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The Transformative Effects of Digital Technologies on the Product Design Practices of Servitizing Manufacturers

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Abstract: Digital technologies have enabled manufacturing companies to extend their product-based portfolios with innovative service offerings. Various aspects of this shift have been explored from a service and system design perspective. However, the transformative effects of the deployment of digital technologies on product design practices, particularly in manufacturing firms have been relatively neglected. To explore this issue, semi-structured interviews were conducted with 22 manufacturing industry experts. Four product design practices that underwent a change process as a result of digital transformation were identified: Modifying product designs to enable diverse servicing options at the outset, redefining the role of customer data in the design process, focusing on the outcomes to facilitate co-creation, and designing feedback mechanisms about the past and current product status. The articulation of these themes contribute to the design literature on the effects of digital transformation, as well as to the literature on service transitions in manufacturing firms.

Keywords: Digital technologies, Manufacturing industry, Product design, Servitization

1. Introduction

This paper is concerned with understanding the transformative effects of digital technologies on the product design practices of manufacturing firms that are moving towards service provision, often referred to as servitization. Products act as implicit signifiers of firms' competences in production and product design in the servitization domain (Spring & Araujo, 2017). Linking them with digital technologies such as the Internet of Things (IoT), cloud computing, predictive analytics, and remote condition monitoring enables value creation beyond traditional design and manufacturing (Ardolino et al., 2018; Grubic, 2018; Rymaszewska et al., 2017). With such technologies, products become connected, being able to sense their own conditions and thus allowing real-time data collection, continuous communication, and interactive feedback (Wünderlich et al., 2015). In Porter and Heppelmann's (2014) terms, "smart, connected products" can be referred to as complex systems, combining *hardware, sensors, data storage, microprocessors, software, and connectivity*. As these systems collect and compute quality data about their current status, usage history and performance (Allmendinger & Lombreglia, 2005), informational or intellectual resources for value co-creation increase (Breidbach et al., 2018); paving the way for a radical change in provider-customer relations (Coreynen et al., 2017). In this respect, algorithmic intervention at large scale is a significant driver of innovation and design is a means to facilitate this with low friction (Funk et al., 2018). Hence, a manufacturer's capability to handle data increasingly determines the success of product design in the digital era (Tao et al., 2018).

Various aspects of the digital transformation have been explored from a service and system design perspective, notably: the antecedents of successful IoT service and system design (Sayar & Er, 2018), the design of smart services (Norman, 2007), and optimization of the design of all parts of a system relative to one another (Porter & Heppelmann, 2014). However, the transformative effects of the deployment of digital technologies on product design practices, particularly in manufacturing firms have been relatively neglected. This requires attention as manufacturers that shift to provision of services need to manage both product and service design practices simultaneously (Pawar et al., 2009). For instance, in order to design its maintenance activities effectively, a manufacturing firm needs to design products that can detect which components are approaching failure and send up-to-date alerts (Allmendinger & Lombreglia, 2005). According to Spring & Araujo (2017, p. 127), digital technologies potentially allow "constant monitoring, adjustment and redefinition of products and their relationships to other actors and artefacts in a network". Manufacturers are therefore able to gain detailed insights on who uses the product at a specific time/usage instance; where the product is located at a specific time/usage instance; how much and why a product is used; how the product is working; how a specific product-related issue can be solved; and how tasks can be done more effectively/efficiently (Ardolino et al., 2018). As it becomes possible to make a wide range of products 'smart', and as the systems for data capture and analysis develop, opportunities for novel value creation can be created (Spring & Araujo, 2017). Thus, the implications of these changes for product design practices need to be investigated.

2. Digital Technologies in the Manufacturing Industry Context

In the context of manufacturing, technologies are designed and engineered according to industrial needs, logistics, and economies of scale (Funk et al., 2018). Roos (2016) suggests that digital technologies such as Big Data, Big Data Analytics, Artificial Intelligence, algorithmic development, and IoT are referred to as Key Enabling Technologies (KETs), characterized by their ability to impact the manufacturing industry via changes in opportunity space – i.e. comprising what is possible in terms of manufacturing; and demand space – i.e. an increasing awareness among customers of what is available in the market. These technologies have enabled manufacturers to compete with complex offerings that comprise products, services, and data, and improve their business performance by analysis, optimization, prediction, and integration (Töytari et al., 2018). For example, a manufacturing company might invest in remote monitoring and diagnostics so it can deploy a technician ahead of an equipment failure preemptively (Allmendinger & Lombreglia, 2005).

MAN Truck and Bus UK is one of the manufacturers that relies on digital technologies to track vehicles, measure driver behaviour, and record fuel consumption (Grubic, 2018). Another well-known company is Xerox, which has moved its focus from photocopiers and printing to the effective management and optimization of customers' digital information/document-related processes (Visintin, 2014). Digital technologies enable the creation of a *digital workflow*, allowing copiers to digitize, store and distribute documents, besides increasing the machine's reliability (Visintin, 2014). Therefore, what is sold is no longer the physical product, but the 'value' or business benefit derived from the product (Pawar et al., 2009). Porter & Heppelmann (2014) suggest that companies utilizing these technologies must select the set of capabilities which will help them deliver the value demanded by their customers. They group these capabilities into four areas: 1. *Monitoring* of a product's condition and tracking its operating characteristics; 2. *Controlling* product functions and personalising the user experience; 3. *Optimizing* product operation and use to enhance its performance; 4. Achieving a level of *autonomy* that facilitates coordination with other products and systems (Porter & Heppelmann, 2014). Therefore, new requirements are placed on the design of products, as the process becomes more and more virtualizing, networking, and visualizing (Tao et al., 2017). Some major challenges ahead of product design driven by digital technologies have also been identified, such as: a) Effectively filtering data into useful information that can be used by designers to support their decisions at different phases of the design process; b) Effectively integrating a variety of data about the product and customers that are collected from diverse resources; c) Rapidly responding to a current event based on the real-time data; d) Predicting a future event that will occur based on historical data (Tao et al., 2018). Overcoming these challenges and benefiting from the opportunities of digital transformation require efficient mobilization of resources internally and/or collaboration with other companies in the business ecosystem (Goduscheit & Faullant, 2018).

3. Method

To explore the transformative effects of digital technologies on the design of products, 22 semi-structured interviews were conducted with manufacturing industry experts in the context of a research study, each lasting between 1,5-2 hours. The experts were selected from different industries such as aerospace, furniture, automotive, industrial automation and IT, to gain a rich picture of the changes in product design practices. Their positions included directors of the service organizations, product managers, business development managers, design managers, field service managers, and innovation managers. An information sheet that explained the overall aims of the study was sent to the interviewees via e-mail. All interviews were recorded and transcribed verbatim. The interview guide included questions about the nature of the current offerings, how these offerings were designed and developed, how data collected from the customers were handled, and how (if at all) the established design processes were adapted to support the utilization of digital technologies.

In the data analysis, a thematic account of the interviews was developed (Braun & Clarke, 2006). First, interview transcripts were read and re-read and initial ideas were noted. In the next phase, first-order codes for the entire data set were identified. These codes were then combined to create second order themes. Finally, the linkages between first-order codes, second order themes and aggregate themes were refined, resulting in the identification of product design practices that underwent a change process as a result of digital transformation.

4. Findings

The analysis of the interviews revealed four main themes as explained below: 1. Modifying product designs to enable diverse servicing options at the outset; 2. Redefining the role of customer data in the design process; 3. Focusing on the outcomes and performance improvements to facilitate co-creation with customers; 4. Designing feedback mechanisms about the past and current product status.

4.1 Modifying product designs to enable diverse servicing options at the outset

Using data to enhance or develop new products and the merging of products and services are two important dimensions of technological change and industry convergence (Hopp et al., 2018). This theme refers to the recognition of service requirements at early phases in the design and development of products; meaning that the product is designed as part of the service, rather than designed separately and added on to the service. Thus, manufacturers need to refine their product designs with serviceability, maintainability, and reliability in mind at the outset. The data gathered from customers offer novel insights on different usage patterns (Spring & Araujo, 2017), helping manufacturing companies to reconfigure their products with emphasis on recovery, re-use, maintenance, management of spare parts, or replacement of hardware/equipment. This was particularly evident in a furniture company. Their office furniture entailed materials and components with different lifecycles. Analysing how the products and office space was used enabled the company to think about the ways that they could make their furniture last longer – i.e. offering different services such as reupholstering old chairs and upholstery cleaning, or designing multi-purpose products that made work activities more flexible.

In the aerospace and defence company, product design activities had to focus on making the product more robust and reliable, since the company's major aim was to minimize downtime when the engines were not able to fly. Sensors and communications equipment were installed on the product to support in-service monitoring, as explained by the Innovation Manager:

> We're increasingly trying to design our products for service, recognizing that the customer doesn't want a jet engine. They want to get from A to B. So we should be designing a whole solution system, which means they've got the product but they've also got that product in a reliable, serviceable, maintainable, available way. When you mentioned about the life cycle of designing a product, then we're increasingly trying to recognize service requirements at early phases in the design and development of that product. We've been successful actually at removing inherent reliability issues within our engines. We're recognizing them and designing out those flaws within the hardware or software of the products, but there's a lot more we can do. (Innovation Manager, Aerospace and Defence)

Furthermore, a special team was setup to analyse the criticality of component wear and failure to determine required improvements to design and predictive maintenance needs. In this way, they could understand which parts might need servicing sooner and modify the design of the product accordingly. On the other hand, besides examining component parts only, the company also looked at the system as a whole and the emerging behaviour by combining different elements together for the impacts they had on the overall product (the engine). To achieve this, the company's design process provided a framework for reviewing projects through operation of independent gate reviews at key points during the lifecycle of the product. It therefore ensured that business benefits were optimized and project risks were managed effectively before further commitment.

The industrial automation company perceived product and service design as integrated practices. To enable this integration, the product design team also involved people from the service organization. Therefore increasingly, the products that the company sold had a service element built into them at the outset:

> I think the whole aspect of designing products, you're really in effect saying that service is an integrated part of product design. A significant aspect of our work is that when you start to look at producing the product, you also need to be thinking

about the servicing that will be developed around it. (Customer Training Business Manager, Industrial Automation)

4.2 Redefining the role of customer data in the design process

The digital transformation has generated a data-rich environment where increasingly, companies acquire and analyse a variety of customer data to enhance their innovation activities (Rindfleisch et al., 2017). Desai et al. (2017) highlight the potentially creative character of data, showing how they become embedded in webs of relations and reshape everyday interactions. Along the same lines, the deployment of digital technologies in manufacturing firms necessitate a reconceptualization of data, as not only outputs of customers' use of products, but also as agents to organize and manage the product design process with the other actors. The interviewees provided examples of the various ways they have treated and utilized customer data: To build synergy between product, service, and information components of the design process; to minimize internal resistance regarding the implementation of the new offerings; to explain the roles of different actors in the network; and to educate customers on more efficient product use. For example, in the industrial automation company, data on components' reliability and failure modes were collected and analysed. Based upon this analysis, revised designs could be prepared to reduce the occurrence of failure. Customers' process and operational data were collected and analysed to predict the optimum time for plant and machine component maintenance. The evaluation of these data helped the manufacturer to identify the obsolescence of equipment, increase energy transparency, prevent unscheduled downtimes, and to improve productivity and performance. Using specific software tools, the company could pick the most critical areas so that maintenance activities could be carried out more efficiently.

As manufacturers produced tangible manifestations of the collected data through sketches, drawings, diagrams, and manuals, they also facilitated conversations with their customers. Hence, they provided customers the means to be able to get partly involved in designing their own solutions. In the office furniture company, the provision of data-driven insights enabled the company to make design proposals that optimized the use of space and choice of furniture, creating an agile working environment suitable for both employees and businesses. Moreover, the majority of the experts emphasized that data triggered the design of new products in the manufacturing companies, by revealing and making visible customer problems that could otherwise go unnoticed.

In the company that provided IT solutions, core offerings were based on collecting data from the customers' installed base in various ways such as employing a collector in their network or connecting to individual devices. Then, using a software, customers' network information were correlated with the company's service contract database, identifying the type of service coverage for each device and the number of devices that have passed the last date of support. Finally, customers were notified about the critical assets that were not covered and hardware replacements were scheduled proactively. This reduced the mean time to resolutions for customers' problems and the amount of downtime within the customers' network. Through its consultancy organization, the company could also give advice about how sensors at various points could be deployed in a network configuration to allow local monitoring. It could then provide predictive analytics to spot any other areas that might be failing and to monitor the system throughout the course of its operation. These insights enabled customers to obtain visibility into their assets, plan which products to purchase, improve the operational efficiency of their IT infrastructure, and forecast future needs.

Data also allowed development teams to make informed decisions as they enabled them to measure against a variety of performance metrics and therefore design on the basis of evidence rather than intuition (McAfee & Brynjolfsson, 2012). Moreover, customers' finance departments could quickly allocate financial resources to the required areas, since the collected data were proof that certain components needed maintenance:

> We've got some tools now that we can use to analyse the equipment that's on-site. They can conduct the full life analysis for the product and it's like people mending roads. They don't have the money to mend all the roads so they only do the important parts. These software tools allow us to pick out the parts that are most critical, which is useful for the maintenance people. Because they can then go to the finance people and say 'I need to spend some money in that area and here is the proof'. (Business Development Manager – Service Coordination, Industrial Automation)

4.3 Focusing on the outcomes and performance improvements to facilitate co-creation with customers

Outcome or performance-based strategies are the most advanced stage of a manufacturer's shift to service, since they enable to achieve a better fit with customer needs. With these strategies, manufacturing firms deliver specific outcomes required by the customers and offer full performance guarantees (Visnjic et al., 2018). The Innovation Manager of an aerospace and defence company explained how their value proposition evolved with the IoT technology from selling engines to managing the maintenance of the engine through its life on wing, by capturing engine performance data in real time. This required very close customer collaboration and in-depth understanding of airline operations. Thus, customers got involved in the early stages of the design process, particularly providing engineering input regarding the product architecture. Moreover, another expert highlighted that the differences in their customers' performance goals needed to be acknowledged and therefore, *customization* became a significant aspect of their product design practices.

The information collected from customers also needed to be processed and calculated, to help different agents in planning or decision-making (Callon, 2002). Hence, another significant factor in the provision of customer outcomes and improving performance is developing appropriate measures and metrics; or in Callon's (2002) terms, *quantification*. According to the experts, this was a way of defining the main components/features of the offering and keeping track of whether the business goals were met or not:

> We take something really complicated and we measure it quite simply, so we try and get a handful of metrics. How quickly can we turn it around? If we have to take an engine off, how quickly do they get the next one? And it's not just about how many times you've taken it off, even when it's on, is it causing you an issue? How do we minimize and measure that? What percentages of availability are customers prepared to pay for and what's a reasonable price to charge for that? So the outcomes are very output-based rather than input-based, so we're focusing on the customer's operation and what's important to him. (Senior Vice President and Director, Aerospace and Defence)

New software-based features and virtualization have enabled the industrial automation company to focus not only on the product itself but also on the provision of measurable outcomes:

> The focus seems to have changed to just saying 'I'm going to replace this machine and put a new machine with a shiny new motor' and things like that. Customers are not interested in that. They will do it if there is a financial benefit to doing it. So it uses less power, it's more efficient, it's more reliable, and all these things matter to the customer. You can't sell on price, you have to sell on value. So it moves the discussion completely away from the product. (Service Sales Manager, Industrial Automation)

Another expert from the IT sector mentioned that the evolution from a traditional product manufacturer to include high-touch services had to overcome the traditional product design approach both in mindset and in practice. Currently, design deliverables are based on helping customers get specific business outcomes such as reducing operational risks and doing financial planning around their assets. This strategic orientation towards outcomes required designing solutions that combine hardware and software capabilities to gain near real-time product visibility. As a result, a more sophisticated, consultative engagement with the customers could be achieved. The Director of Partner Service Product explained how the nature of the interaction with customers have changed and how customers have become active participants in the design process to ensure that their intended business outcomes are achieved:

> How we interact with customers is changing as we bring in digital elements. In the past, there used to be a lot of focus groups, 'voice of the customer' meetings. More and more though, we're engaging the customers in the actual design process. So we get feedback before we develop things as opposed to developing something, putting it out there, and then waiting for a 'voice of the customer' session or a focus group. We need that interaction, especially to validate how much we're delivering the value that we have targeted and how much our customers are getting the return on the investments they have made. (Director – Partner Service Product, IT hardware and software provider)

4.4 Designing feedback mechanisms about the past and present product condition

A significant aspect of manufacturers' transformed design practices was providing feedback about the past and current product status to various stakeholders. It is assumed that the output parameters including the product's performance and the condition of the product's components are functionally dependent (Grubic & Jennions, 2018). This dependency can be communicated to the customers and/or end users through sending regular reports and alerts. According to Valencia et al. (2015), interactive feedback mechanisms help customers to assess a specific situation and take action accordingly. For example, Business Development Managers of a multinational truck manufacturer explained the design process of a mobile application that enabled their customers to monitor fuel consumption of the trucks and to check their reports 24/7. Similarly, experts from the aerospace and defence industry aimed to improve their mobile capabilities through designing a new portal so that they could mobilize staff to the right places when problems occurred as quickly as possible. Furthermore, an Operations Centre was established to monitor the aircraft all over the world, in the air, on a minute-by-minute basis. In this way, they could provide pilots with information on more efficient flying techniques. Another expert from the industrial automation sector illustrated their global platform, where they collected all the information about customers' installed base of equipment. From this platform, the firm provided different levels of reporting on whether the equipment was available or whether it was obsolete etc. These reports comprised feedback that were directly linked to performance outcomes, such as energy savings, efficiency savings, and reliability savings. Similarly, the aerospace company used the feedback gathered on the engine's condition in the design process to ensure that the aircraft availability and performance objectives were met:

> You can start designing a product, which whilst it starts with an attribute like 'we want it to be this percentage available'. To make that happen you kind of think, well in that case we're going to need data. We're going to need to understand what condition it is in. We need to be able to predict how it's going to age. That then starts to shape your whole design process. (Capability Lead for Field Services, Aerospace and Defence)

The products manufactured by the industrial automation company also had a service element built into them automatically that enabled them to send indications about their status, making it much easier to find the causes of problems:

> So you want things to tell you what to do. 'The machine stopped because that broke over there' and increasingly now we're looking at products which we call it 'serviceability'. So inside the device, it will tell you when it's going wrong. Instead of you waiting for it, it tells you. (Service Sales Manager, Industrial Automation)

The IT solutions company provided a series of detailed reports and proactive alerts including security warnings and field notices through a web-based portal. These entailed insights into the service coverage status of customers' assets. Furthermore, as part of the support system, the products sent notices in the case of a failure, enabling the company to proactively schedule for a hardware replacement. This significantly reduced the mean time to resolution to customer issues. Moreover, the company developed metrics that allowed for easier and better communication of the value customers have acquired from using the products. Finally, the Sales Manager of a leading office furniture manufacturer mentioned that they were planning to embed simple sensors on their furniture to better monitor which products were underused or overused, and therefore design a more efficient workspace for customers:

> We're thinking about for instance, building very simple sensors to our products. The idea is that you can build sensors into all your furniture in your space so that you can tell what's used and what isn't used, between which hours. You can then overlay that with questionnaires and all sorts of other data sources to build a map of how the office space is being used. Ultimately, you can reduce the amount of space that you need as you're trying to optimize it. (Design & Brand Manager, Furniture)

5. Discussion and Conclusion

Digital technologies such as the IoT, predictive analytics, cloud computing, and remote condition monitoring transform the way companies develop their offerings and the way they interact with their customers. In this new context, products become part of a complex system, leading to an increase in the number and variety of the components, activities and actors involved (Zou et al., 2018). The interviews with the industry experts illustrated four product design practices that underwent a transition, facilitated by the utilization of digital technologies. The implications of these changing design practices for manufacturing companies are presented in Table 1.

Table 1. Good design strategies in the digital products and service lifecycle.

Changing product design practices	Good design strategies in the digital products and service lifecycle
Modifying product designs to enable diverse servicing options at the outset	Recognizing service requirements at early phases in the design and development of products
	Setting up special teams to analyse the criticality of component wear and failure
	Focusing on the customer's product usage patterns

Redefining the role of customer data in the design process	Producing tangible manifestations of the collected data to facilitate conversations with the customers
	Utilizing predictive analytics tools to monitor systems throughout the course of their operation
Focusing on the outcomes and performance improvements to facilitate co-creation with customers	Involving customers in the early stages of the design process
	Developing appropriate measures and performance metrics
	Reconsidering design deliverables based on the achievement of specific business outcomes
Designing feedback mechanisms about the past and current product status	Sending regular alerts and detailed reports to the customers
	Enabling products to send indications/notices in the case of a failure

First, connecting to the products, capturing data from them, and interpreting these data have become major aspects of the design process. Therefore, firms are required to design the 'access points' on the products that would enable them to proactively diagnose issues and to make modifications to the components when needed. Second, from an organizational perspective, manufacturing companies need to alter the relationship of product design with other internal functions (e.g. sales and marketing) and with the operations of different actors in the value network. As manufacturers build closer relationships with their customers due to the recurrent interaction triggered by digital technologies, different departments and stakeholders are also required to exchange information/knowledge frequently, to be responsive to the changing demands. Data play an important role in this respect, facilitating coordination among diverse functions and actors by providing further proof of the critical areas that they need to focus on. Third, it is significant for manufacturers to create numerical indicators as they process the data collected through sensors and software, so they can measure against identified performance targets. This *quantification* helps them build up a more stable, long-lasting relationship with customers (Callon, 2002), by providing evidence on how much they have achieved the targeted business goals. The fourth implication is related to making sense of the different usage patterns revealed from the data collected from the products and customers, particularly in the early phases of the design process. This potentially allows manufacturing companies to consider how they could extend the life of their product and to deliver more personalized customer experiences. Finally, the alerts and reports provided as a result of data analysis continuously reconfigure product design activities, guiding manufacturers' decisions on the allocation of human and financial resources, on the capabilities to be accessed or developed, and on the features/components to be included in future products.

Consequently, the findings of this study show that digital technologies require a reconsideration of manufacturers' product design practices as; focusing on customer outcomes and performance goals, being shaped and organized by customer data, allowing for modifications to enable effective service delivery, and informing different actors in the value network about the past and current product condition. Servitizing manufacturers can utilize these four themes to develop 'good design' strategies in an era of digital transformation.

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