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FROM HYPE TO REAL BUSINESS BY UTILIZING DIGITAL TWINS IN INDUSTRIAL SERVICES

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Abstract

The Digital Twin (DT) is a well-known concept, which every practitioner notices today in the manufacturing industry. DTs are the digital replication of a physical object, process, or even factory. Many industrial DT implementation examples are available today but commercializing the DT concept is very challenging in practice. This study presents findings from multiple case studies developing sustainable industrial services based on the DT concept. The Service Blueprinting Method was used for identifying the customer view to DT services and for understanding roles within the service ecosystems. It is not clear how data really helps customers using machines, and thus customer value is questionable. DT value is created mainly in the operations and maintenance phases of machine lifecycle. The benefits include improvements in safety, reliability of operations and savings in operative costs. This study presents commercialization opportunities for sellable DT based services and responsibilities needed to consolidate data collection and analytics. Not so many papers are available about DT service development and this study discusses whether DT services are real business or just hype.

Keywords
digital twin; data; Industry 4.0; industrial services

1 Introduction

There is a huge hype around industrial digitalization, Industry 4.0 and related concepts (Hemilä, et al. 2022). Many studies have predicted that industrial value creation will be data driven, as nowadays there has now been many digitalization initiatives and development activities in manufacturing industries globally (Porter and Heppelmann, 2015). Several key lessons have emerged during the last few years when heavy commitments to digital capability development have met basic financial performance problems (Davenport and Westerman, 2018). Today, a lot of effort is used on industrial digitalization; some developments fail but there are also success stories. Digitalization itself does not make any profit, but improving processes and the replacement of manual work does. From this arises the question how to make profitable business with digitalization in manufacturing industries? Alongside the digitalization trend, the servitization trend is still continuing in manufacturing industries. Services based on the utilization of data will become the norm across the industry over the next few years (Roth et al. 2022). It has been estimated, that by 2030, companies will sell most of their equipment as part of bundled solutions including software and services, reducing hardware's share of total profits (Roth et al. 2022). The combination of a physical machine and the related software will be the offering of the future, however, it is not clear how to monetize and earn in the future in this combination of physical and digital worlds. Do manufacturers still sell hardware or are they moving towards capacity selling and other forms of offerings, which already exist today in some businesses? A very well-known industrial service example of data utilization is Rolls-Royce, which actively manages aircraft engines through their lifecycle to achieve maximum flying availability. Rolls-Royce's power-by-the-hour long term service agreement concept called TotalCare is charged on a fixed USD per flying hour basis (Rolls-Royce, 2020). Service promises are ensured with extensive data analysis of flight operations. It has been realized that many times digitalization helps machine manufacturer themselves, but the customer value is just a nice to know or nice to have type of offering. The real benefit, which the customer is willing to pay for is hardly achieved in many cases. When thinking about a complex production line, where many kinds of individual machines coexist, for example feeding robots, industrial presses, conveyors, packaging machines, production managers' need to be sure that everything works as planned. In that kind of scenario, it might be useful if a production manager could have one control room view into entire production line. Today, all individual machines are usually purchased from different suppliers. However, there are solution providers offering for example intelligent packaging and palletizing lines, which consist of different manufacturer's machines. The solution provider takes the overall risk for offering the solution. This kind of solution, where one partner is responsible for entire production line, is much easier for a production manager to use to ensure manufacturing operations. It is another story how digitalization is today realized in these solution provider models, as in many cases an overall control room view is missing.

A Digital Twin (DT) is a virtual representation of a physical object, product or process, or even a factory (Kritzinger et al. 2018). With the DT concept, the concepts of the Digital Model (DM), sometimes called the Virtual Model (VM), and the Digital Shadow (DS) (Kritzinger et al. 2018) are synonymously used. The DM, VM and DS concepts have a manual or only a unidirectional automated dataflow between a physical object and a virtual object. Fully integrated data flow in both directions between an existing physical object and a digital object is referred to as a DT. DTs can be the basis for new kinds of industrial machine offerings and related services with entire new value offerings during the product lifecycle. There have been difficulties for many manufacturers to copy the ideas of Rolls-Royce for power-by-the-hour concepts, but today, DT can offer a technical baseline for those kinds of service offerings. The purpose of this paper is to explore DT based industrial service opportunities and examine how to develop and commercialize sustainable DT based services successfully. Multiple DT is the approach for managing the above defined solution provider model, where individual machine DTs constitute one production line DT, or even a factory DT.

2 Methodology

This study is a part of an international project focused on researching the new service opportunities provided by the DT concept in three ecosystems in Finland, Turkey and the Netherlands. The Finnish ecosystem includes two use cases, one for industrial cranes and one for machine tools, supported by software providers. The Turkish ecosystem is the press-line of an automotive supplier with an operative production line. The Turkish case includes software partners. The ecosystem from Netherlands consists of two use cases, one related to 3D printing machines and the other to Automated Guided Vehicles (AGVs), also supported by software partners. Additionally, the consortium has partners in Korea, where there is an AGV demonstration case for industrial factory logistics, but it is not included in this study. The consortium includes also three universities and two research institutes. More detailed information is available at the project website (Machinaide, 2022). Two research questions were formulated for this study: 1) How can Digital Twins boost value creation in the industrial product-service lifecycle, and 2) Which kinds of business models are needed in future digitalized industrial contexts. The empirical data about service innovations was gathered by semi-structured interviews with company representatives. The findings of company interviews were used as a basis for understanding the current stage and the future business potential of Digital Twin enabled services. This study focuses on the service process and service development phases. Customer Journey Mapping was used for identifying the actual customer view of DT services within the ecosystems (Richardson, 2010) and the Service Blueprinting method for understanding the roles and responsibilities within the service ecosystems (Patrício et al 2011). The details of the data collection interviews and workshops are in Table I below.

TABLE 1. DATA COLLECTION INTERVIEWS AND WORKSHOPS

Interviews / workshops			
Country	Date	Workshop theme	Participants
Turkey	October 12th, 2021	Mapping the DT enabled service process by service business blueprinting	2 R&D engineers, large manufacturing company; 4 SW developers, SME SW provider
The Netherlands	January 25th, 2022	Mapping the current state of DT enabled services and service business blueprinting	1 SW developer, research institute; 1 Research and Development (R&D) engineer, SW provider; 1 SW engineer, University; 1 SW engineer, SME SW provider
The Netherlands	January 25th, 2022	Mapping the current state of DT enabled services and service business blueprinting	2 R&D engineers, SME machine manufacturer
The Netherlands	January 26th, 2022	Mapping the current state of DT enabled services and service business blueprinting	1 R&D engineer, SME machine manufacturer
The Netherlands	March 22nd, 2022	Future vision of DT enabled services	1 R&D engineer, SME machine manufacturer
The Netherlands	March 22nd, 2022	Future vision of DT enabled services	1 R&D engineer, SME machine manufacturer
Finland	June 11th, 2021	DT solutions in the Smart Factory domain	3 researchers, 1 professor, university; 3 SW engineers, SME SW provider;

Interviews / workshops			
Country	Date	Workshop theme	Participants
			4 Engineers, large machine manufacturer; 1 engineer, SME machine manufacturer; 1 SW engineer, SME SW provider; 4 research scientists, research institute
Finland	February 4th, 2022	DT solutions in the Smart factory ecosystem and roles	3 researchers, 1 professor, university; 1 SW engineer, SME SW provider; 4 Engineers, large machine manufacturer; 1 engineer, SME machine manufacturer; 1 SW engineer, SME SW provider; 4 research scientists, research institute
Finland	March 8th, 2022	DT solutions in the Smart factory ecosystem and roles	3 researchers, 1 professor, university; 2 SW engineers, SME SW provider; 3 Engineers, large machine manufacturer; 1 SW engineer, SME SW provider; 4 research scientists, research institute
Finland	March 23rd, 2022	DT solutions in the Smart factory ecosystem and roles	3 researchers, 1 professor, university; 2 SW engineers, SME SW provider; 3 Engineers, large machine manufacturer; 1 SW engineer, SME SW provider; 4 research scientists, research institute

A literature study and benchmarking studies enriched the empirical findings (Eisenhardt, 1989; Yin, 2003). The study discusses the business potential and business development challenges related to the DT concept and investigates how DT services are becoming real business after huge hype.

3 Findings

The latest trend of Industry 4.0 brings the Internet of Things (IoT) to the manufacturing industry. With cheap sensors and connectivity solutions it is possible to collect real-time data from machines, which supports decision making in operations and maintenance. However, it is not clear how data really helps the customer using the machine and therefore customer value is questionable. Many times, digitalization and data support manufacturing companies internally, and the value is clear for the manufacturers themselves. The customers using the machines are interested mostly in the operational efficiency or the minimized downtime of the machines (Hemilä, 2022). The data can be used for DT, the digital replication of the machine. Then, the DT can be used as a basis for a value proposition for customers. Actually, as stated earlier, an individual machine DT can bring value, but for the customers it is more valuable if they get an overall status of the production line or even the factory. Multiple DTs and factory DT opportunities are the main opportunity for machine manufactures to offer entirely new kind of value to customers. Generally, DT value is created mainly in the operations and maintenance phases of the machine lifecycle, but in the future also in the production line or in factory lifecycles. The following subsections describe the main findings from the case studies in the different lifecycle stages of smart factories.

3.1. The smart factory installation and operation phase

There are plenty of recognized opportunities to solve customer needs in the smart factory domain. The main challenge in the smart factory domain is different customer touchpoints, as Original Equipment Manufacturers (OEM) have their own touchpoints through which customer needs can be fulfilled, and software providers have theirs etc. However, the majority of recognized customer insights can be considered as a valid starting point when building new service concepts. If customers are willing to minimize transactions with suppliers, then integrated offerings is the answer. The smart factory domain consists of a lot of different stakeholders with various levels of interest and decision power over smart factory services. During the studies it became apparent that the stakeholder group, which was the production manager in this case, requires accurate and up-to-date information about other machines' statuses in the production line. The result supports the existing hypothesis that timely and accurate information from machines to humans has a large role in a fully functioning smart factory. Based on the study results, there seems to be multiple new opportunities to offer new value-adding services to Smart factory/digital twin (SF/DT) customers. These opportunities are related to configuration, design, usability, and optimization of smart factories, and they are distributed to different phases of the overall value chain. The biggest business opportunity in the future is the possibility to offer SF/DT services as a turnkey solution with a consortium-style provider where each partner can deliver their part of the overall value based on their own core competences. Alongside the turnkey solution it is possible to offer additional services supporting the customer during an entire lifecycle of SF/DT solutions (consultation, training, configuration, maintenance/upkeep). It is still very unclear what would be an actual touchpoint through which the customer explores smart factory/digital twin solutions: would it be through an OEM company or a software company? This is a relevant question due to the fact that no OEM can deliver comprehensive SF/DT solutions by themselves but only with a network of suppliers.

In the installation and operation stage, the main purpose is ensuring Overall Equipment Effectiveness (OEE) by making sure that all necessary software is functioning as expected and that it is updated accordingly. All requested documentation can be achieved via DT in the installation phase and also all changes in the installation can be updated to original plans and documents. The machine operational setup can be simulated with DT to ensure operations at the customer site. A line-level digital twin tracks production parameters and communicates with the manufacturing operator to fix potential problems. Factory DT combines all machine DT in one place and offers a control room view for the customer. Many OEMs and software partners are needed to collaborate closely, but finally the fully digitalized factory can ensure OEE. Training and safety procedures at the customer site can utilize DT and with Virtual Reality (VR) glasses the factory environment could easily be learned by humans. Our case studies have identified the following operation phase benefits where DT has a strong supporting or enabling role:

- Production line and factory works as expected (availability guarantee can be achieved)
- Formally proves what is wrong and proves what has been fixed
- Detailed view from each component on what has gone wrong
- Time savings, money savings
- Just in time delivery support
- New business model opportunities for the machine manufacturer because of a detailed view of how the machine operates
- Simplifies the job of the machine users: Less time needed on daily work activities and more time available on non-daily activities, e.g., "operator being more a manager". Operator work content can be moved towards operations planning, production scheduling and other activities more than currently. DT can support organizational changes in the future.
- For AGVs, moving robots, DT supports route planning, as well as management of unexpected situations in operations
- Higher quality and traceability of final products
- Easier for the customer to know what happens inside the machines

- Improved interaction with the customer
- The customer is able to have customized views (control room / Human-Machine Interface (HMI) solutions) of the factory and machine situation for different users (production managers, machine operators, service personnel).

In the installation and operation phase, DTs are used as a communication tool to enable interaction at the machine, line, factory, or ecosystem level. The above mentioned Rolls-Royce TotalCare is possible today for any kind of OEM. But, the real advantages in the smart factory context come when a production line or factory is offered as a service together with many OEMs.

3.2. The smart factory maintenance phase

Before implementing DT in practice, most of the companies have succeeded in maintenance phase related digital services that are linked to predictive maintenance purposes throughout the lifecycle of the machines and improving the production of the customers. The digital service portfolios of the interviewed companies currently include (Hemilä et al. 2022):

- E-commerce for spare parts
- Real-time remote monitoring, support and control through sensors
- Education/training of customers remotely
- Consultative digital services
- Software, licenses, systems and platforms

These mentioned services are from individual OEMs. In the industries, there are generic maintenance providers in the market who can offer services to multiple machines or even on a whole production line. In the smart factory maintenance stage, the main focus is on predictive maintenance activities enabled by the digital twin, where the key customer benefit is maintenance downtime optimization. An OEM offering DT based services needs to make sure that the preventive maintenance activities based on the information enabled by the digital twin are done accordingly.

From the smart factory customer`s point of view the maintenance phase includes modernization, which extends an individual machines' lifecycle. Thus, update and modernization as a part of the maintenance phase is identified as one of the critical stages of the DT enabled service process. This stage highlights the upgradeability, reparability, and modularity of the DT application areas. The decision when factory level updates and modernization is needed, need to be supported with DT. Both history and forecasting data are utilized to optimizing the factory, as well as system dynamics modeling and simulation. Single machine optimization does not give significant advantage, but entire factory optimization will bring big savings. Furthermore, a DT enabled service process captures the cyclic nature of maintenance as the functions of update always return the process to earlier stages and again move forward towards another round of updates. Again, for a single machine this can be done any day by its OEM, but it does not bring much competitive edge anymore. However, a multiple DT supported factory update will be a huge opportunity for OEMs ensuring future customer value. The accuracy of the data plays a critical role. The correctness in collecting and analyzing data has a significant impact here in terms of ensuring the faultlessness of the updates and the modernization of production lines and factories. Similarly, errors in updates can lead to significant challenges or problems in the customer`s processes. Below is a summary of preventive maintenance and modernization possibilities with DT:

- Easiness for the customer when service operations are well planned and predicted
- Time savings in service operations
- Fewer ad hoc situations

- Added revenue for the customer can be collected from the end-users by providing updates
- confirming that the software system does not contain any errors (simulations with DT)
- New business model for services/maintenance: Make a model that provides constant updates for end-users

4 Conclusions

Not so many studies are available in academia about DT service development and the present study discusses whether DT services are real business or just hype. Future smart factories consist of a growing volume of data, complex machines, and increasing requirements of operational efficiency and sustainable operations. In smart factories, it is an option to each OEM to develop their capabilities to provide SF/DT solutions based on customer requests by using their own supplier networks (for example other OEMs, software, data, broker, authentication suppliers). Here, an OEM receives a significantly high profit by being a solution provider rather than offering single machines. However, it would also require a lot of effort for OEMs to arrange a capable supplier network alone with all the required roles fulfilled, making it difficult to create comprehensive SF solutions for customers. Another option is to form a consortium of companies, which could deliver SF/DT turnkey solutions to customers through a single touchpoint. A consortium solution would also enable customers to individually choose the suppliers from the network if willing to do so. However, this approach would most probably require an orchestrator on top of the consortium through which solutions are offered, and yet the management and governance of the consortium would require a lot of effort (Hemilä, 2022). For factory DTs it is sure that forming an industrial ecosystem with multiple actors and roles is needed. The realization of factory DT requires new kinds of competencies, for example comprehensive data analytics, visualization, simulations and other functionalities that typical OEMs do not have today. Unique and new value propositions can be offered with factory DT. Business strategies should be updated when forming new ecosystem partnerships and factory DT. OEMs should decide their future role—whether to take the ecosystem orchestrator role or the solution provider role. An entire new business model is needed for the manufacturers, especially when thinking about the factory as a service type of offering.

This study presents many commercialization opportunities for sellable multiple DT based services and the responsibilities needed to consolidate data collection and analytics. According to this study, after the huge hype around Industry 4.0 and DTs, real business can be achieved. However, complex multiple DTs still need more studies and development, but the business opportunities are bigger than today. With systematic development steps, a successful DT-based service business can be realized. Companies need to think about existing competencies and make or buy decisions that are needed for realizing DT based services in practice.

The phenomenon of utilizing DTs in industrial service development is very complex. This study approached this phenomenon from a rather narrow empirical perspective with three manufacturing ecosystems in three different countries. Practical evidence of multiple DTs and factory DT are still limited, as these were not in an operative environment within the case studies. Future research will focus on the development of a new frame of reference for service business innovations based on multiple DTs. The existing Service Development Phases (Hemilä and Vilko, 2015) will be updated by creating a step-by-step model for factory DT services development.

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