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Service business model innovation: the digital twin technology

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Why this paper might be of interest to Alliance Partners:

The rise of the digital technologies such as, digital twins, the internet of things (Industry 4.0), augmented reality, machine learning among others, provide new platforms and avenues to enable services and innovate service business models. Digital Twins (DT) are one the most promising state-of-the-art digital platforms. They create digital/virtual twins of the physical assets. The majority of DT research focus on the engineering and data transmission of this platform and less on the applications. Little is known about how DT are integrated in the firms' operations and their impact on firms' business models. Considering the importance of this emergent topic, it is of paramount importance to study the effect of Digital Twins on service business model innovation. In other words, what effect do digital twins bring to existing service business models? A two-phases exploratory research was set up to understand this research enquiry. Phase One focused on the overall understanding of how DT are set, implemented and used. 37 interviewees across three large industrial engineering firms, in addition to two DT platforms architects. Phase Two focused on the study of the context of the use and effect on the firms' service business models on three pairs of cases. Our research shows four generic types of service business models founded on the DT platform and their trajectories.

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Abstract

This study is set up to investigate the effect of Digital Twins on service business model innovation. In other words, what effect do digital twins bring to existing service business models? A two-phases exploratory research was set up to understand this research enquiry. Phase One focused on the overall understanding of how DT are set, implemented and used. 37 interviewees across three large industrial engineering firms, in addition to two DT platforms architects. Phase Two focused on the study of the context of the use and effect on the firms' service business models on three pairs of cases. Our research shows four generic types of service business models founded on the DT platform and their trajectories.

Keywords: Servitization, Services, Business Models, Digital Twins

Introduction
Manufacturing and Engineering firms have increasingly diversified into services, by adding and accompanying services to their product propositions (Neely, 2008; Baines and Lightfoot, 2013; Cusumano, Kahl and Suarez, 2015). The rise of the digital technology such as, digital twins, the internet of things (Industry 4.0), augmented reality, machine learning among others, provide new platforms and avenues to enable services and innovate service business models.

Digital Twins are one the most promising state-of-the-art digital platform. They create digital/virtual twins of the physical assets. By having real-life input from the assets in-use, manufacturers observe the functionality of the asset, predict with more accuracy failures and get feedback to re-adapt product-design (Herterich, et al, 2016; Tao et al., 2017). DT has the capability to break siloed internal activities for Manufacturing and Engineering firms and open a wide after-sale visibility on their products (Tao, Cheng, Qi, Zhang, Zhang and Sui, 2017).

The majority of DT research focus on the engineering and data transmission of this platform and less on the applications. Little is known about how DT are integrated in the firms' operations and their impact on firms' business models (Kindstrom and Kowalkowski, 2015). Considering the importance of this emergent topic, it is of paramount importance to study the effect of Digital Twins on service business model innovation. In other words, what effect do digital twins bring to existing service business models? To answer this question, we reviewed the literature in service, digitalization and digital twins. As a result, the research design was developed. Data was collected over twelve months, analyzed and synthesized. The research findings and methods from this study answered the research questions and are discussed in the following sections.

Literature Review

A systematic literature review was carried out for a better understanding of the identified research strings. This systematic literature review was divided into two main steps.

• First, three search engines, Scopus, ScienceDirect and IEEE Xplore are used for an extensive article search with key word combinations. A board map of the research areas is built by screening the titles and abstracts of 109 articles.

• This map has then be filled up in detail after having read the body of 58 papers.

This final mindmap allowed the identification of the research gaps.

For both steps, an adaptation of Tranfield's Literature Review Methodology (Tranfield Denyer and Smart, 2007) was used as a working protocol. The "snowballing" technique was also used to collect the papers during the "articles searching" phases. It was found during the literature review that the number of articles about some particular topics was very limited. These topics are indicated in bold in Table 1.

Table 1. Summary of Systematic Literature (an extract)

Research String	Subcategory	Number
Digital Twins (18 articles)	Definitions	8/18
	Benefits	18/18
	Technical features	5/18
	Challenges	**2/18**
	Strategy and BM	**0/18**

Service Innovation and Digitalization

With the third generation of ICT, digital technologies are no more considered as simple tools but as active actors in value creation. In other words, they are no more considered as bare facilitators, implemented to satisfy a need of efficiency but real actors that lead to new value proposition (Herterich, Eck, and Uebernickel, 2016). Many articles deal with the new value creation opportunities around digitalisation: automated manufacturing systems, market intelligence, risk mitigation, service innovation (Rymaszewska, Helo, and Gunasekaran, (2017). In particular, smart connected objects, that are part of the Digital Twin concept, enable the manufacturers to servitise their products by collecting and exploiting in-service data and enhance their relations with the customers.

Many articles suggest frameworks to help the companies to seize these opportunitites in a thoughtful a strategic manner. Porter (2005) puts forward a framework composed of 10 questions that companies need to tackle when choosing their digitalisation strategies. Some of these questions are high-level such as the ones related to portfolio management, whereas some others are more practical, about whether developing an open or close system, which data to capture and how to monetize the created value.

The framework suggested by IBM links digitalisation with servitisation (Services, 2001). Two main strategic paths are highlighted in this framework. The companies can be chosen to invest massively in digitalisation for the sake of knowledge ownership and develop solutions using these digital technologies afterwards. They can also choose to introduce digitalisation gradually and focus on direct applications of the introduced digital technology in the development of new services or solutions. However, if many articles deal with the digitalisation strategies developed by the companies to leverage the benefits of the ICT, there is a serious need for a better understanding of the internal capabilities that these companies need to strategically match in their digitalization journey. These internal challenges have been rarely tackled in the literature.

Digital Twins

Digital Twins, refers as the virtual duplicate of a physical asset, is one of the most promising digital technologies of the future (Herterich, et al, 2016). Digital Twins (DT) were first introduced by Grieves in 2002 during a seminar on Product Lifecycle Management (PLM). At that time, the concept was called “Conceptual Ideal for PLM”. Successively called “Information Mirroring Model” by Grieves in 2006, the final appellation “Digital Twin” came in 2010 (Grieves, 2014). The concept of Digital Twin has then evolved from being a simple PLM tool to actually being a powerful tool for digital business decision assistance and a catalyst for service creation (GE Digital 2016; (Tao, Cheng, Qi, Zhang, Zhang and Sui, 2017).

Understanding the PLM roots of the Digital Twin is essential to fully capture its two main characteristics: 1) it is a tool that integrates the physical product’s entire lifecycle, from conception to disposal, 2) hence, it fundamentally deals with dynamic data with updates and machine learning processes (Tao, Cheng, Qi, Zhang, Zhang and Sui, 2017). Those two characteristics differentiate the Digital Twins from all existing digital technologies.

The majority of DT research focus on the engineering and data transmission of this platform and less on the applications. Little is known about how DT are integrated in the firms’ operations and their impact on firms’ business models (Kindstrom and Kowalkowski, 2015). Considering the importance of this emergent topic, it is of paramount importance to further study the effect of Digital Twins on service business model innovation. In other words, what effect do digital twins bring to service business models?

Research Design

A two-phases exploratory research was set up to understand this research enquiry. Phase One focused on the overall understanding of how DT are set, implemented and used. 37 interviewees across three large industrial engineering firms, in addition to two DT platforms architects. Phase Two focused on the study of the context of the use and effect on the firms' service business models. Three pairs of cases – industrial firms operating on the aviation, automotive and construction-equipment industries – with DT implementations (Edmondson and McManus, 2007). In addition to three systems-integrators' firms, which their primarily job is develop DT applications. Participating firms from Phase One did not participate in the Second Phase. The unit of analysis is the business unit of the firm that uses DT in their own assets.

Data was collected over twelve months using structure questionnaires. The data collection instrument covered four interrelated areas:

- Context: business and technology
- Functionality and integration
- Implementation and use
- Service business model and monetization

Questions were informed by literature. Interview data was complemented by secondary data (e.g. company reports, videos and news) and documentation and processes (business goals, operating model, performance measures, processes, data structures and programs).

Interviews were recorded and transcribed. Data was coded and analyzed by individual case and then cross-compared (Yin, 2009). The data analysis of the first phase informed the data collection of the second one.

Findings: Phase 1

This study found through a systemic review of the DT literature that this is an emergent field in Servitization. While still there is lack of agreement on a single DT definition, the majority of literature agrees on the application and benefits of Digital Twins. Particularly on getting real-time data from assets in-use and the operational implications of the assets.

The first phase of our exploratory study found that most DT in-use were not fully implemented across all products – We called localized twins. Participating firms have great desire to fully expand the implementation and use of DT all across all products and all four product-lifecycle phases. Our research shows that a consistent pattern across these firms, where Digital Twins mainly enable their operations and planning and significantly improve the agility of their supply processes, but not their demand processes. For instance, a large industrial engineering firm use Digital Twins to boost the efficiency of its design and manufacturing processes by keeping track of its products after they are sold. The cross-case comparison shows that the most common services offered to customers based on Digital Twins are dash boarding and failure detection. By interviewing different people in each firm and cross referencing it with the DT Architects' interviews four collective problems firms encounter in the use and application of Digital twins, they are:

a) The silo orientation of the DT. The implementation and use of a DT lead by a function.

b) The lack of data in a digital format to get started
c) The "disintegration" of feeding data with the DT analytics and
d) The difficulty to sell the business benefits from the Digital Twins in-house.

From the platform architects' perspective, a common consensus among these highlight that the use of DT is still at a growing stage in many firms. As one of the leading DT Architects pointed out *"DTW platforms provide massive benefits from basic level 1 and beyond level 4, but in average the maturity of real implementations resides on Level 1 and 2"*.

Findings: Phase 2

Having learnt from the exploratory phase one, in the second phase of our study, we targeted firms with more mature DT implementation to observe the effect of DT on the use and service business model innovation. Three pairs of cases – industrial firms operating on the aviation (A), automotive (C) and construction-equipment (E) industries – with DT implementations participation in this second research phase.

The data collected from the second phase was analysed using cross-case analysis by comparing pair of cases and then cross-comparison across all three pairs of case. Our early findings from this second phase shows emerging patterns from the three pair cases.

In answering our research question – what is the effect of Digital Twins on service business model innovation? We focus on the analysis of the functionalities of the Digital Twins and the value innovation enabled by them. These are the findings:

The utilisation of in-service data: The implementation of the Digital Twins involves the collection and utilisation of in-service data, such as the pressure of the valves, the amount of fuel consumed by the engines, etc. The amount of collected data and how far the companies push the utilisation of this data for analytics vary significantly. While some companies use the data for monitoring only, others use it for simulation, prediction and operation optimization.

The integration of planning tools: It is possible to connect the data collected and stored in the Digital Twins with planning tools. Before production, it allows the optimisation of the manufacturing strategy. During the manufacturing phase, the data stored in the Digital Twin helps to keep track of the operations and optimize planning.

During the utilisation phase, some failures or breakdowns can be predicted through the analysis of the data stored in the Digital Twin and affect task scheduling both for the operator and the manufacturer that might have to do some repair.

The integration of simulation tools: To push the analytics further, it is possible to integrate simulation tools into the Digital Twins. Traditionally, these tools are only used for product design. However, they are increasingly combined with sensor data collected via the Digital Twin. The comparison between in-service data and theoretical data obtained through modelling and simulation allows the assessment of the performance of the physical asset, the detection of failures, the prediction of potential problems and the determination of the next best actions. The simulation tools can also take into account parameters such the cost involved by the different simulated scenarios.

The integration of the product lifecycle steps: A very important characteristic is the levelof integration of the different lifecycle steps of the product into the Digital Twin. Many companies still fail in building digital continuity between these lifecycle steps and are still working with fragmented digital tools. The most performant companies would have a comprehensive, unique platform for the Digital Twin that allows teams from different lifecycle steps to cooperate.

The creation of simple services: Using Tukker's service classification, the "simple services" refer to "product-oriented services" (Tukker, 2004). These services consist essentially in advice and consultancy using the data stored in the Digital Twin. It can also be some basic real time monitoring features such as asset localization, fuel consumption, etc.

The creation of advanced services: Again, using Tukker's service classification, the "advanced" services refer to "use-oriented" or "result-oriented' services. By using the in-service data of the assets, these services aim at optimizing the operations and predicting failures. Hence, the manufacturer becomes the key partner of the asset operator and assists the operations using the data of the Digital Twin, simulations and planning tools. Innovation in terms of Digital Twin related service selling paradigm: In the past, the relation between a manufacturer and its customers was mainly transactional and based on a one-shot pricing system.

The creation of services, enabled by the Digital Twins, allows the manufacturers to develop new selling paradigms. They can build subscription systems for the services, pay per use systems for the product and also base their revenues on the result obtained with the services they provide.

Table 2 shows the level of integration of the aforementioned series of tools and functionalities for the different companies. The coding is done as follows: (0) for not implemented, (1) in progress but not prioritized, (2) for in progress, (3) for implemented.

The level of integration of the tools in the Digital Twin and the level of implementation of the services vary significantly between the different companies. The choice made by the companies for prioritizing some features instead of others have different consequences on their business models. Some interesting patterns emerge through the analysis of the precedent Table.

Two ways of Product-Service Business Model improvement with the Digital Twins. The literature gives many definitions of the concept of Business Model. To Casadesus-Masanell et. al (2010), the Business Model is "the logic of the firm, the way it operates and how it creates value for its stakeholders" (Casadesus-Masanell, and Ricart, 2010). Hence, it is composed of two parts: "Part one includes all the activities associated with making something: designing it, purchasing raw materials, manufacturing, and so on. Part two includes all the activities associated with selling something: finding and reaching customers, transacting a sale, distributing the product, or delivering the service." (Magretta, 2002). These two parts are represented in a very simplified manner on Table 2. In this research project, the activities related to Part 1 are called "Back-end activities" whereas the activities related to Part 2 are called "Front-end activities".

Back-End Cases: Companies C1 and C2 are both automotive companies and are mainly tackling both back-end and front-end improvement. Compared to the other cases, these only provide simple services based on the Digital Twins. These services include: security services, such as car localization and automatic emergency call in case of car accident and stolen car tracking service. The companies offer also convenience features such as remote checking and control of the car temperature, windows and doors status and remote control of the car charging status for the electric cars. Finally, they also offer the very basic engine, cooling system and tire failure detection. Unfortunately, a more advanced service models are not yet provided.

Front-End Cases: Companies E1 and E2 are most advanced in front-end improvement. Their services offer to their customers with the Digital Twins go from asset monitoring and performance management to smart maintenance. Company E1 also offers asset utilization optimization. Unlike the services offered by companies C1 and C2, these services directly affect the way the end-users operate the products. Both companies also work on big data analytics. Company E1 is moving towards fleet optimization.

Conclusions and Contributions

Our research demonstrate how manufacturers are moving from product-centric to service-centric business models to gain in value creation. They are using the opportunities offered by digitalization – in particular the Digital Twins – to improve their processes and extend services across their products' lifecycles.

In answering our research enquiry, two ways of improving companies' business models have been identified in this research. The Digital Twins can help the companies to either strengthen the back-end or the front-end of their business models. Based on the level of back and front-end improvement, four categories of companies have been highlighted. Each category follows a different path to implement the Digital Twins: 1) They can develop both back and front-end but put more emphasis on back-end process improvement, 2) They can develop both back and front-end but put more emphasis on front-end service innovation, 3) They can choose to only focus on back-end improvement, 4) Some of them are already mature in both back-end and front-end improvement

The expected contributions from this study are (i) this research shows two distinct ways that Digital Twins improve business models: "Back-end" and "Front-end processes". (ii) Shows how DT are used and the maturity of the platform. (iii) Highlight how DT spring board the creation of new services business models. (iv) Illustrate few cases and the importance of DT in future services.

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