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Abstract Digitalization is a trend that is changing society and that will also have significant effects on the asset management and manufacturing industry. Simultaneously with the digitalization trend, formerly product-centric companies have been increasingly adopting service components in their products and basing their competitive strategies on services. The purpose of this study is to increase the understanding of how manufacturing companies see the effects of digitalization in their business, and how digitalization might affect their product and service provision including asset related services. The paper utilises explorative case study approach. The research data was collected by semi-structured interviews with experts representing different roles in manufacturing ecosystems. The paper builds a classification for digitalization-enabled PSS for manufacturing industry.

1 Introduction

Digitalization is one of the major global trends that is expected to transform the manufacturing industry by enhancing the collection and analysis of information in a crucial way. One of the commonly used definitions of digitalization is using "digital technologies to change a business model and provide new revenue and value-producing opportunities" (Gartner, 2016). The digitalization process has been ongoing in the manufacturing industry for decades, for instance in forms of condition-based maintenance and remote control. However, the recent developments in technology and the reduced cost of sensors and IT systems enable a more advanced form of digitalization called the Internet of Things (IoT). According to Gubbi et al., (2013) IoT can be defined as interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications.

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This requires seamless large-scale sensing, data analytics and information representation using cutting edge ubiquitous sensing and cloud computing.

Simultaneously with the digitalization trend, formerly product-centric companies have been increasingly adopting service components in their products and basing their competitive strategies on services (Lerch and Gotsch, 2015, Baines and Lightfoot, 2013). The service research has moved from dyadic supplier customer relationships to service ecosystems and value co-creation through service platforms (Lusch and Nambisan, 2015). This development has been commonly known as servitization, or expanding the offering to product-service systems (PSS). PSS can be defined as "a marketable set of products and services capable of jointly fulfilling a user's needs" (Goedkoop et al., 1999).

Recently de Senzi Zancul et al. (2016) have studied the application of IoT technologies in PSS. They argue that one major opportunity for IoT adoption is the continuing trend towards servitization. Digitalization offers possibilities to extend service offering by enabling the service provider to monitor and to gather data from its products during the usage phase. Rymaszewska et al. (2017) present case studies and a framework for developing digitalization-enabled PSS. They conclude that IoT-based solutions can play a significant role in the development of the PSS of the future. IoT-based servitization strategy enable companies to create value propositions based on reliable data on product usage and performance.

Companies are at varying levels of development in relation to implementing the digitalization-enabled PSSs. The level of adapting digital solutions is dependent, for instance, on the size, industrial sector, and location of the company. Advanced PSSs can be classified into four levels, based on their capabilities: monitoring, control, optimisation, and autonomy (Porter and Heppelmann, 2014). Tukker (2004) divides PSS into product-oriented, use-oriented, and result-oriented services where product-oriented services represent a low level and result-oriented a high level of servitization.

The goal of this study is to increase the understanding of how manufacturing companies see the role of digitalization and PSS in their present business. In this paper, we first introduce the methodology of the study, and then present the details about the studied companies and the results of the case studies. Finally, we present conclusions that can be drawn from the results.

2 Research design

The methodological approach utilised in this study is qualitative case study research (e.g. Yin, 2003). The nature of the study is exploratory and its goal is to

generate theory from case study evidence (e.g. Eisenhardt, 1989). Selective (or purposeful) sampling was used to choose the case companies for the research (Morse, 1991, Coyne, 1997). A typical manufacturing value network includes actors such as the lead producer and its suppliers and customers (e.g. Miltenburg, 2005). For this study, we focus on lead producers who provide the PSS and their subcontractors and IT infrastructure providers who are the crucial suppliers in the value network. The case firms were selected based on their reputation as advanced actors in digitalization. The selection was made in an expert group that conducted a study on status of industrial internet in Finland (Ailisto et al., 2015).

Representatives from ten companies operating in the Finnish manufacturing industry were interviewed on their views and insights regarding the effects of the digitalization on their industrial branch and their company's competitive position Five of the companies were manufacturing companies providing solutions with emphasis on systems and services. Two companies were IT infrastructure and service providers and two companies were subcontractors for manufacturing industry. One interviewee was from a development agency that supports regional companies. The interviewees were responsible for new digital services or product development in their companies or organisations. Semi-structured interviews were conducted either face to face, by phone, or using IP-based communication software. The interviewees were asked to express their views on the industrial internet, digitalization, and the related product-service systems, both in their own company and in the relevant industrial sector.

The authors analysed the results as a team, thus increasing the creative potential of the study and the confidence in findings (Eisenhardt, 1989). Detailed write-ups were made for each case. The interview data was coded. The cases and actors were analysed individually to identify similarities within them. Additionally, the patterns across actor groups were analysed.

3 How is the manufacturing industry affected by digitalization?

Lead producers consider that digitalization enables better integration of companies and business networks, which has great potential for increasing the productivity of the manufacturing industry. Overall, companies in the manufacturing industry are following the development and developing digital applications at varying levels; some companies are integrating sensors into their products and manufacturing plants, whereas others are already exploring the opportunities of big data and other forms of advanced analytics. There are some frontrunners regarding the intelligent products, but also a lot of those who have neither noticed nor reacted to the trend. Large companies are more advanced than SMEs in applying digital technologies.

Some bigger manufacturing companies are not yet very advanced in digital services, because their machine fleet is so versatile; newer products are technologically advanced but a large part of their revenue comes from previous product generations. Most companies are still uncertain about what kind of impact digitalization will have on their business.

The dominance of hardware is diminishing as the new business environment emphasises services and software. Frontrunner lead producers aim for new ecosystems and business related to the intelligent products through partnerships. Information produced by other actors in the business ecosystem, and also by third parties, is utilised. This forms the basis for more transparent as-a-service business models, which are expected to be more popular in the near future. Advanced companies consider the digitalization of existing services that could be offered to new customer segments. Many lead producer companies already have a strong tradition in utilising digital applications. Currently, the digitalization affects mostly assets and asset-related services, and the main applications concentrate on how to get better predictions from the data, how to automate analytics, and how to increase the productivity of maintenance activities. More advanced companies develop innovation platforms and application programming interfaces (APIs), organise innovation contests, and discuss with start-ups and SMEs to provide novel content for their platform and third-party services. Lead producers develop and offer autonomous and intelligent machines, fleet-level solutions (optimising and prioritisation), and PSSs. Some advanced companies have a standard portfolio of advanced digital services in place. However, digital applications currently represent only a small part of the whole offering of the companies.

IT infrastructure provider companies see digitalization as a big opportunity that is affecting all the industrial sectors. Intelligent products are a natural growth area for their current competencies, as cloud services and servers are central in solution delivery. ICT solutions will be increasingly cloud based, and electronic commerce is going to change radically. IT infrastructure providers see two perspectives of the digitalization: (1) having lots of data in their own networks offers business opportunities through analysis, and (2) network management and remote control services can be offered to customers. Internally, the intelligent products have a major role; there is a large amount of data in the companies' networks that can be analysed. The goal of the analysis is to improve their processes and prioritise investments better. Digital services have been utilised already for a long time in network management. For instance, the management of customers' networks, remote control, and network development are digital services that are already offered. Companies can sell their digitalization competencies and strive for pilot cases to test potential new services, which also include joint offerings with third-party companies.

Subcontractors that deliver mainly components and individual subsystems to system providers find that digitalization is not yet actualised at subcontractor level.

Subcontractors think that lead producers are the main utilisers of intelligent products, and see the applications as an increased number of wireless sensors. The interviewed companies do not have digital applications, apart from sensors in the manufacturing process, in use, but they offer products in which it could be utilised in the form of condition monitoring. Additionally, there are product development projects in place that also concern the supporting IT solutions. The interviewed subcontractors raised up the use of solutions that do not require as much initial investment and that are "good enough" for their use, such as social media, cloud services, and microblogs. These internet-based solutions are in use to spread information and hold discussions with the lead producer's development department.

4 Classification of digitalisation-enabled PSS in manufacturing industry

Based on the interviews and classifications of Porter and Heppelmann (2014) and Tukker (2004), we classify digitalization-enabled PSSs into four categories, reflecting the complexity and potential benefits of a service delivery:

1. digital services related to products and manufacturing processes,
2. optimising the performance of a fleet of machines, components, and manufacturing equipment,
3. advanced asset management and productivity services, and
4. integrated business ecosystems.

The first category deals with single product-related services and aims to increase the effectiveness of maintenance and other product-related services through operation and business-related data. From the manufacturing perspective, the goal of these services is to improve the reliability and quality of the product or the manufacturing process. In the second category, the focus is on the fleet of products, services, and manufacturing equipment. These solutions aim to improve the reliability, resource efficiency, quality, and performance of PSS delivery and manufacturing equipment, through analysis of a large amount of data and understanding the best practices in the industry.

Advanced asset management and productivity services (third category) consider intelligent, resilient, and self-adapting manufacturing equipment and the PSS. Digital services are integrated into customers' systems, optimising the performance and life-cycle costs of the PSS. For instance, remote monitoring of products, and information on asset location, condition, and use, are necessary on this level. From the manufacturing perspective, the third category contains automated decision-making, based on predictive and condition-based maintenance. The integrated business ecosystem level (fourth category) includes all the features on the previous levels on an

ecosystem level. It focuses on creating the service experience together with an extended business ecosystem consisting of customers, subcontractors, service providers, consumers, and so on. In this category, the manufacturing ecosystems are transparent and enable the different actors in the network to plan their functions optimally. It includes the choice of a manufacturing method that is optimal for the PSS.

5 Discussion and conclusions

In this paper, we presented views of different actors in the manufacturing ecosystem, lead producers, IT infrastructure companies and subcontractors, on digitalization. Additionally, we presented a framework of different levels of a digitalization-enabled PSS. The study increased the understanding of how Finnish manufacturing companies see the role of digitalization and digital services and how different actors in the manufacturing industry position themselves in the framework. Manufacturing industry companies have been adopting, or have considered adopting, digital services as a part of their offering, or to enhance their manufacturing processes. Based on the interview results, lead producers are the most advanced in providing a digital PSS to their customers.

Solution and IT infrastructure providers, in particular, see that digitalization brings new types of PSS and business models. The importance of service components increases and the nature of service delivery may change, especially in maintenance. These changes require new information management and information systems-related competencies in companies. With the increased data intensity of the PSS, questions about the ownership, availability, and security of data become more important.

In our study, the subcontractors (all SME companies) expected that the lead producers would drive the change. On the other hand, lead producers were anticipating new entrants to the market and changing roles in the supply chain. IT providers expecting changes in the logistics chains and major changes in the industry. This suggests that manufacturing ecosystems are in transformation. We still lack understanding on the transformation towards digitalization enabled PSS. Especially, how to involve SMEs to the change and new value sharing models.

The importance of IT and service components increases when moving towards more advanced PSSs (see Figure 1). The increased importance of IT is a potential source of disruption for the manufacturing industry. It is uncertain which actors in the business ecosystem will take control of the increased value in IT, and which will be reduced to a lesser role. IT infrastructure providers or platform providers may

take over the management of platforms and take a major share of the value of manufacturing. However, it is also possible that their role will be reduced to providing connectivity between the actors in the network. Similarly, solution providers may control the whole ecosystem or may be "just" hardware product providers. Additionally, subcontractors may take a larger role in the supply chain, and may start to compete with solution providers, retain a similar position as currently, or be forced out of the market.

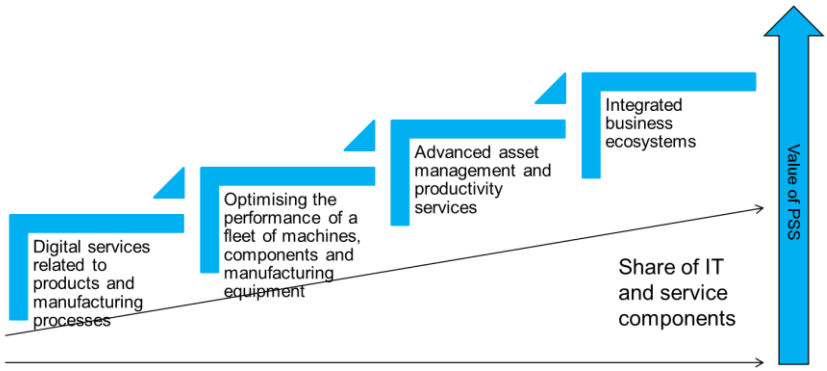

Figure 1. Advanced forms of the PSS increase the importance and value of IT and service components

The most advanced solution providers are already active or have plans to be involved in providing PSSs to their customers. All the actors in the manufacturing industry have been adopting or have considered adopting digital services as a part of their offering, or to enhance their manufacturing processes, but there are significant differences in the level of digitalization between actors. Subcontractors are adopting digital services in their service portfolio more slowly than solution providers or IT infrastructure providers. All the actor groups see a transition towards deeper partnerships and ecosystems in the future. This is enabled by connecting all the machines to the internet, if there is a benefit seen in the connection. The connection of machines and applications is enabled by platforms, which are of rapidly growing importance (e.g., Porter and Heppelmann, 2014, Yoo et al., 2012). Solution providers seem to be the most likely leaders in developing both advanced asset management and productivity services, and integrated business ecosystems. However, the other actors, or the functions they provide, are also needed in the complex integrated business ecosystems of the future.

Companies provide a PSS to their customers based on the data created in their business ecosystem. Advanced manufacturing companies already offer knowledge as a service component, as a part of their PSS. In the future, an increasing number of companies may move from providing data or information as a service, to providing comprehensive knowledge-based services as a part of their PSS.

The research explores the state of digitalization in the manufacturing sector. As such it contributes to the scare body of literature that deals with digitalization enabled PSS. Our research also raises up some important topics like data ownership and changing service delivery beyond traditional PSS. These findings should also be reflected in the future PSS research. This paper gives managers guidelines on how to develop a more advanced digitalization-enabled PSS in their companies. Additionally, it enables the comparison of their digitalization-enabled PSS to some of the more advanced companies. The case study research has been criticized of its lack of rigor and basis for generalization, and requirement of lots of resources and time to conduct (Yin, 2003). The case studies presented in this paper rely on qualitative data, which can be regarded as a limiting factor. In this study, the number of case companies and interviews in the three actor groups is limited which affects the generalisability of results. The effects of the limited amount of case companies and interviews on reliability of results are diminished by careful sampling of companies and interviewees.

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