly, firms must prepare in the long term for how they will employ digital technologies in order to develop their business model and adapt to the new situation. One of the primary trends in firm strategy is the expansion of product service content [34]. Product-related services are those that are closely tied to the items in the products. In this paper, the authors investigate product-related services in the automotive industry. Automobile production is a classic example of a business that provides a product–service combination.

Car manufacturers provide a wide spectrum of services to their consumers, including finance, maintenance, and availability, among others. This trend of developing car-related services has lately been accelerated using digital technologies. They want to provide clients with new sorts of "telematics services" [35]. For the purposes of this research, the following product-related services are used:

- Spare parts—exchangeable components stored in an inventory and employed to restore damaged equipment.
- Maintenance—includes performing functional tests, and maintaining and replacing relevant machinery.
- Training—implies informing or instructing to help and improve knowledge.
- Leasing—is a sort of funding that may be obtained from an outside firm if there is insufficient cash at the time.
- Renting and Pay Per Use—is an arrangement in which a payment is paid for the momentary use of another's products or services.
- Full-service contract—a long-term arrangement between the firm and its customers.

Previous study indicates that product-related services impacted by digital technologies may have a favorable impact on manufacturing enterprises' financial performance [6]. Furthermore, the digital product–service system may be created by combining digital technology with product-related services. Based on digitalization, digital product–service systems might assist car manufacturers in reducing their environmental impact while increasing their financial performance.

2.3. Digital Supply Chain

Academic studies on the digital supply chain phenomena are still in their early phases. This field has lately evolved as a result of technological advancements and the complexity of the international market. Supply networks must deal with ever-changing client demands as well as a wide range of external disruptions. Smart goods combined with advanced supply chain services pave the path for a paradigm change in supply chain management [36]. The Digital Supply Chain is a comprehensive examination of the platforms and models that enable the design and administration of digitally related supply chains. Digital technologies have a huge influence on the value chains in the automobile sector [37]. Ivanov et al. (2020) consider that the supply chain could only be as useful as the digital technologies that power it [38]. To fulfill the dynamic expectations of customers in a highly competitive market, the supply chain must be efficient and cost-effective [39]. This necessitates a high degree of digitalization and automation in the company's supply chain.

IT technologies with transparency and visibility of the information shape supply chain resilience [40]. Supply networks were already under strain before the COVID-19 pandemic. Increasingly complicated supply networks, globalization, and outward factors have all contributed to supply chain disruptions in recent years [41]. Nonetheless, no recent occurrence has shown the fragility of supply chains in the same way as the COVID-19 outbreak [33]. During the COVID-19 pandemic, suppliers were unable to satisfy their supply requirements [38]. With the growth of social media, unfavorable experiences may be quickly shared with a huge audience [9]. This information may quickly taint a company's reputation. The development of the pandemic has heightened the urgency of creating supply networks that can be better sustained. Supply chain redesign to achieve Circular Economy goals is still in its early stages [42]. The Circular Economy in the supply chain has gained traction as a result of the COVID-19 pandemic [38]. Circular Economy systems may be supported by Industry 4.0 principles, which can influence the digital supply chain [43]. According to Hussain and Malik (2020), the Circular Economy is related to supply chain resilience and capacities [44]. Companies are beginning to adopt e-commerce platforms that preserve links between manufacturers and users to enhance supply chains throughout the epidemic [45]. These new relationships between manufacturers and customers help to promote the re-manufacturing process, which affects suppliers in the automobile sector [46].

Several firms from several manufacturing sectors are involved in the automobile supply chain. Worldwide automakers have a policy in place for recycling and reusing their products. As a result of these factors, the automotive supply chain is being driven to alter its resources and operations in order to meet environmental standards [47]. Connecting Industry 4.0 with the Circular Economy can enhance supply chain partners' operational and logistical issues for achieving long-term sustainability [43].

3. Methodology

To answer the research questions presented in the introduction, according to the previous research, authors propose to use Social Network Analysis (SNA) as a method to address findings. SNA is an often used technique in social science; however, in the last decade, this method has increased its application in manufacturing research. Furthermore, the goal of this research is to identify connections in the automobile industry's supply chain. According to this aim, with this method, this study provides a network perspective of the automotive supply chain.

3.1. Data Collection

The data for this empirical study originate from the annual reports from 2018 and 2020 in the automotive industry. Previous studies show that annual reports provide relevant information for research in the automotive industry [48]. For this research, authors use data from automotive manufacturers such as Volkswagen Group, Ford Motor, General Motors, BMW, and Toyota Motor. From the automotive suppliers, the authors use data from firms such as Magna, Continental, ZF, Lear, and Bosch. The authors choose these 10 companies because they are in the top 5 by revenue in both groups (i.e., manufacturers and suppliers) in the automobile industry worldwide. Every annual report is directly provided by the company website and provides financial, innovation, technology, and other useful information. All this information gives a good overview of the automotive manufacturers' and suppliers' overall performance before and during the COVID-19 pandemic.

To obtain data from these annual reports, authors use a snowball sampling method to find all digital technologies and product-related services which are connected to the firms. Moreover, the snowball method helps authors to find which automobile manufacturers are closely related to automobile suppliers. In the application of snowing ball methods, authors search for the relations between manufacturers, suppliers, and their use of digital technologies and product-related services. This study has two sets of actors: firms (manufacturers and suppliers) and resources (digital technologies and product-related services). Authors labeled firms with a combination of letters and numbers ranging from AM1 to AM5 for automotive manufacturers and from AS1 to AS5 for automotive suppliers. The digital technologies are labeled with the following marks: DT1—"*3D-Printing*", DT2—"*Collaborative robots*", DT3—"*Artificial Intelligence*", DT4—"*Big Data Analytics*", DT5—"*Cloud Computing*", DT6—"*Cyber Security*", DT7—"*Internet of Things*", DT8—"*Augmented and Virtual Reality*", and DT9—"*Digital twin*". Product-related services are marked as follows: TS1—"*Spare parts*", TS2—"*Maintenance*", TS3—"*Training*", TS4—"*Leasing*", TS5 —"*Renting*", TS6—"*Pay-per-use*", and TS7—"*Full-service contract*".

3.2. Data Analysis

To visualize relations between automotive manufacturers and suppliers, the authors used SNA graphs with the metrics, which describe the cohesion of the network. For the data analysis, the authors use centrality measures [49]. Degree centrality shows how many direct connections each manufacturer has to suppliers via digital technologies and product-related services in the network. Eigenvector centrality quantifies a firm's impact by counting the number of ties it has to other companies in the network via digital technology and product-related services. Eigenvector Centrality then considers how well linked a business is, how many interconnections its connections have, and so on via the network. Closeness centrality scores each firm based on its 'closeness' to all other firms in the network. The number of times a business stands on the shortest path between other firms in the network in the usage of digital technology and product-related services is measured by betweenness centrality. To measure the centrality of the automotive network, authors use a sociogram table as a base. Table 1 shows a sociogram of the automotive network.

Table 1. Sociogram of the automotive industry.

	DT1	**DT2**	**DT3**	**...**	**DT8**	**DT9**	**TS1**	**...**	**TS7**
AM1	1	1	1	1	1	1	1	1	1
AM2	1	1	1	1	1	1	1	1	1
...	0	1	1	1	1	0	1	1	1
AM5	1	1	1	1	1	0	1	1	1
AS1	1	1	1	1	1	0	1	1	0
...	0	1	1	1	1	0	1	1	1
AS4	0	1	1	1	1	0	1	1	1
AS5	1	1	1	1	1	1	1	1	0

In the sociogram, the binary data describe whether a firm (manufacturer or supplier) did (+1) or did not (0) use the resources (digital technology or product-related services) in the automotive network.

4. Results

Figures 1 and 2 show the structure of the automotive network before and during the period of the COVID-19 pandemic. Figure 1 shows the automotive network in 2018.

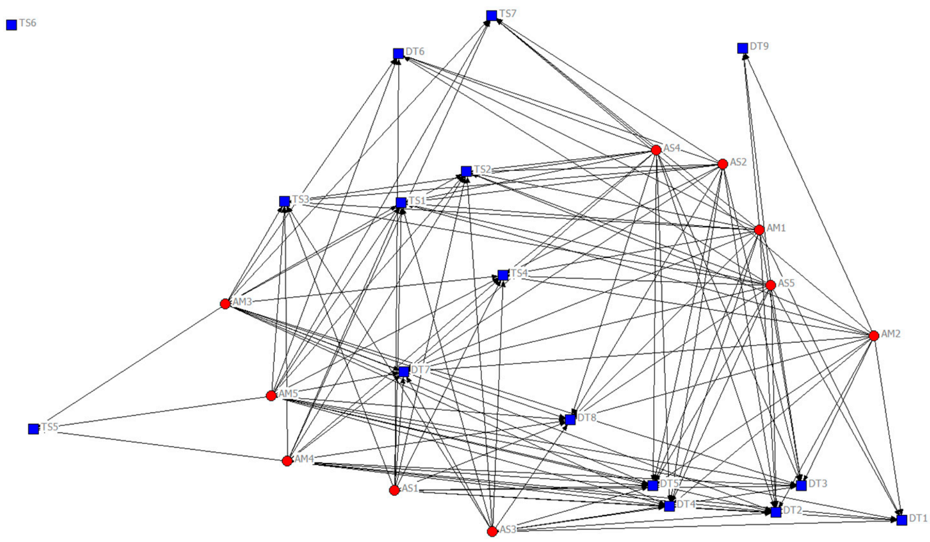

Figure 1. The automotive network in 2018.

In the graphs, the blue squares represent digital technologies and product-related services. The blue square from AM1 to AM5 represents automotive manufacture, and the blue square from AS1 to AS5 is for automotive suppliers. The red circles represent automotive manufacturers and suppliers. The red circles from DT1 to DT9 represent digital technologies, and the red circles from TS1 to TS7 represent product-related services. The density of the network has a value of 0.788, the network average geodesic distance has a value of 1.667, and the network diameter has a value of 4. Figure 2 shows the automotive network in 2020.

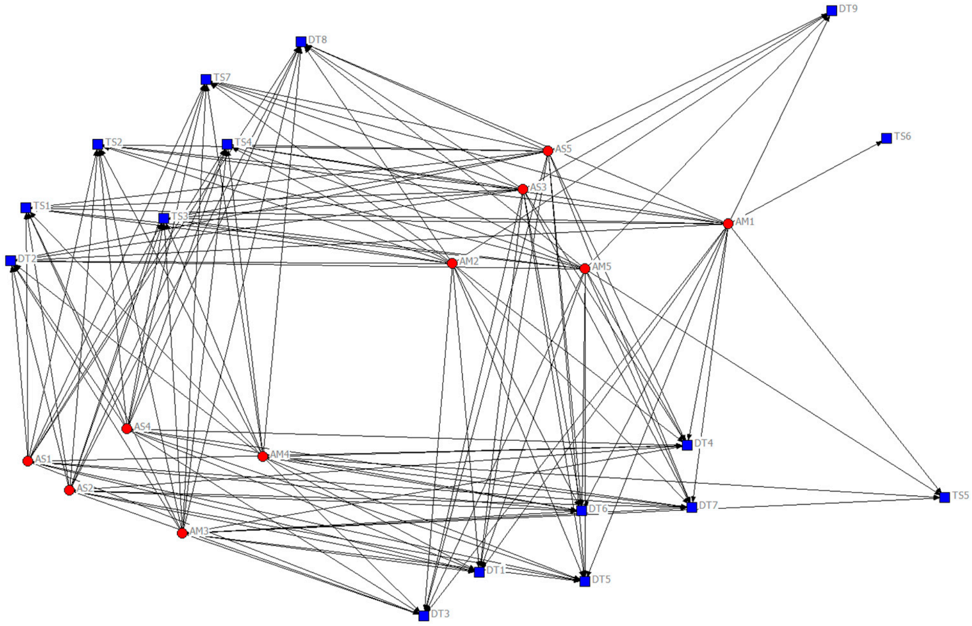

Figure 2. The automotive network in 2020.

The degree of the network in 2020 has a value of 0.875, the network average geodesic distance has a value of 1.631, and the network diameter has a value of 3. According to the description of the network in 2018 and 2020, authors find the difference in all three categories, which shows the power of the networks. The degree measure of the network grows from 0.788 to 0.875 and shows that in the COVID-19 pandemic period, manufacturers have more opportunities to be connected with suppliers via digital technologies and product-related services. The network average geodesic distance went from 1.667 in 2018 to 1.631 in 2020. This value shows that firms are closely connected in the automotive ecosystem. Furthermore, the value of the network diameter goes down from 4 to 3. This value shows that manufacturers and suppliers in the automotive networks have more opportunities to implement new digital technologies and product-related services during the COVID-19 pandemic than before the COVID-19 pandemic. Tables 2 and 3 show the centrality measures of the networks in the automotive industry in 2018 and 2020.

Table 2. Centrality measures of the networks in the automotive industry in 2018.

Firm	Degree Centrality	Eigenvector Centrality	Closeness Centrality	Betweenness Centrality
AM1	**0.875**	**0.339**	**0.971**	**0.065**
AM2	0.75	0.295	0.872	0.046
AM3	0.813	0.32	0.919	0.053
AM4	0.813	0.32	0.919	0.053
AM5	**0.875**	**0.339**	**0.971**	0.064
AS1	0.75	0.311	0.872	0.03
AS2	0.75	0.312	0.872	0.03
AS3	0.688	0.292	0.829	0.022
AS4	0.75	0.312	0.872	0.03
AS5	**0.813**	**0.32**	**0.919**	0.054

The results from 2018 show that auto manufacturers AM1 and AM5 had the highest value in all the centrality measures, except betweenness centrality, where AM1 had better results than AM5. All other manufacturers also had very strong relations in the use of digital technologies and product-related services. Furthermore, results show that automotive suppliers had fewer average relations with automotive manufacturers in the use of digital technologies and product-related services. Only AS5 had similar values as automotive manufacturers. The results from 2020 show different values in the centrality measures. All automotive manufacturers and suppliers had the strongest relations between themselves in the use of digital technologies and product-related services. Moreover, AM1 had relations with all suppliers in the use of these resources. In addition, in the COVID-19 era, all suppliers implement more digital technologies and product-related services to be more competitive in the automotive value chains. Table 4 shows the eigenvector of digital technologies.

Table 3. Centrality measures of the networks in the automotive industry in 2020.

Firm	Degree Centrality	Eigenvector Centrality	Closeness Centrality	Betweenness Centrality
AM1	**1**	**0.33**	**1**	**0.14**
AM2	0.875	0.318	0.895	0.039
AM3	0.875	0.316	0.895	0.043
AM4	0.875	0.316	0.895	0.043
AM5	**0.938**	**0.328**	**0.944**	**0.057**
AS1	0.813	0.306	0.85	0.027
AS2	0.813	0.306	0.85	0.027
AS3	**0.875**	**0.318**	**0.895**	**0.039**
AS4	0.813	0.306	0.85	0.027
AS5	**0.875**	**0.318**	**0.895**	**0.039**

Table 4. Eigenvector of digital technologies in automotive industry in 2018 and 2020.

Digital Technology	2018	2020
DT1	0.207	**0.273**
DT2	**0.295**	**0.273**
DT3	**0.295**	**0.273**
DT4	**0.295**	**0.273**
DT5	**0.295**	**0.273**
DT6	0.21	**0.273**
DT7	**0.295**	**0.273**
DT8	**0.295**	**0.273**
DT9	0.089	0.139

The results of the eigenvector centrality from 2018 show that Collaborative Robots, Artificial Intelligence, Big Data Analytics, Cloud Computing, the Internet of Things, and Augmented and Virtual Reality had a higher number of links that connected automotive manufacturers and automotive suppliers. On the other hand, results from 2020 show that all digital technologies, except Digital Twin, had strong relations with automotive manufacturers and suppliers. These results show that from 2018 to 2020, automotive manufacturers and suppliers created a digital ecosystem to survive the influence of the environment. Table 5 shows the eigenvector of the product-related services industry in 2018 and 2020.

The results of the eigenvector centrality of the product-related services show a similar situation as the eigenvector centrality of digital technologies. The 2018 results show that Spare parts, Maintenance, and Leasing had strong relations with automotive manufacturers and suppliers. On the other hand, results from 2020 show similar eigenvector values for all product-related services, except Renting and Pay-per-use services.

Table 5. Eigenvector of product-related services in automotive industry in 2018 and 2020.

Traditional Services	2018	2020
TS1	**0.295**	**0.273**
TS2	**0.295**	**0.273**
TS3	0.267	**0.273**
TS4	**0.295**	**0.273**
TS5	0.091	0.111
TS6	0	0.028
TS7	0.209	**0.273**

5. Discussion

5.1. Theoretical Implications

The manuscript presents connections in the supply chain of the automotive industry. The data for this study are collected from the annual reports from 2018 and 2020 in the mentioned industry, to find the relations between manufacturers, suppliers, and their use of digital and service resources.

One of the goals of this research is to show the structure of the automotive network before (in 2018) and during the COVID-19 pandemic (in 2020). The degree of the network during the pandemic has a greater value compared to the situation before, which means that in that time interval, the relations between producers and suppliers have become stronger. Automotive manufacturers increasingly realize that improved supplier integration leads to improved performance for the supply chain as a whole [50]. The results from 2018 show that two auto manufacturers had the highest value in all the centrality measures, but all other manufacturers had very strong relations in the use of digital technologies and product-related services as well. However, the results from 2020 show that all automotive manufacturers and suppliers had the strongest relations between themselves in the use of digital technologies and product-related services. In addition, the results show which digital technologies have a higher number of links that connect automotive manufacturers and automotive suppliers. In 2018 these technologies were *Collaborative Robots, Artificial Intelligence, Big Data Analytics, Cloud Computing, the Internet of Things, and Augmented and Virtual Reality*. On the other hand, results from 2020 show that all digital technologies, except Digital Twin, had strong relations with automotive manufacturers and suppliers. This research backs up earlier studies that illustrate the benefits of digital solutions for the automobile sector [51].

The results for product-related services show a similar situation. The 2018 results show that the product-related services *Spare parts, Maintenance, and Leasing* have strong relations with automotive manufacturers and suppliers. On the other hand, results from 2020 show high values for all product-related services and have strong relations with automotive manufacturers and suppliers, except for Renting and Pay-per-use services. Hereafter, the outcomes of this study suggest that digital technology and product-related services have a significant impact on the resilience of manufacturing firms. These findings fill the gaps in the literature about business, sustainability, and digital supply chains in the COVID-19 pandemic era [49]. The ideas of Industry 4.0 assist manufacturing organizations in overcoming the hazards posed by the COVID-19 pandemic. Digital technology, in particular, assists manufacturing organizations in resolving human resource difficulties, which mostly influence supply chain operations [9]. Given the COVID-19 pandemic, supply chain resilience has taken center stage. The Circular Economy and digital supply chains help to ensure social and environmental sustainability [43]. The Circular Economy has served as a catalyst for transformation in the automobile industry, increasing the robustness of business models [40]. From the methodology perspective, this research supports previous related works which employ SNA as a method in manufacturing research [49,52]. These findings open new questions about the implementation of social methods in manufacturing research to obtain relations between different segments.

5.2. Practical Implications

For RQ1: *"Which digital technologies encourage the relations between automotive manufacturers and suppliers?"*, the results show that the digital technologies that boost the relationship between car manufacturers and suppliers are as follows: 3D-Printing, Collaborative robots, Artificial Intelligence, Big Data Analytics, Cloud Computing, Cyber Security, Internet of Things, and Augmented and Virtual Reality.

These findings indicate that the aforementioned digital technologies have the best connections in the industrial ecosystem and strengthen the interaction between vehicle manufacturers and suppliers. For RQ2: *"Which product-related services encourage the relations between automotive manufacturers and suppliers?"*, Spare parts, Maintenance, Training, Leasing, and Full-service contract are product-related services that have the best connections in the COVID-19 pandemic era and boost the relationship between car manufacturers and suppliers. For RQ3: *"How does COVID-19 affect relations between manufacturers and suppliers in the use of digital technologies and product-related services?"*, the results show that manufacturers and suppliers in the automotive networks are more involved in the implementation of new digital technologies and product-related services during the COVID-19 pandemic than before the COVID-19 pandemic. Firms that use more digital solutions have a higher chance of surviving environmental issues. When comparing the situation in 2018 and 2020, it was observed that during the pandemic, all the digital technologies listed in this study had strong relationships with car manufacturers and suppliers. A similar situation exists with product-related services, where also during the pandemic period (2020), all product-related services (except for two) listed in this study had strong relationships with car manufacturers and suppliers.

With this information, managers in the automotive industry could shape their circular business models based on digital services to achieve better market success. During the World Economic Crisis in 2008, the automotive industry transformed its business from traditional producers to service providers (especially Maintenance and Spare parts). The reason for this transformation was the lower level of the economic power of the customers. On the other hand, during the COVID-19 crisis, the automotive industry employs different digital technologies in combination with traditional services to achieve resilience in the environment. The future trends of managers in the automotive industry could be to provide solutions for the customers that support relations with their suppliers, such as electric cars, which enable the Circular Economy. Digital solutions could be a trigger for new business models in the automotive industry. For example, a combination of Maintenance with the IoT and Cloud Computing could result in a predictive maintenance service for customers. Predictive maintenance could enable new information for the suppliers about the need for spare parts to better organize their business. Furthermore, customers could better organize old parts, which could be disposed of by the manufacturers or suppliers based on big data analyses.

6. Conclusions

This study investigates the relations in supply chains of the automotive industry and involves a mixed-method approach, using SNA methods and annual reports of the automotive firms. The purpose of this article is to assess the interaction between manufacturers and suppliers in terms of resource use in respective business models. To achieve the greatest position in the manufacturing ecosystem, firms couple digital technology with product-related services. Worldwide automakers have a policy in place for recycling, reusing, and recovering their products. For these reasons, the automotive supply chain is being compelled to modify its activities to accomplish the governmental guidelines and achieve sustainability goals. The present stage of development of the world automotive industry in the conditions of digitalization indissolubly and everywhere relates to the implementation of new technologies. Today, the automotive industry is moving towards complete digitization, which leads to the development of electric vehicles. Furthermore, the outcomes demonstrate possibilities for firms to improve their processes, making them more sustainable and resilient to challenges such as the COVID-19 pandemic. The emergence of the pandemic has further accelerated the need to make supply chains more sustainable. Due to the COVID-19 pandemic, this Circular Economy supply chain resilience linkage has gained momentum. The mentioned digital technologies, which also affect the digital supply chain, can support the Circular Economy system, which is reflected in the resilience and capabilities of the supply chain. Finally, this study provides information that the combination of digital technologies with product-related services enables a stronger relationship between manufacturers and suppliers in the manufacturing ecosystem. These relations support the manufacturing ecosystem to survive the influence of different environments.

The main limitation of this study is the data set. This study only used annual reports of the automotive firms and analyzed the five most dominant manufacturers. For future research, authors could use the results from a whole consortium to show a wider picture, as well as to expand the research with other actors. It is also desirable to include the annual report from 2022, to investigate possible differences and to try to establish a two-year trend of progress. Moreover, future research could include more information about Industry 5.0 concepts in the supply chain of the automotive industry. With this information, production managers could receive a clearer picture of the sustainability and resilience aspects, rather than only of the value of digitalization in the automotive industry.

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