Digital Twin Based Industrial Services - Just Hype or Real Business?

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***Abstract* - The paradigm change towards digitalization in industries has been a huge hype for years. The Internet of Things, Industry 4.0, and recently Digital Twins, are the buzzwords that every practitioner notices in the manufacturing industry. However, how to make real business after the hype? The ongoing international research is developing the utilization of machine operations data as a basis for Digital Twins. Digital Twins are the digital replications of real industrial machines. New industrial services and new earning logics can be created, but it takes time to get a real business going with digitalization. This study presents the findings from multiple case studies in Europe and discusses the business opportunities related the Digital Twin concept.**

Keywords-Digital Twin; Data; Industry4.0; Industrial Services.

I. INTRODUCTION

Data based industrial services are still hard to realize in practice, despite the fact that there is plenty of hype around Industry 4.0 and related concepts [1]. However, in the future of the industrial service systems, value creation will be data driven, as there has now been many digitalization initiatives and development activities in manufacturing industries globally [2]. In some sectors, individual companies already generate more than 50% of their revenue and 100% of their profit with their service businesses [3]. The servitization trend is still today continuing in manufacturing industries and will become the norm across the industry over the next few years [3]. By 2030, companies will sell most equipment as part of bundled solutions including software and services, reducing the hardware's share of total profits [3].

A Digital Twin (DT) is a virtual representation of a physical object, product or process, or even factory [4]. The level of data integration marks the difference of DT compared to the concept of Digital Model (DM), sometimes called a Virtual Model (VM), and the concept of Digital Shadow (DS) [4]. These mentioned concepts are often used synonymously. The digital representation can be modeled manually, without connection to a real physical counterpart. Alternatively, digital representation can be done fully automated way. DM is realized manually, with a manual data exchange flow. DS has an automatic data flow from the physical object towards the digital object, but the reverse data flow is manual. The data flow between an existing physical object and a digital object fully integrated in both directions is referred to as DT [4]. Multiple DTs are a real-time integrated combination of many physical objects and their digital objects. This paper uses the DT concept to refer to fully automated data exchange between real physical object and its digital replication. Therefore, because of real-time and automated data exchange, DTs can be the basis of new kinds of industrial services with entirely new value offerings. Often digitalization helps the machine manufacturer themselves, but the added customer value is just a nice to know or a nice to have type of benefit. The real benefit, which a customer is willing to pay for is hardly achieved. The purpose of this paper is to explore DT-based industrial service opportunities and examine how to develop and commercialize DT-based services successfully. The nature of the study is conceptualization. However, it does not focus on technologies for realizing DT, data analytics or data connection technologies. Today Artificial Intelligence (AI) can be used for data analytics, machine operation simulations and maintenance optimization. The rest of the paper is structured as follows. Section II defines the used research approach and methodologies. Section III presents the study findings. We conclude our work in Section IV.

II. DESIGN/METHODOLOGY/APPROACH

This study is a part of an international project focused on researching the new service opportunities provided by the DT concept in several industrial use cases. The project includes three machine manufacturing companies, one automotive supplier with an operative production line, seven software development partners, three universities and two research institutes that represent three different business ecosystems in three countries. The empirical data is gathered by semi-structured interviews with company practitioners, which research organization facilitated workshops developed further. 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. Next, several workshops were conducted to map the service processes of the use cases in three ecosystems in Finland, Turkey and the Netherlands. The ecosystem partners are listed in Table I below, and more detailed information is available at the project website [5].

TABLE I. ECOSYSTEM PARTNERS ROLES AND SIZES

Ecosystem	*Company role in the ecosystem*
Ecosystem in Turkey	Company 1: Manufacturing company innovating and offering new digital twin enabled services for their customers, large-scale company.

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	Company 2: Service development partner, Software (SW) provider, Small and medium sized (SME).
Ecosystem in Netherlands	Company 1: Manufacturing company innovating and offering new digital twin enabled services for their customers, SME Company 2: Manufacturing company innovating and offering new digital twin enabled services for their customers, SME Company 3: Service development partner, SW provider, SME. Company 4: Service development partner, SW provider, SME. Research institute 1: Software Research and Development (SW R&D) partner University 1: SW R&D partner
Ecosystem in Finland	Company 1: Manufacturing company innovating and offering new digital twin enabled services for their customers, large-scale company Company 2: Manufacturing company innovating and offering new digital twin enabled services for their customers, SME Company 3: Service development partner, SW provider, SME Company 4: Service development partner, SW provider, SME Company 5: Service development partner, SW provider, Large University 1: SW R&D partner Research institute 1: Service development partner

The workshops were held remotely using Microsoft Teams due to the ongoing COVID-19 situation and the limitations to travel. The methods for conducting the workshops in each ecosystem were customized to correspond the specific background of the consortiums. Customer Journey Mapping was used for identifying the actual customer view of DT services within the ecosystems [6] and the Service Blueprinting method for understanding the roles and responsibilities within the service ecosystems [7]. A total number of ten interviews and workshops were organized within the ecosystems. The details of data collection interviews and workshops are in following Table II below.

TABLE II. DATA COLLECTION INTERVIEWS AND WORKSHOPS

Interviews / workshops			
Country	***Date***	***Workshop theme***	***Participants***
Turkey	October 12^{th}, 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 25^{th}, 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 25^{th}, 2022	Mapping the current state of DT enabled services and service business blueprinting	2 R&D engineers, SME machine manufacturer
The Netherlands	January 26^{th}, 2022	Mapping the current state of DT enabled services and service business blueprinting	1 R&D engineer, SME machine manufacturer
The Netherlands	March 22^{nd}, 2022	Future vision of DT enabled services	1 R&D engineer, SME machine manufacturer
The Netherlands	March 22^{nd}, 2022	Future vision of DT enabled services	1 R&D engineer, SME machine manufacturer
Finland	June 11^{th}, 2021	DT solutions in the Smart Factory domain	3 researchers, 1 professor, university; 3 SW engineers, 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	February 4^{th}, 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 8^{th}, 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 23^{rd}, 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 rnstitute

A literature study and benchmarking studies enriched the empirical findings [8][9]. Two research questions were formulated: 1) How can the Digital Twins boost value creation in the industrial product-service lifecycle, and 2) Which kinds of business models are needed in the future digitalized industrial contexts. The research questions are related to the main theme of this paper, namely are the DT services real

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business or just hype? The study discusses the business potential and business development challenges related to the DT concept.

III. Findings

Digitalization has reached a mature level in industries, as the companies have modern Information and Communication Technology (ICT) tools for supporting operations. Enterprise Resource Planning (ERP) solutions are today cloud based software, available everywhere and support many kinds of industrial operations, not only production. Customer Relationship Management (CRM) software supports every kind of customer interaction from marketing, to sales and aftersales. For service operations, like installation and maintenance, markets offer dedicated solutions. Every kind of documentation can be managed in the digital format. The latest trend of Industry 4.0 brings the Internet of Things (IoT) to manufacturing industry. Cheap sensors and connectivity solutions create many opportunities to collect real-time data from machines which supports decision making related operations and maintenance. Data itself is not valuable, but the information gathered from the data using analytics and visualization is. Artificial Intelligence (AI) and machine learning can be utilized for data analytics, operative predictions and maintenance optimization. Generally, today all industrial operations can be digitalized. However, these mentioned solutions mostly support manufacturing companies internally, and the value of the software solutions is clear for the manufacturers themselves. The customer value is questionable, as it is not clear how digitalization helps the customers who are using the machines. Customer understanding is the key for success. Which kind of information does the customer need? Do they need information at all or are they just interested in operational efficiency or the minimized downtime of the machines? In many cases, the answer is yes. The data collected by the machine manufacturer, when the customer operates with the machine, should be turned to a customer value proposition. The value proposition is dependent on the case and customer [10]. 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. According to our case studies, typically, value is created in the selling, installation and operations, and maintenance phases of the machine lifecycle. The following subsections describe the main findings from the case studies in the different lifecycle stages.

A. The selling stage

The selling stage includes machine ordering and planning of the service delivery. The main actions in this stage demand a lot of interaction between the customer and the manufacturing company. In the selling stage, the identification of potential customers for DT enabled services, arguing the value propositions of DT enabled services to the customers and helping them to make a positive purchasing decision take place. Based on the machine design data, DT visualizes the machine for the customer. Surely, DT is not a sellable or monetized service in the selling stage, but DT can have positive enabler role for buying decision.

B. The installation and operation stage

At this stage, collecting and processing data plays a pivotal role. In the installation and operation stage, the main activity is ensuring Overall Equipment Effectiveness (OEE) by making sure that all necessary software is functioning as expected and that is updated accordingly. DT can support installation when all requested documentations can be achieved via DT, and machine operational setup can be simulated with DT to ensure operations at the customer site. Training at the customer site can utilize virtual replication of the real world by using Virtual Reality glasses and 3D models of the machine and the surrounding factory environment. In this stage, all actors (the customer, the manufacturing company offering digital twin enabled services and the service development partners) have a great role and seamless cooperation and communication between the actors is very important. Our case studies have identified the following operation phase benefits where the DT has a strong supporting or enabling role (in random order):

- Machine works as expected (availability guarantee, e.g., 98%)
- 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 the daily work activities and more time available on the non-daily activities, e.g., “operator being more a manager”. Operator work content can be moved towards operations planning, production scheduling and other activities than they do today. The DT can support organizational changes in the future.
- For moving robots, DT supports route planning, as well as management of unexpected situations in operations
- Higher quality and traceability of the 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).
- The customer is able to visualize in a real-time what the machine is doing
- Reduced waiting time and faster time to market by generating new operation schedules (optimized operations based on the DT) for the system

Generally, the digital twin is used as a communication tool to enable the interaction at the machine, line, factory, or ecosystem level. The customer benefits include improvements in safety (e.g., product safety and occupational safety),

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improvement in product delivery efficiency, improvement in the reliability of operations, improvement in product quality, and financial factors, such as savings in operative costs.

C. The maintenance stage

In the maintenance stage, the main focus is on predictive maintenance activities enabled by the digital twin. On a general level, the key customer benefit is maintenance downtime optimization. Prediction, in general, tends to be highlighted as one of the key benefits of the digital twin-enabled service across the service process stages. Communication and data exchange within the diverse levels of digital twin implementation play an important role. If the machine is a critical part of the customer's operation or production line, DT is even more important for ensuring successful maintenance operations. The main activities of the software partners are to make sure that the software works as it should and that it provides accurate information related to the machine, machine fleet or the entire factory. The main activities of the manufacturing companies offering DT-based services are to make sure that the preventive activities based on the information enabled by the digital twin are done accordingly. The main activity of the customers is to let the maintenance activities take place in order for their downtime to be minimized and their operations to run with full operational rate. Below is a summary of preventive maintenance and modernization possibilities with the 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
- Make sure that the software system is without any errors (simulations with DT)
- New business model for services/maintenance: Make a model that provides constant updates for end-users

IV. CONCLUSIONS

Because of the growing volume, complexity, and strategic importance of data in industry, manufacturers need to create DT-based services together with selected strategic partners. The participants of future digital twin-enabled service operations are forming an industrial ecosystem with multiple actors and roles. Actors are needed to fulfil dedicated tasks when delivering digital twin solutions with and to different stakeholders. The realization of DT requires new kinds of competencies, because of the need for data analytics, visualization, simulations and other functionalities that might be new for manufacturers. Therefore, collaboration is needed between manufacturers and SW providers to consolidate data collection, aggregation and analytics for making data and insights available across different business functions and units. These mentioned tasks need many kinds of individual roles from the employees. Roles can be considered as action-oriented tasks, like connectors, identity verifiers or service provides. As part of a customer's personnel, there are, e.g., persons responsible for production, different levels of managers, procurement personnel and service engineers. The most apparent roles in a manufacturing company are e.g., sales, maintenance, training and engineering staff taking part in the DT enabled service operations. The ecosystem orchestrator role is also something that is currently being discussed to determine whether, in the future, there should or could be one actor that is responsible for selling the total DT enabled service solution to the customer with one-stop-shop principle. So far, there is no such actors in the manufacturing industry.

Unique and new value propositions can be formulated with DT. However, while sellable services are not easily done, there are many commercialization opportunities in DT-based services. Business strategies should be updated when investing in DT-based service offerings. In the end, an entire new business model is needed for the manufacturers. As the value proposition change, new outsourced SW elements are needed and the customer base needs to be segmented differently, since traditional customers might not be interested in DT offerings.

A. Practical implications

This paper highlights the DT-based service opportunities and challenges. A new understanding is needed on how to develop economically sustainable service offerings with the data and with multiple DTs of products. The study presented promising results, but realization in each case is dependent on the DT level of detail. With systematic development steps, a successful DT-based service business can be realized. Practitioners need to think about existing competencies within the company, and make or buy decisions are needed for realizing DT-based services in practice.

B. Research limitations

The present study has limitations that need to be taken into account. The phenomenon of utilizing DTs in industrial service development is very extensive and complex and this study approached this phenomenon from a rather narrow empirical perspective with three manufacturing ecosystems in three different countries. However, by understanding these particular cases in more depth, we eventually learned about the greater phenomenon of DT-based service development in the industrial context. Practical evidence of multiple DTs is still limited, as multiple DTs were not in an operative environment within the case examples.

C. Future research

Future research will focus on the development of a new frame of reference for the service business innovations based on DT and future business models in manufacturing industries. The service business development model will be updated, i.e., by Service Development Phases [11]. With the updated step-by-step service development phases, an entire business model can be made more competitive. A very promising concept spinning out from this research project is the Digital Twin Web (DTW). The DTW is a network of digital twins formed by DT documents that describe the contents of DTs and the relationships between the DTs. The DTW concept can support multiple DT realizations in practice. Factory DT and Ecosystem DT can benefit from DTW, but so far, the DTW's relation to industrial services is unclear and, therefore, needs to be studied in the future.

REFERENCES

[1] J. Hemilä, M. Salo and P. Petänen, "Utilization of Digital Twins in Industrial Service Supply Chains", The 17th International research symposium on service excellence in management (QUIS17), Jan 2022, pp. 326-335 DOI: http://dx.doi.org/10.4995/QUIS17.2022.15169

[2] M. E. Porter and J. E. Heppelmann, "How smart, connected products are transforming companies", Harvard Business Review, October 2015.

[3] P. Roth, K. Strempel, O. Straehle and H. Liu, "Machinery as a Service: A Radical Shift Is Underway", [online]. Available from: https://www.bain.com/insights/machinery-as-a-service-global-machinery-and-equipment-report-2022/ [Retrieved: 06, 2022]

[4] W. Kritzinger, M. Karner, G. Traar, J. Henjes and W. Sihn, "Digital Twin in manufacturing: A categorical literature review and classification". IFAC-PapersOnLine, Volume 51, Issue 11, pp. 1016-1022, 2018.

[5] Machinaide. Knowledge-based services for and optimisation of machines, Machinaide project website [Online]. Available from: https://www.machinaide.eu/ [Retrieved: 07/2022]

[6] A. Richardson, "Using Customer Journey Maps to Improve Customer Experience", Harvard Business Review, November 2010.

[7] L. Patrício, R. P. Fisk, J. Falcão e Cunha and L. Constantine, "Multilevel service design: from customer value constellation to service experience blueprinting". Journal of Service Research, 14(2), pp. 180–200, 2011.

[8] K. M. Eisenhardt, "Building theories from case study research", The Academy of Management Review, Vol. 14, No. 4, pp. 532–550, 1989.

[9] R. Yin, "Case Study Research – Design and Methods", 3rd ed., Applied Social Research Methods Series, Vol. 5, Sage Publications Inc., Thousand Oaks, CA, 2003.

[10] T. Rintamäki and H. Saarijärvi, "An integrative framework for managing customer value propositions". Journal of Business Research, 134, pp. 754–764, 2021.

[11] J. Hemilä and J. Vilko, "The development of a service supply chain model for a manufacturing SME", The International Journal of Logistics Management, Vol. 26 No. 3, pp. 517-542, Nov 2015, https://doi.org/10.1108/IJLM-01-2014-0001