Towards a digital twin of a service: a case of communicating cost and control implications of a new after-sales service with an animation

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Abstract

Purpose – New service businesses carry opportunities for industrial companies. The different cost management and management control implications of those service businesses deserve attention, which is a widely under-researched area in management accounting and control literature. Digital twins could hold potential in unveiling and supporting those new service business opportunities, as a unique approach of this paper. Thus, the purpose of this paper is to examine the possibility and potential for creating a digital twin of a service, especially to unveil the management accounting and control implications of the digital twin in developing new service businesses.

Design/methodology/approach – This paper investigates the potential of a digital twin in unveiling cost and control implications of new service businesses by examining the characteristics of a digital twin in the service business development context. The paper use an in-depth interventionist case study, where the designed animations illustrate the possibilities of a digital twin of a service. The animations showing the service process characteristics were first used as a communication tool and eventually those animations were actively used in customer cases for different purposes. This motivated the idea for examining the implications of such animations representing a digital twin of a service.

Findings – The paper provides empirical insights regarding the potential for developing and using a digital twin of a service for different cost management and management control purposes. The digital twin of a service may include all main details of a new service offering, simulating the functionality of a service, hence making the performance and the implications of the new service concept clear for all the stakeholders. The digital twin of the service enables defining the processes, setting targets and helps communication about the value generation. Thus, they represent a significant toolkit for the management accounting and control function of the manufacturers.

Originality/value – This paper is among the first attempts to understand the digital twin of the service. The paper is unique in providing financial and control implications of digital twins also in the context of

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service business development. The in-depth interventionist approach enabled an exceptional exploration process on the subject. The article paves the way toward further research on managing the digital twins of services in the future.

Keywords Digital twin, Digital twin of a service, Cost implications, Communication, Management control, Servitization

Paper type Research paper

Introduction

Despite the remarkable potential of service businesses among manufacturing companies (Vandermerwe and Rada, 1988; Wise and Baumgartner, 1999; Oliva and Kallenberg, 2003; Baines *et al.*, 2009; Lindholm *et al.*, 2017) understanding, managing and realizing such potential has not received wide attention in the management accounting and control literature (Neely, 2008; Laine *et al.*, 2012a; Lindholm *et al.*, 2017; Tenucci and Supino, 2019). Furthermore, as digital tools and technologies, such as digital twins, remarkably change the way of doing business in manufacturing companies, there are several business implications to be better understood and managed in this area. In response, this paper focuses on the possibilities and potentials for creating a digital twin of a service, especially to unveil the cost and process implications of the new service businesses, to pave the way for managing the wider, embedded business implications of service business in manufacturing.

Indeed, in today's business environment, many original equipment manufacturers (OEMs) face high competition and decreases in new equipment sales. Therefore, to increase their competitive advantage, manufacturers focus on servitization, which is nowadays considered as a key strategic asset (Lay, 2014, p. 2). As a part of servitization, aftermarket service revenues are stable and oftentimes have even higher margins than sales of new equipment (Baines *et al.*, 2009; Laine *et al.*, 2012a; Lindholm *et al.*, 2017). Therefore, to enhance profits, companies should pay more attention to aftermarket services, including supplying spare parts, field technical assistance and preventive and corrective maintenance.

In addition, the development of intangible services carries an opportunity to complement the main product-based innovations, which creates a bigger market share (Lerch, 2014, p. 179). As a result, to provide sufficient aftermarket service, an organization needs to consider a new service offering development (Penttinen and Palmer, 2007; Rabetino *et al.*, 2017). Accordingly, a crucial part of the research and development (R&D) activities is communication within a team, which includes the internal organizational team and outside stakeholders (Grönroos, 2000; Kindström and Kowalkowski, 2009).

One of the communication tools used in a product-oriented environment is a digital twin. The digital twin is used for an optimization of the process and a simulation of a product's lifecycle, but at the same time, the digital twin can be used as a communication tool during the development process (Tao *et al.*, 2017; VanDerHorn and Mahadevan, 2021). The service, however, is intangible; thus, a question arises of how to make a digital twin of an intangible service, to facilitate communication with the key stakeholders.

When developing a new aftermarket offering, all stakeholders involved in the development process should share the same vision of the technological innovation, including the service concept itself as well as its process and, hence, value implications (Grönroos, 2000; Kindström and Kowalkowski, 2009). The vision of the innovation and, more broadly, the vision of the servitization with its business consequences (Laine *et al.*, 2012a) can be operationalized by defining common targets, service processes and related value generation. As an articulated need in the servitization literature, the lack of understanding of such

processes are still widely hindering the servitization processes (Baines *et al.*, 2009; Laine *et al.*, 2012b; Lindholm *et al.*, 2017).

Digital tools could help in such processes of setting targets and managing the processes in realizing them with different approaches of management accounting and control. Especially, recent studies show that digital twins can provide new possibilities for management control (Ukko *et al.*, 2022; Saunila *et al.*, 2022), by enabling exploration, guidance and playing with the processes at hand. Such possibilities seem to be highly important and interesting in the context of service, where tangible services pose extra challenges for management control with traditional means. However, as outlined above, there is very limited academic understanding on supporting service business development with management accounting and control in general, and especially with digital tools, such as digital twins, for unveiling cost and control implications of the new service businesses.

In this paper, we take a closer look at animations that represent powerful tools for facilitating communication related to the service elements within and between the key stakeholders at the early stages of the service development. Interestingly, such an animation can be built in a way that it includes and demonstrates all the relevant service process characteristics and thus also shows the process and cost implications of the new service, which makes the value creation and value capture logic more explicit, too. The way a simple animation can be used as a tool for communication, making an intangible service more tangible for the stakeholders, subsequently has motivated the considerations regarding the possibilities for developing a digital twin of a service.

Altogether, digital twins could hold potential in unveiling and realizing new business opportunities, in case understood and examined thoroughly also in the service context. Therefore, *the objective of the paper is to examine the possibility and potential for creating a digital twin of a service, especially to unveil the management accounting and control implications of the digital twin in developing new service businesses.* This paper investigates the potential of a digital twin of a service by comparing the characteristics of a digital twin with peculiarities of service businesses. The paper takes advantage of an in-depth case study, where the designed animations illustrate the possibilities of a digital twin of a service. The animations showing the service process characteristics were first used primarily as a communication tool, but during the process, eventually, those animations were actively used in customer cases for different purposes. This motivated the idea for examining the characteristics and implications of a digital twin of a service with the help of the animations on the service processes, especially when designed and used in the context of service development.

Understanding the digital twin of a service and its control implications thoroughly requires empirically grounded insights both on the service business development and the design and use of the digital technologies supporting that. Furthermore, longitudinal, in-depth access would be desired to understand the dynamics and implications more widely and permanently. This paper is based on a long-term interventionist case study (see Jönsson and Lukka, 2007; Suomala and Lyly-Yrjänäinen, 2012; Suomala *et al.*, 2014; Lyly-Yrjänäinen *et al.*, 2017; Baard and Dumay, 2020) in a network, consisting of a hose assembly supplier, OEM making modular, mass-customized machines and its distributor and customer organizations.

Essentially, the case focuses on the new after-sales services business opportunities around the hose assemblies used as elemental part of the OEM's machines. Such business opportunities were recognized and put forward by one of the authors of the paper, who was deeply involved earlier in designing and implementing new production approaches and patented innovations regarding the hose assemblies (see Lyly-Yrjänäinen *et al.*, 2016). The

new production concept improved the tolerance in hose cutting, enabling the development of plug-and-play hose bundle for machine booms, a solution similar to the wire harness widely used in the automotive industry. Interestingly, when the boom hoses are assembled with a plug-and-play module instead of routing the hoses one by one, the same value creation logic applies also in the maintenance activities on the customer sites. As a result, the OEM decided to start the development of a similar plug-and-play after-sales hose bundle concept, with the intervening researcher again playing a facilitating role in the process. A patent application has been filed for the service concept with one of the intervening researchers, again, included as one of the co-authors in the patent application. Indeed, the business opportunities stemming from similar approaches for after-sales services are something new in this business, and the identification, understanding and realization of those opportunities requires new tools for communication among the parties involved in the case.

The research collaboration started already in 2011 with the production related interventions. The first ideas reading the after-sales services were brought up 2016. However, the data collection process resulting in this paper took place 7/2020–4/2023, when the momentum for the after-sales service business development had increased. The empirical data consists of 72 documented visits or meetings, 121 calls or telcos and 1,025 emails discussing the new services businesses of the OEM among parties involved in the case. The data provided extensive insights on the cost and control implications of the new service businesses, unveiled and examined with the help of the animations designed by the interventionist researchers, representing the digital twin of a service in this context. Essentially, in the core of the empirical study underlying this paper are the six interventions, where the animations designed by the researchers were used as a basis for discussions and analyses among the stakeholders. Overall, the animations first represented communication tools about the value generation processes of the new services. Then, the nature of the animations representing a digital twin of a service was revealed, and thus, new animations could be designed and used focusing on different customer cases. The analyses on the cost and control implications of the digital twin of a service were based on the involvement of the researchers in three customer cases in different market areas.

As a scientific contribution, the active participation in the longitudinal, interventionist research process has enabled the researchers to conceptualize the digital twin of a service and unveil more detailed, empirically grounded findings regarding it. As confirmed by the empirical findings, the digital twin of a service may include all main details of a new service offering, simulating the functionality of a service, hence optimizing the communication processes by making the performance and the implications of the new service concept understandable and clear for all the stakeholders (Laine *et al.*, 2012b). Furthermore, the digital twin of the service (based on the empirical findings of the paper) enables defining the processes related to the service, setting targets about them, and thus, helps unveiling and communicating the value generation of the service at hand to the parties involved (Neely, 2008; Laine *et al.*, 2012a, Lindholm *et al.*, 2017; Tenucci and Supino, 2019). This enables unveiling and discussing all the relevant cost implications of the processes under examination. Finally, digital twin of a service as an approach represent a significant toolkit and data source for the management accounting and control function of the manufacturers (Saunila *et al.*, 2022; Ukko *et al.*, 2022), with several implications.

The rest of the paper is organized as follows. Next, the literature part of the paper addresses developing new services among manufacturers, the characteristics of the digital twins, especially in the service context and the possible implications therein for management control. After that, the research methodology and the empirical findings will be presented in a detailed way. The paper is concluded with discussion and concluding remarks.

Services businesses and digital twins – implications for management control

Developing after-sales service businesses

The context of the paper is the service business development in the machinery manufacturing sector. Thus, an overview of such service business development is provided here, especially with the focus on the nature of the service business as well as the requirements for the service business development, before going to the details of the digital twins and their management accounting and control implications.

Services are activities provided by a company to support customers' value generation processes (Laine *et al.*, 2012a). To succeed in such a role in the customers' business, it is not enough to offer only high-quality products, but effective, comprehensive and high-quality services are needed as well (Grönroos, 1990; Wood, 2010), Traditionally, services have been considered intangible items, in contrast to physical goods (Zeithaml *et al.*, 1985). However, service business might as well include tangible elements (Kindström and Kowalkowski, 2009; Martinsuo *et al.*, 2020). For example, spare part and maintenance services include typically physical goods as central elements of the value generation processes.

In the manufacturing sector, servitization has taken place already some decades (Vandermerwe and Rada, 1988; Oliva and Kallenberg, 2003; Baines *et al.*, 2009). Indeed, companies pursue expanding their service businesses to increase sales of their goods, improve and strengthen the relationships with customers, find new growth opportunities in emerging markets and respond to the needs of the value generation processes at the customer (Brax, 2005).

According to Kowalkowski and Gebauer (2012), there are two types of service activities: customer-oriented and product-oriented service activities. First, customer-oriented service aims to serve customers with a wider range of activities, and it is focused on serving customer needs, enhancing customer's loyalty and satisfaction (Kowalkowski and Gebauer, 2012). Second, product-oriented service cannot be performed without underlying products, and it is defined as activities toward purchased units. It requires technical knowledge of the product, including engineering skills and knowledge of product's functioning. In the context of this paper, these two types of services are partly combined and intertwined. The after-sales services under development in the case are essentially related to the customers' machines. However, there is a potential that the digital twin of a service unveils visibility to the wider processes of value generation at those customers.

One rationale for developing after-sales service businesses in the manufacturing sector is profitability (Laine *et al.*, 2012a; Lindholm *et al.*, 2017; Tenucci and Supino, 2019). Indeed, after-sales services cover about 25% of all sales revenue and around 40%–50% of all profits for manufacturers (Holmström *et al.*, 2011). However, to remain economically vital, such services need to have positive implications for the profitability of the customers (Laine *et al.*, 2012b). Modern complex engineered products attribute a higher value to the reliability, cost efficiency and high quality of delivered after-sales services. Hence, creating well-prepared, well-functioning after-sales service businesses has become very important (Roy and Wilding, 2014).

Servitization initiatives in general and after-sales service business development in particular has been hindered due to the lack of supportive managerial tools and techniques (Baines *et al.*, 2009). It is noteworthy that especially tools and techniques related to the management accounting and control for those service businesses have been lacking (Neely, 2008; Laine *et al.*, 2012a, Tenucci and Supino, 2019). Therefore, there is a need for new academic knowledge on the new means and experiences on how service business development could be successfully supported and executed.

One remarkable requirement for service business development is to thoroughly understand customers' value generation processes (Grönroos, 2000). Such understanding can be attained in service business development in different ways: search and capture customer knowledge related to the new service or product and apply it during the development phase, or codevelop the new service and products with customers (Woerter *et al.*, 2020). Especially, in the servitization, the manufacturing companies may have limited understanding of the value generation processes at the customers, thus hindering the successful services business development. In response, Laine *et al.* (2012b) developed a business game concept for the manufacturing company to analyze, discuss and optimize the value generation at the customer. Such concept was suggested to be used in understanding how the manufacturing company could support value generation processes at its customers.

Kindström and Kowalkowski (2009) suggested a four-stage framework for developing the new service businesses, based on the market research, development, delivery and sales. In this context, it is crucial to go through the four stages continuously and not to become contented after one revolution. It is important to reflect on the completed steps before proceeding to the next one, to learn and improve. First, market sensing is done based on a comprehensive analysis of the customers, competitors, current situation in an organization and internal parties. Only after gathering necessary information, it is possible to move to the next step (Kindström and Kowalkowski, 2009; Woerter *et al.*, 2020).

However, the proposed framework by Kindström and Kowalkowski (2009) does not solve the problem of limited understanding of the internal business objectives and the customers' value generation processes. Indeed, communication on those aspects is extremely important in the development of the new service offering (Hedman and Valo, 2015). As concluded by Edvardsson and Tronvoll (2013), clear strategic goals, available resources and the market analysis are important prerequisites for service business development (Edvardsson and Tronvoll, 2013). Furthermore, a detailed understanding on the dynamics of the value generation at the customers is needed throughout the service business development processes (Laine *et al.*, 2012b)

he digital twins, especially embedded with the management accounting and control considerations, support the idea of developing new service businesses in line with the manufacturing companies' business targets and in response to the needs of the value generation processes at the customers (see e.g. Laine *et al.*, 2012b; Lindholm *et al.*, 2017). Such perspectives have not been examined in this context. However, to unveil the potential of those perspectives, they will be discussed next.

Digital twins with their implications for cost management and management control

A digital twin is one of the potential solutions for the lack of understanding of the business potential and limited communication related to the processes at hand. In this vein, scientific literature considers the digital twin of a product not only as a tool for simulation, but as a broader tool for communication and decision-making (Söderberg *et al.*, 2017; VanDerHorn and Mahadevan, 2021). According to Tao *et al.* (2017), the digital twin is used to improve transparency and speed of information communication with the real-time transmission data. Figure 1 demonstrates the main idea of the digital twin concept.

As shown in the figure, the concept of the digital twin refers to a comprehensive physical and functional digital description of a product or a system, which includes all necessary useful information about the product (Boschert and Rosen, 2016; Haag and Anderl, 2018). The digital twin consists of three main parts: the product itself, its virtual copy and data linking physical and virtual parts together (Grieves and Vickers, 2017; Tao *et al.*, 2017).

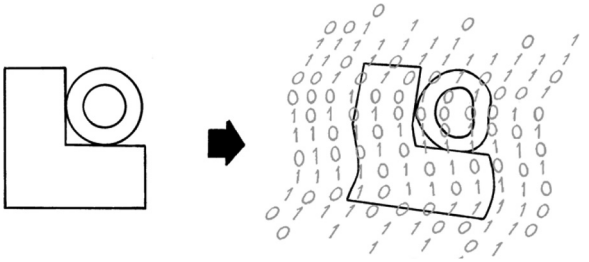

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Figure 1.
A digital twin

The three elements of a digital twin can be seen as its characteristics. A digital twin can be recognized by representing a tangible asset existing in physical reality. The digital twin then provides its virtual representation, but always the original and the twin are interconnected, providing feedback to each other (VanDerHorn and Mahadevan, 2021). The digital twin develops along with the real system and remains its digital counterpart throughout whole lifecycle (Haag and Anderl, 2018). The digital twin integrates all available new existing knowledge about its physical twin (Boschert and Rosen, 2016). Boschert and Rosen (2016, p. 59) offer to use the digital twin for product simulation to plan rational operations and failure predictions. It is important to note that the digital twin is not entirely limited to a physical object itself, but it oftentimes considers the environment around and interactions with it (Parrott and Warshaw, 2017; Pang *et al.*, 2021).

Overall, the development of digital tools has changed management control in many ways (Bhimani, 2020). Digital twins, among those digital tools provide new opportunities for management control at different levels, from multiple perspectives. Essentially, as the organizational processes and entities within them become more completely documented and their dynamics become more easily analyzable, the values and costs of those processes become more visible and manageable. As the members of the organization become more aware of the information relevant to their work, they may become also more motivated to work for the targets set for them (Saunila *et al.*, 2022). More broadly, Ukko *et al.* (2022) examined the impact of digital twins on management control and observed that digital twin could help in influencing the members of the organization by supporting their exploration behavior, by providing guidance and offering different ways to analyze the processes and their circumstances.

In this paper, the focus is on the cost and control implications of the new service businesses, possibly enabled by the digital twin of a service. The digital twins of products are already to some extent used in developing the after-sales businesses. With data received from the product, suitable repair, maintenance and service solutions are created (Boschert and Rosen, 2016; Tao *et al.*, 2017). Even though the digital twin contains large amounts of data about the service, it does not add tangibility to the developing service offering. This raises the question of how to resolve the problems of understanding, controlling and communicating relevant aspects of the new service businesses under development at the manufacturing companies.

Digital twin of a service to facilitate new service business development

To be able to support new service business development with the help of the digital twins, it is important to understand multiple layers of management control, communication and development work.

Regarding communication, Parker (2009) distinguishes two main parts in team communication: interpersonal communication and communication of information. First, interpersonal communication is defined as trust and openness between team members, and the efficiency of their communication. Salas *et al.* (2005) confirm that, for better cooperation within a team, team members have to anticipate and predict each other's needs through shared understanding of the working environment. Second, communication of information is characterized as information flow to and from the team. The degree of communication of information is efficient if team members get necessary information for their work, and if they share information with others about their work (Parker, 2009). Overall, communication of information helps to monitor mutual performance, which includes identification of mistakes and lapses in actions of team members (McIntyre and Salas, 1995).

Digital twins hold characteristics that could enable new forms of control and communication. As was discussed earlier, the digital twin is considered as the sufficient simulation tool of tangible products (Grieves and Vickers, 2017; Tao *et al.*, 2017). The digital twin is not needed to make already tangible products more tangible. Nevertheless, things change when development of a service is considered. From the definition of the digital twin arises a challenge of how to make the service more tangible, that is how to make the service and the overall service process clearer and more visible for the parties involved. Such an approach has not been yet discussed broadly in academic literature. Molloy *et al.* (2011) have attempted to make intangible company resources tangible, which would create a common language and understanding for all the participants of the process.

The process nature and intangibility of a service make it hard to clearly define it, and therefore, complicates the process of creating a digital twin. Furthermore, although there are clearly tangible elements in the after-sales services, the service processes take place largely outside the factories, which make the physical environment more complex and versatile. In the case of products, 3D models and mock-ups can be used to replace the digital twin. This is not applicable for the intangible service in a comprehensive way. It seems that animation could be a powerful tool to make things as tangible as possible. Thus, the animation could be used to facilitate understanding of the idea, to improve quality of the communication and validate future performance under given circumstances. An animation would, as well, match at least some of the characteristics of a digital twin of a service, especially, as in this paper, if it includes all the relevant characteristics of the service process under examination. However, animations are here used with limited functionalities in contrast to comprehensive digital twin solutions. Altogether, animations can be considered an intermediate step toward developing a digital twin of a service. This idea is demonstrated in Figure 2.

As shown in the figure, an animation can be a more tangible way to represent and communicate a service, providing a virtual representation of the service at hand. This way, an animation becomes a stepping-stone toward a digital twin of a service. With further

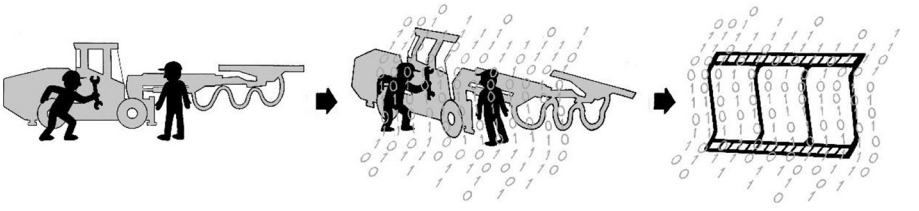


Figure 2.
Animation as a step toward the digital twin of a service

Source: Developed by authors, artwork by Niffe

development, it has the potential to progress in that direction as well. Potentially, changes can be implemented to the animation based on the observations of real-life service. At the same time, the animation may serve as a decision-making support, closing the loop of physical-to-virtual connection. Furthermore, ways to explore, get guidance about and play with the new service processes seem to become unveiled (building on Ukko *et al.*, 2022). There may never be a physical object to represent, but the tool can be used to support decisions that affect the real physical world. It is, therefore, important to consider the animation as a continuous project and keep gathering data even after the service implementation.

As a synthesis, if a digital twin is to be considered in the service setting, many of its characteristics need to be reconsidered. Literature extensively discusses the characteristics of digital twin in the product or physical system setting. However, when applying the idea of a digital twin in the service context, some of the characteristics can only be extracted or deduced to a certain degree based on the service characteristics identified in the service literature. Table 1 constitutes a literature-based comparison related to the characteristics of a digital twin in the product and service contexts.

First, as a difference between the digital twins of products and services, the modeled system changes from the physical system and its interaction with the environment more toward the digital representation of an intangible service. Second, focus on services emphasizes the *locus* outside the organization, at the customer sites. With regard to virtual representation and information interconnection, digital twins of a product and service should be rather similar. However, when looking at the data transfer, digital twin is often considered to take advantage of various IoT elements, making the data transfer digital, though some manual data transfer may be used as well. However, with regard to often manual activities within the service processes, the possibilities of automatic digital data transfer are limited relying more on service operators inputting information related to the service event. The literature-based comparison of the characteristics of digital twin of a product and service provides the lens through which the case will be evaluated.

Table 1. Comparing the characteristics of the digital twin of a product and the digital twin of a service

Similarity/ Difference	Characteristic	Digital twin of a PRODUCT	Digital twin of a SERVICE
Difference	Modeled system	Physical system + elements of environment (Parrott and Warshaw, 2017; Pang *et al.*, 2021)	Digital representation of intangible service (Tao *et al.*, 2017)
Difference	Physical environment/place of consumption (VanDerHorn and Mahadevan, 2021)	Inside and outside of the organization	Outside of the organization; at the customer
Similarity	Virtual representation	Data and computational models for the physical objects, environment and processes (VanDerHorn and Mahadevan, 2021)	Data and computational models for the physical objects, environment and processes (VanDerHorn and Mahadevan, 2021)
Similarity	Information interconnection	Physical-to-virtual and virtual-to-physical connection (VanDerHorn and Mahadevan, 2021)	Physical-to-virtual and virtual-to-physical connection (VanDerHorn and Mahadevan, 2021)
Difference	Data transfer	Digital and manual (VanDerHorn and Mahadevan, 2021)	Manual

Source: Authors' own work

Altogether, based on the analyses on the potential of the digital twin of a service, it appears that many positive features of the digital twins could potentially be embedded to the digital twin of a service, and even animations representing them. Indeed, the digital twin of a service could make the new service more visible and thus observable by the parties involved. This would enable anticipating and preliminarily analyzing the values and costs related to them (Laine *et al.*, 2012b). When it comes to the control implications (Saunila *et al.*, 2022; Ukko *et al.*, 2022), digital twin of a service, despite its limitations, could potentially enable new ways to support the people involved in developing new service businesses.

Methodology

Long-term interventionist research collaboration

Understanding the digital twin of a service and its control implications thoroughly requires empirically grounded insights both on the service business development and the design and use of the digital technologies supporting that. Furthermore, longitudinal, in-depth access would be desired to understand the dynamics and implications more widely and permanently. In addition, as service businesses tend to require multiple stakeholders' interaction at different stages, insights from those different parties involved would be valuable, too. The aforementioned characteristics are present in this paper that takes advantage of an interventionist case study. The case study shows a set of animations of a service concept under development, facilitating the communication between and within various stakeholders during the development process. The companies involved in this case study are shown in Figure 3.

The interventionist research collaboration started in 2011, with us becoming involved with a product factory of a global OEM in Finland. Based on the invitation of the OEM, we facilitated its local hose assembly supplier (owned by an Italian parent) to apply a new digital hose cutting technology with the aim of building a production concept for manufacturing machine-specific hose assembly kits (see e.g. Lyly-Yrjänäinen *et al.*, 2016; Lyly-Yrjänäinen *et al.*, 2017) for the OEM. A hose assembly consists of a piece of hose with fittings crimped (i.e. squeezed) at both ends, illustrated right in Figure 4.

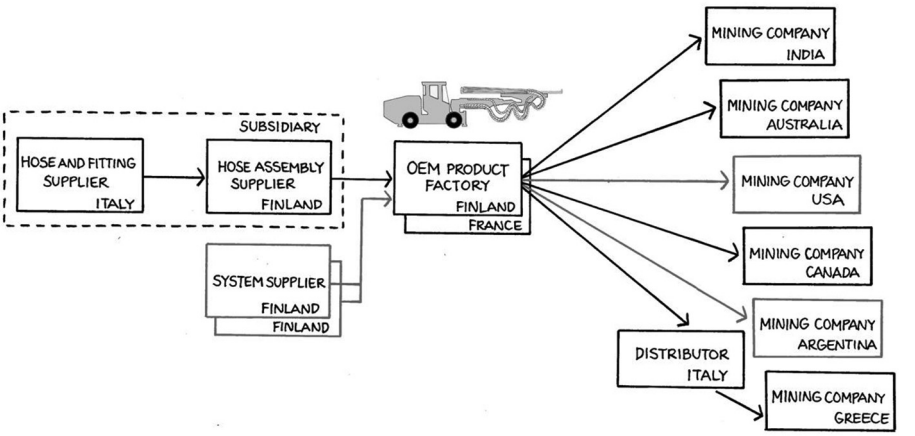


Figure 3.
The companies involved in the interventionist case study

Source: Developed by authors, artwork by Niffe

In machines with telescopic booms, the hose assemblies in the boom are bundled together (shown in Figure 4). Building these hose bundles was time-consuming, and, hence, in 2014, the OEM invited us to facilitate the outsourcing of the hose bundle assembly by developing a process similar to the plug-and-play wire harnesses used in the automotive industry. After two years of trial and error, the development team eventually found a solution, reducing the bundle assembly time at the OEM almost 90% (from 24 h to 3 h per machine boom).

When the hose harness concept worked in the production, the OEM sourcing engineer realized that the same value dynamics would also apply in the periodical hose bundle rebuilds at the mines. Based on the experience in the OEM final assembly, in 2017, the OEM decided to start developing this new service concept, later branded as a hose swap kit (HSK). Unlike in production, in rebuilds the boom needs to be stripped first, and hence, the downtime was reduced "only" by 60%.

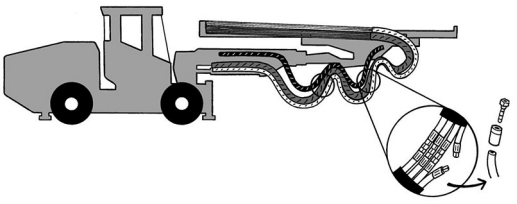
Research interventions focusing on digital twin of a service

Because HSK was a completely new service concept, the OEM marketing team prepared an animation showing how the boom hose bundles are changed using the HSK. Selling the HSKs through the OEM's own global service organization, sometimes also involving local distributors, involved many stakeholders whose actions had to be aligned. To facilitate communication with various stakeholders, we prepared simple animations (i.e. animated movies) illustrating the service process characteristics and, more broadly, cost and control implications related to the service concept. Figure 5 shows six interventions related to the use of animations, connected to three customer cases: Australia (AUS), Canada (CAN) and Greece (GRE).

This paper focuses on the research collaboration related to the animations, hence starting 07/2020. Initially, we built three animations related to the localization needs in Australia. In 2022, the idea of comparing an animation to a digital twin of a service emerged. In spring 2023, the two new customer cases were started (a mining customer in Canada wanted to expand the HSK offering to new machine models and a mine in Greece wanted to develop its machine maintenance processes) bringing on the surface similar communication challenges. To support these two cases, all the three initially used animations were recreated to emphasize management control elements.

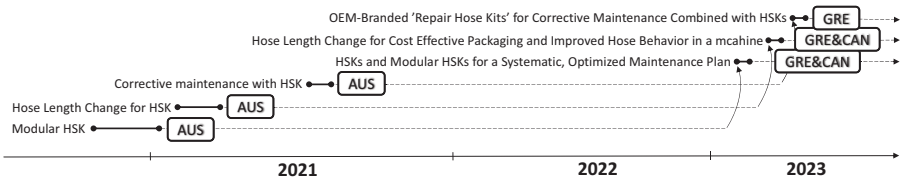
Project stakeholders and their roles in the data gathering process

With regard to data gathering for this paper, Table 2 documents the interaction with the companies involved, altogether 72 visits or meetings, 121 telcos or calls and 1,025 emails. The pandemic reduced the possibilities to visit the Italian hose and fitting supplier as well as the OEM, and thus, visits were replaced with telcos and calls. The hose assembly supplier restricted visitors only for summer 2020, visible in the table.



Source: Developed by authors, artwork by Niffe

Figure 4.
Hose assembly and bundle in a mining machine with a telescopic boom



Animation as a communication tool in service development

Researchers involved in:

-HSK Documentation for a new machine model (USA) (System Supplier 1)
-Collecting materials for the OEM's internal innovation competition
-Visualization of the HSK for the new machine model (USA)
-Development of shorter packaging for easier handling and reduced freight costs
-Development of modular HSK solution to enable faster HSK deliveries with reduced need for capital
-Ramping up a hose bundle for tunneling machine (System Supplier 2)
-Animation for the modular HSK solution including the cost and capital impacts (AUS) *(Figure 6)*
-Changing the corrective maintenance practices (AUS)
-Modularization of option hoses in HSKs
-Animation on hose lenght change to enable easier handling and reduced transportation costs (AUS) *(Figure 8)*

Animation as a "Digital Twin" of a service

Researchers involved in:

-HSK packaging for a new machine model (USA)
-Process for ramping up harness with frontline
-Investigating a possibility to use the hose&fitting supplier's global distribution network for the OEM spare part hose business
-First HSK rampup process with frontline service organisation (AUS)
-Animation for changing the corrective maintenance practices (AUS) *(Figure 10)*
-Process for reverse engineering bundle geometry using still photos (AUS)
-Illustration of the bundle ramp up process to reduce uncertainties within different stakeholder groups
-Feasibility study of 3D scanning for knowledge transfer needed for ramping up HSKs no longer in production
-Redefine the use of option hoses in HSKs to speed up global logistics and customs processes (ARG)

Animations with customer focus

Researchers involved in:

-Visit to product factory to start collaboration on new HSKs and cost-effective ramp up process (FRA)
-Process for fast, cost effective installation of hose kits for large surface mining machines (USA)
-Animation on child kits in precentive maintenance for optimised costs (GRE, CAN) *(Figure 7)*
-Animation on improved hose behavior and lower cost of shorter package (GRE) *(Figure 9)*
-Animation on 'repair kits' provided by OEM for corrective maintenance for optimized total maintenance costs (GRE) *(Figure 11)*
-Analysis of cost impact of OEM-branded hoses for improved aftersales business (ITA)
-Feasibility of smart phone 3D scanning application for cost-effective ramp up HSKs no longer in production
-Process to speed up HSK ramp up with global coordination of frontline organisations (CAN)

Figure 5.
Key interventions related to the animated videos discussed in the paper

Source: Authors' own work

Organization	Emails	Telcos/calls	Visits/meetings
Hose and fitting supplier	*171*	*8*	*5*
Hose assembly supplier	*531*	*65*	*55 + 2*
OEM HSK team	*265*	*39*	*9*
OEM product factory (France)	*5*	–	*1*
OEM Australia	*36*	*3*	–
OEM Canada	*12*	*4*	–
OEM Europe and distributor (Greece)	*5*	*2*	–

Table 2.
Contacts with the organizations related to the animations 07/2020–04/2023

Source: Authors' own work

To further elaborate the data gathering, Table 3 lists the key managers involved in the cases related to the use of animations in HSK development. First, the managing director of the Italian hose and fitting supplier was involved when special knowledge on hoses and fittings was needed. Second, the HSK development team consisted of the project manager located in Chile, documentation project lead located in India, two sourcing engineers located in Finland as well as two managers working for the hose assembly supplier in Finland. An aftermarket specialist located in the OEM product factory in France became involved in the project fall 2022. Finally, when the new customer cases started, the HSK development team collaborated with the local managers.

When looking at the data gathering, the interventionist involvement in the service development has provided in-depth knowledge of the service process and the challenges in the development and diffusion of a new service concept. The case is not only about a

Title (location)	Organization	Project role
Managing director (ITA)	Hose and fitting supplier	Hose and fitting specialist
Sourcing engineer (FIN)	OEM	Project champion
Category manager (CHL)	OEM	Project manager
Project lead (IND)	OEM	Documentation specialist (spare parts)
Sourcing engineer (FIN)	OEM	Logistics specialist (spare parts)
Managing director (FIN)	Hose assembly supplier	Hose assembly specialist
Production manager (FIN)	Hose assembly supplier	Hose harness specialist
Documentation manager (FRA)	OEM	Service specialist (machines made in France)
Category manager (AUS)	OEM	AUS project champion
Category manager (CAN)	OEM	CAN project champion
Key account manager (UAE)	OEM	GRE project champion
Sales engineer (ITA)	Distributor for GRE market	Sales engineer in charge of the customer in Greece
Sales engineer (ITA)	Distributor for GRE market	Manager in charge of the customer in Greece

Source: Authors' own work

Table 3. Key stakeholders in the cases involving the use of animations

solution for preventive maintenance with existing spare part, but instead, the spare part and service combination includes elements new to the industry. Interestingly, showcasing the "tangible" HSK to the industry experts easily leads to misinterpretations regarding the more "intangible" service process elements, thus calling for tools to facilitate communication about the service characteristics and related value generation mechanisms. The active participation in the meetings with the key stakeholders and the use of the animations developed has enabled us to witness many interesting insights with the project stakeholders as informants, providing empirical data on the service development and the use of the animations in facilitating the development.

Case study – toward a digital twin of a service

Machine options challenge the use of hose bundle in corrective maintenance

With regard to many machines powered by hydraulics, hose assemblies are ware parts and changed regularly. However, very few OEMs have been able to penetrate the hose assembly after-sales market. Instead, it is a market dominated by global hose assembly retail/service chains who sell spare part hose assemblies as over-the-counter business or using service vans, with the hose assemblies manufactured on demand. Some of these companies are even partnering with the mines having their over-the-counter hose assembly workshops inside the mines. Hence, the top management of the OEM was very pleased with the new preventive maintenance service solution branded as an HSK, later patented with the main field MA researcher named as a co-author. In a technology-driven company with about 40,000 employees globally and 100–150 new patent applications per year (OEM website), this patent application was the first one focusing on the aftermarket business. As stated by the project champion:

> I have heard some of our VPs say that finally there is something completely new in the after-sales area.

The HSK was a powerful tool for preventive maintenance, but different machine options made corrective maintenance a challenge. For the first machine model included in the HSK

service offering, 512 different HSK configurations was needed to cover the product variants of that model. Thus, to ensure short response time for corrective maintenance, large number of HSKs with different specs would have to be stored at the frontline. As pointed out by the project manager:

> Our top management likes the bundle concept but, according to them, we have to make it work also with corrective maintenance. And we will have to do that without a need for a big front-line stock.

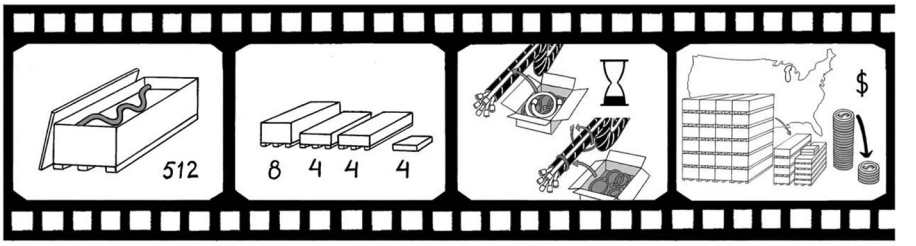
To solve the problem, in addition to the complete HSKs, the harnesses would also be offered as modules. However, to reduce the number of module variants, a decision was made that option hoses would be kept separate and belted on top of the hose harness on site. With this solution, the number of different inventory items was reduced from 512 to 20. To help communicate the idea, we built a simple animated video (Figure 6) showing the service process for corrective maintenance and its business implications.

The animation first showed how each of the three harnesses and option hoses are packaged as separate modules (Frames 1 and 2) and how the option hoses are attached on top of the harness (Frame 3). Attaching the option hose on top of the harness would require some work on the site, though justifiable when considering the fast response time with limited inventory. However, if the option hoses were attached before the machine is taken to the workshop, it would have no impact on the machine downtime, the main sales argument of the HSK concept in the first place. Finally, the animation demonstrated the impact this approach had for ne number of different HSK variants needed in the frontline stock and its financial implication (Frame 4) as pointed out by the OEM project manager:

> This simple animation helped me to recognize all available configurations of the after-sales bundles and clearly demonstrates how to manage the options with this service offering and the impact it has on the front-end stock.

The harness modules were not actively marketed until the case in Greece started in spring 2023. The customer was interested in the HSK concept to reduce machine downtime, yet at the same time, the cost of a complete HSK was a concern. To respond to the customer's concern, the HSK development team proposed a maintenance plan combining complete boom hose rebuilds (i.e. HSKs) with high-wear hose harnesses changed in-between the complete rebuild cycles (typically 1,500 h of drilling). To help communicate the proposed service offering, we built an animation (shown in Figure 7).

The maintenance cycle starts with a complete HSK (Frame 1). The fastest wearing harness together with the loose hoses going to the drill module should be changed every 500 h (Frames 2 and 4). The service specialist in France factory pointed out that, based on



Source: Original animation and simplified illustration for confidentiality by authors, artwork by Niffe

Figure 6.
Animation showing how dividing the HSK to harnesses and option hoses impacts capital tied up in the front-end inventory

his experience, only the front part of the largest harness typically wears, and hence, only the front part could be changed in between the rebuilds to save money for the customer (Frame 3) while ensuring error-free machine operation. The animation facilitated the discussion between the front-line after-sales managers, distributor and end customer about the preferred maintenance cycles and respective stock items, including also the cost implications. The animation shows clear consumption patterns for hoses, hence increasing the visibility on maintenance costs, thus making the services processes (and service costs) better to control. As pointed out by the project manager:

> The use of the HSK really makes hose consumption easy for the site managers to trace on a machine level. The money they spend on hose assemblies manufactured on site is huge and, at the same time, they have very little control on which machines the hoses go to.

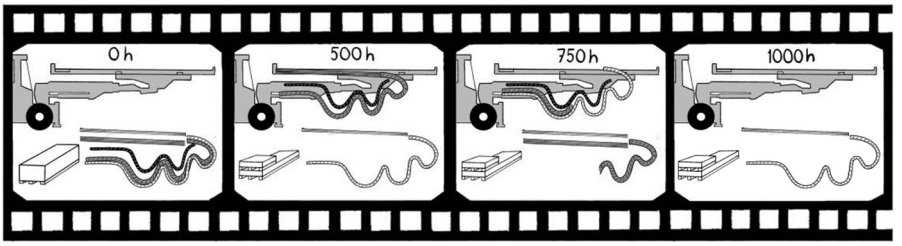
Canada market area had been very satisfied with the HSK concept and, in spring 2023, wanted to expand the concept to new machine models, emphasizing the six-month rebuild cycle for the harnesses in those machines. Those machines, instead of three parallel harnesses, had only one long harness, though split in two parts (carrier to connection plate and connection plate to the drill). Interestingly, after seeing this animation, Canada team realized that only the front-end harness is changed every six months, and the part of the harness connected to the carrier is changed only in every two years. For such a harness, "cost per meter" is significant, and more frequent changeover of only the front-end harness resulted in a more accurate volume estimates in the sales area and hence, control.

Needs for global logistics and corrective maintenance collide

When the HSK concept was first piloted, the largest harness in the machine model in question (gray harness in Figure 4) was 7.5 m long, with each line consisting of three hoses (2.5 m + 2.5m + 2.5m). With such a configuration, customers could have standard-length hoses (2.5 m) in their stock for a quick changeover. One of the two connection points, however, was close to the harness hanging point, making the harness long and stiff. At the same time, it was important to be able to package the HSK in a 3-m crate, as stated by the OEM spare parts logistics specialist:

> When the box length is under 3.1 meters, the transportation cost comes down significantly.

To "squeeze" the harness in the box, the hose lengths were changed to reposition the hose connection point (2.5 m + 2.2m + 2.8m). Nevertheless, the 3-m crate was still considered difficult to handle in logistics. As the project manager later recalled:



Source: Original animation and simplified illustration for confidentiality by authors, artwork by Niffe

Figure 7. Animation showing how to optimize the changeover cycles of harnesses in-between complete bundle rebuilds

> When we first used a three-meter box, we started getting feedback that the packaging does not work in the global logistics. We had to find a way to package the HSKs in a way that we can drive the crate sideways in a sea container.

With the changed hose connection point and by splitting the largest harness in two, all the harnesses could be packed in a 2-m crate. The change in the hose lengths, however, contradicted the corrective maintenance policies, and to help those customers understand the reason behind the change, an animation was prepared (Figure 8). The animation showed how the hose lengths had to be changed for the harness to fit in a 3-m crate (Frame 1). Despite the change in the hose lengths, the package was still difficult to handle (Frame 2), and hence, the largest harness was split in two (Frame 3) for the HSK to fit in a sea container sideways (Frame 4).

The animation showed the tradeoff between the hose length change to ensure cost-effective packaging and, thus, lower transportation costs. Connecting the split harness caused extra 30 min of work at the site, well compensated with the lower transportation costs. Connecting the harness together was possible before the machine was in the workshop, hence not impacting the downtime, the most important element of the HSK value proposition.

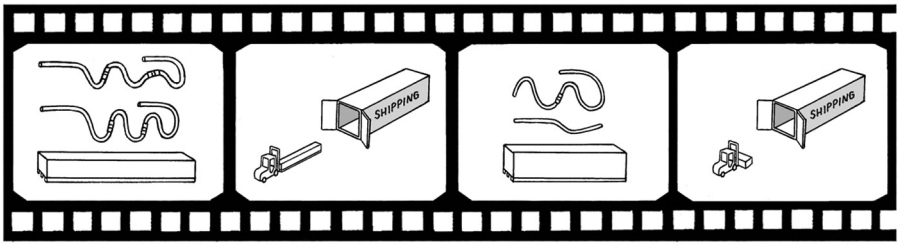
The animation was later used with Canada team to discuss the possibilities to reconsider hose lengths in harnesses to enable cost-effective packaging for the new HSKs under development. The harnesses in the new machine models were longer and the hoses had not been divided in sections, hence challenging the package length. After some discussion, it was decided not to divide the hoses; the connection point is typically a risk for a leak. Nevertheless, the animation demonstrated the service development team the connection between packaging and transportation costs.

With regard to the case in Greece, the frontline team was very concerned about the change in the hose lengths. Thus, we proposed an animation (Figure 9) that showed the effect of hose length change on the package size and transportation costs (Frames 1 and 2) as well as how the hose length change makes the harness behave better when installed (service process better under control) and when the boom is moved (Frames 3 and 4).

When the idea was proposed to the development team, the animation resonated immediately with the distributor:

> This customer is very price sensitive when it comes to the transportation costs. With such material we can convince them that these new hose lengths are indeed better.

As the quotation illustrates, such animations can be powerful communication tools to help both internal stakeholders and customers understand how product modifications can impact service processes in terms of control and cost.



Source: Original animation and simplified illustration for confidentiality by authors, artwork by Niffe

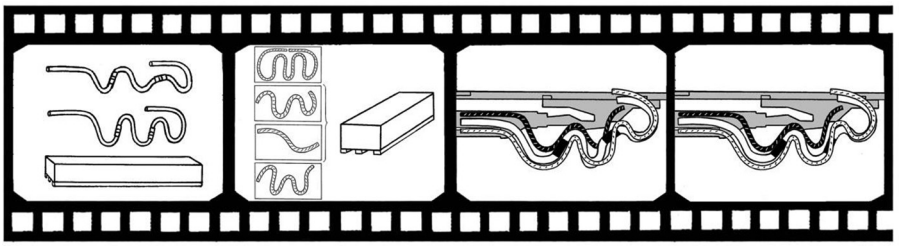
Figure 8.
Animation showing how product changes reduced transportation costs

Corrective maintenance

Despite the animations on the hose length change, the need to change a hose inside the harness using standard length hose kept coming up in the discussions with the frontline people. Interestingly, in some markets, when a hose failure inside the harness occurs, instead of changing one hose inside the harness, the service technicians simply make a long hose and attach it on top of the harness without opening any of the spirals. Despite the change in hose lengths, the harness length had remained the same, and thus, the existing 2.5-m "standard-length hoses" kept in stock would still work for corrective maintenance. To explain the idea, an animation was built, illustrated in Figure 10. When a hose failure occurs (Frame 1), three standard 2.5-m hoses in stock could be used to make one 7.5-m hose (Frame 2), belted on top of the harness (Frame 3). After two or three such unexpected hose failures, a complete harness changeover using a HSK should be scheduled (Frame 4).

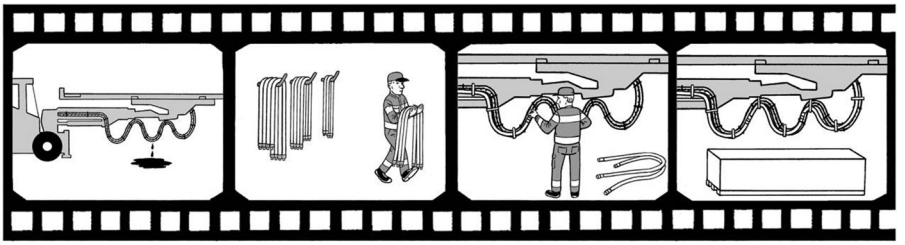
The animation, thus, showed the compatibility of the new HSK hose spec with the hoses kept in stock by mining companies, hence enabling low-cost corrective maintenance using customer's current spare part stock committed to this machine model. After the animation was shown to the OEM team in Australia, they pointed out that, when they were talking about standard hose lengths, they had different concerns. Their customers used local suppliers for hose assemblies and the bundles were built using different hose lengths altogether, hence resulting in different hose bundle geometry, too. Thus, the animation helped ground the discussion to the right problem, and eventually a customized HSK was built to meet the needs of the Australian market.

When the case in Greece started, the front-line managers also pointed out the customer's concern on not using the standard 2.5-m hoses. During the discussion an idea was brought



Source: Original animation and simplified illustration for confidentiality by authors, artwork by Niffe

Figure 9.
New animation showing shorter package and improved harness behavior



Source: Original animation and simplified illustration for confidentiality by authors, artwork by Niffe

Figure 10.
Animation showing corrective maintenance in-between harness rebuilds

up to replace the loose hoses with an OEM-spec repair kit. As pointed out by the project manager:

> Since it is clear that, in case of a sudden hose failure, the customers want a solution for a quick fix. Why cannot we provide them these hoses, just like we provide the option hoses?

Again, we proposed to build an animation that shows a selection of hose repair kits consisting of the hose lengths similar to the ones used in the harnesses. As the option hoses were packaged separately and belted on top of the harness, the idea of the repair kit was very easy to visualize, as shown in Figure 11.

The new animation showed how, in case of a hose failure (Frame 1), there is a stock of boxes, each containing the hose assemblies needed to replace an existing line in the harness (Frame 2). For each hose size, only the highest-pressure hose is provided (over-specification) to bring down the stock value, also pointed out in the animation. When the hose lengths in the repair kit are the same as the ones used in the harness, the hose connection points are positioned elegantly in the harness and the hose is easy to belt on the harness (Frame 3). Again, after two-to-three quick fixes, it would be the time to change the complete harness to ensure error-free machine operation and cost of downtime (Frame 4).

Some of the managers were a bit surprised to realize how many different hose sizes and hoses with different pressure ranges one factory-spec harness contains. Nevertheless, when the hoses in the repair kits were over-specified, the number of variants came down and even the three different lengths inside one box no longer seemed like a major issue. As pointed out by the key account manager in charge of the Greece case:

> Three standard lengths are OK, as long as they are standard!

In this case, the animation made the service concept very easy to communicate, removing some of the perhaps misguided assumptions regarding different hose types and lengths needed, hence increasing the control of the service process. If the repair kit stock became an issue for the customer, a vendor-managed consignment stock was considered as one option to help customer reduce capital tied in hose stock, again grounding the discussion to find solutions to the customers' concerns.

Altogether, the design and use of the animations has enabled the parties involved to recognize and communicate the core of the particular problems of the different cases and thus unveil the financial and control impacts to the related value generation processes, typically possibilities for cost savings and capital reductions. Such a process embeds several control implications, as the previously unknown service processes and their value generation become more understandable, manageable, and thus controllable.

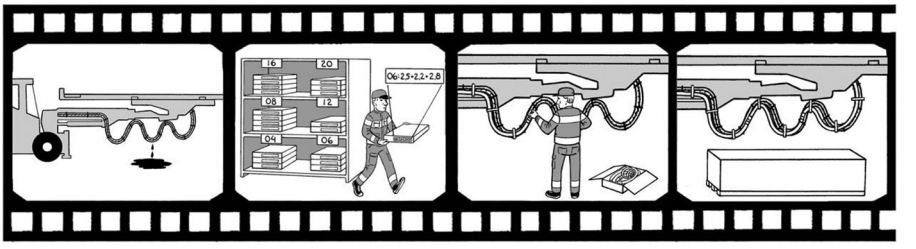


Figure 11.
Animation showing OEM-spec repair kits for corrective maintenance

Source: Original animation and simplified illustration for confidentiality by authors, artwork by Niffe

Discussion – toward a digital twin of a service

Peculiarities of a digital twin of a service

The objective of the paper is to examine the possibility and potential for creating a digital twin of a service, especially to unveil the management accounting and control implications of the digital twin in developing new service businesses. First, we discuss the peculiarities of a digital twin of a service, and in the next section, we will provide insights into the cost and control implications embedded.

The process presented in the paper confirmed the idea that developing those animations can represent developing a digital twin of a service. Overall, the findings confirmed that the digital twin of a service may include all main details of a new service offering, simulating the functionality of a service, hence enabling, and optimizing the communication processes by making the performance and the implications of the new service concept understandable for all the stakeholders. At the same time, the research process revealed certain peculiarities of the digital twin of a service, especially in the after-sales context, and those are presented in Table 4. After that, those findings are further elaborated and discussed.

First, when looking at the relationship between the physical system and the modeled system, the case confirmed the need to focus on activities and interactions (VanDerHorn and Mahadevan, 2021) in the value generation processes related to the after-sales services at

Similarity/ Difference	Characteristic	Digital twin of a PRODUCT	Digital twin of a SERVICE
Similarity	Physical system (modeled system)	Physical system + elements of environment (Parrott and Warshaw, 2017; Pang *et al.*, 2021) for the product enabling value generation	Some physical elements +activities and interactions related to the value generation
Difference	Physical environment/place of consumption (VanDerHorn and Mahadevan, 2021)	Inside and outside of the organization, essentially inside the factories and assembly lines	Frontline mainly, essentially outside factories and assembly lines long chain (regional logistics hub and country units) with independent distributors
Similarity	Virtual representation	Data and computational models for the physical objects, environment and processes (Jones *et al.*, 2019; VanDerHorn and Mahadevan, 2021)	Data and computational models for the physical objects, environment and processes (Jones *et al.*, 2019; VanDerHorn and Mahadevan, 2021)
Similarity	Information interconnection	Physical-to-virtual and virtual-to-physical product connection (VanDerHorn and Mahadevan, 2021)	Physical-to-virtual and virtual-to-service-process connection
Difference	Data transfer	Digital and manual (VanDerHorn and Mahadevan, 2021)	Mainly manual, digital requires totally new approach to sensors on the machine and use of, e.g. wearable technologies to gather/ transfer data on the operator activities
Difference	Purpose	Management and control of the use of machine	Management, control and development of the service process activities

Source: Authors' own work

Table 4. Revisiting the characteristics of the digital twin of a product and the digital twin of an after-sales service based on the case findings

hand. When successful, the digital twin of a service can be rather flexible and adjustable to convey the cost implications of the different services (or the services at different customers) as the case study did show. Such tools have been desired for manufacturing companies under servitization (see e.g. Baines *et al.*, 2009).

Second, with regard to the physical environment, it is noteworthy that after-sales services essentially take place outside the factories and assembly lines, which makes the context complex and heterogeneous for designing a digital twin of a service. Furthermore, the case emphasizes that the *locus* of the service is not only at the customer, but on the contrary, activities throughout the delivery channel involve various nods of the OEM (continental logistics hubs and country units) and the end-user but also the independent distributors and their service organizations. In other words, the service does take place both at the OEM and at the customer; yet, this case emphasizes the various steps in the multi-node distribution channel and the role played by the independent distributors. With the help of the digital twin of the service, the process changes, service features and their value and cost implications become visible to the parties involved. Such a detailed and comprehensive view has been called for by servitization studies earlier (Laine *et al.*, 2012a, Lindholm *et al.*, 2017). In response, the case enabled the parties involved, essentially in the frontline and at the customers to identify, pinpoint and thus manage the process changes, included in the processes within the digital twins of a service in the case.

Third, both in the case of a product and service, the idea is that the digital twin is a virtual representation of the reality, referring to the data and computational models for the physical objects, environment and processes (VanDerHorn and Mahadevan, 2021). Though the digital twin emphasizes the data and computational model, the animation as a step toward a digital twin does refer to the idea that the animation can be used as a tool to make even the processes of the after-sales services more tangible and thus manageable (Kindström and Kowalkowski, 2009; Tao *et al.*, 2017), hence providing a virtual representation of something difficult to represent in the first place.

Fourth, with regard to physical-to-virtual and virtual-to-physical connection (VanDerHorn and Mahadevan, 2021), the after-sales service context requires not only the connection back to the physical world, but also a detailed view to the value generation processes within the digital twin of a service. The findings of the case suggest that the digital twin of a service may provide a platform and communication device for the new service business development (Kindström and Kowalkowski, 2009). As there were several versions and purposes for the animations, the communication took please in connection with and between animations. Therefore, the digital twin of a service was able to capture both the physical reality to the virtual representation and the virtual representation back to the processes and related value generation of the after-sales service process. Thus, one of the implications of the findings is that the digital twin of a service can make the service process manageable and at least one step "more tangible" (Molloy *et al.*, 2011; Kowalkowski and Gebauer, 2012).

Fifth, the findings of the case are related to a rather labor-intensive after-sales service process. Although the increased use of IoT facilitates automatic data gathering and transfer from the physical world to the digital twin which, in the case of services, it is not that straightforward. Thus, in the context of a service, the data gathering needed for a digital twin would, most likely, be relying more on manual processes. The IoT elements built into the machines to support remote diagnostics (and, hence, providing inputs for a digital twin as well) are not yet supporting the monitoring of manual maintenance activities around the machines. While IoT sensors may be used for automatically detecting that a part has been changed, the IoT tools used for such monitoring would not provide information on the time needed for the service work needed. As a result, digital twin of a service – as a concept –

may offer interesting potential to automate not only the gathering of the data related to the machine itself but also to the service process variables. Such IoT applications would be interesting in highly productized, repeatable services like the ones discussed in this case, at least in the later stages, once the service has become more mature.

Finally, in Table 4, findings on the purposes of use of the digital twins were summarized. Essentially, regarding the digital twin of a service, as presented in this paper, the use can be extended to also cover management control and service business development activities, as interventionist case study confirmed the possibility to support new service business development with the designed animations. More broadly, the digital twin of the service, based on the empirical findings of the paper, enables defining the processes related to the service, setting targets about them and thus helps unveiling and communicating the value generation of the service at hand to the parties involved. This responds to the need for supporting the service business development of the manufacturers with new tools and techniques (Baines *et al.*, 2009; Laine *et al.*, 2012a; Tenucci and Supino, 2019). The digital twin of a service may enable unveiling and discussing all the relevant cost implications of the processes under examination. Altogether, such cost and control implications of the digital twin of a service, as the main contribution of the paper, will be discussed in the next section.

Unveiling cost and control implications of a digital twin of a service

Essentially, the idea of the digital twin of a service holds implications to the management accounting and control of the after-sales services. Understanding better the cost and control implications of new after-sales services under development at the manufacturers is a timely topic of the servitization literature (Neely, 2008; Laine *et al.*, 2012b; Tenucci and Supino, 2019). Furthermore, the management control implications of the digital twin in general have only recently drawn scholarly attention (Ukko *et al.*, 2022; Saunila *et al.*, 2022), with so far rather explorative studies, especially outside the service context.

In response, the empirical case provides a rich account on the financial and control implications unveiled by the animations, representing digital twin of a service (Table 5). As an observation, first, many financial implications were observed as tradeoffs. Indeed, the animations were able to show a cost increase (e.g. extra work needed) somewhere, and at the same time, cost reduction (e.g. release in stock) elsewhere (in line with Laine *et al.*, 2012b). Second, regarding the financial implications, the animations could also show that some of the process characteristics, and thus, costs remain unaltered, despite the process changes and possible negative expectations. These may include avoiding the risk of obsolete inventory or extra downtime. Regarding the control implications, third, there were observations that the increased understanding on the financial implications enhanced the quality of communication on the processes, new services and thus the value to the parties involved, thus enabling the control and learning possibilities preliminarily suggested by Ukko *et al.* (2022). Fourth, visibility on the service process makes the entire process and its several details and characteristics more controllable and, therefore, the animation could be used in various discussions on the actual service, not only in communicating the value of the service. Finally, the findings suggest that quite often the discussions on the financial implications take place before the control implications. In other words, understanding the financial implications with the help of the animation (or full digital twin of a service) paves the way for choosing and enacting the suitable means of control.

Overall, this paper argues that, indeed, there are significant cost and control implications embedded in the new service businesses of the manufacturers, and these can be more effectively managed with the help of the digital twin of a service. As discussed above, a

Animation	Financial/cost implications identified	Control implications identified
1	–Dividing HSK on different boxes reduce stock value needed for fast response times –Option hoses require work but significantly reduce stock needed –When option hoses are connected beforehand, no impact on downtime	
2		–Animation shows how HSK improves visibility on hose use, hence improving service process and cost control –Animation enabled discussion with front-line managers and customer about preferred maintenance cycles and inventory levels –Improved volume estimates increase accuracy of a new HSK sales estimate for Canada
3	–Demonstrated the tradeoff between hose length change and transportation cost –Connecting two sides of a harness caused extra work on site but enabled even less costly package –When the two sides of a harness are connected beforehand on site, it has no impact on downtime	
4		–Facilitated discussion on the cost-effective packaging of a new HSK by making the tradeoffs more visible –Repositioned hose connection points facilitated the installation process and improved harness movements when the boom is moved –Animation provided a tool to help the customer see the value of product modification
5	–Demonstrated how the hose length change did not make the customers' spare part stock obsolete	–Helped the HSK team to understand the main concern in the Australian market
6	–Over-specification can be used to reduce spare part stock at the customer –Vendor-managed consignment stock proposed to help customer reduce capital tied in the inventory and favor factory-spec hoses for corrective maintenance	–When factory-spec hose lengths are used, the hose for corrective maintenance is easier and faster to install on the machine –The animation helped stakeholders correct their understanding on different hose sizes and types use in the factory-spec harnesses improving the process control

Source: Authors' own work

Table 5. Management accounting and control implications identified with the help of the animations representing digital twin of a service

digital twin of a service can be there to identify, discuss and manage those implications (similarly to the tool presented in Laine *et al.*, 2012b), as it can capture the value generation process in a more manageable form. Altogether, digital twin of a service as a approach represents a significant toolkit and data source for the management accounting and control function of the manufacturers, with several implications.

As noted, recent studies show that digital twins can provide new possibilities for management control (Ukko *et al.*, 2022; Saunila *et al.*, 2022), by enabling exploration, guidance and playing with the processes at hand. The findings of this paper confirmed the

existence of such potentials also in the context of the new service businesses, so far unexamined in the literature. Building on the existing literature, it would be potentially useful to find different control mechanisms as well as different purposes of using them along with the service lifecycle, from the development stage to launch and active use of those services, as the desired exploration and guidance changes over time.

Indeed, as management control is essentially about affecting people to perform well in their work (Ukko *et al.*, 2022), the digital twin of a service seems to essentially support the management control related to the new after-sales processes at hand. The parties involved were there to play with the different alternatives and had constructive discussions on the new service businesses. Furthermore, the digital twin of a service seems to unveil opportunities to guide and educate different stakeholders on those new service businesses. It is noteworthy that, regarding the after-sales services under examination, front-line managers and salespeople are trained to sell the concept in the right way – including for example steady, pre-planned flow of customized bundles for regular, scheduled maintenance and the new way of handling option hoses to ensure fast response in case of sudden, unscheduled breakdowns. More broadly, when looking at the operative service process from identification of the customer need (machine failure) to the service delivery, the digital twin can play a rather larger role from the management control point of view (VanDerHorn and Mahadevan, 2021). An animation as well as a digital twin of a service is a powerful tool to train the front-line service teams and customer's field technicians to standardize the service process as much as possible. In service delivery process, customers often impact the process and, therefore, some flexibility is needed. However, at the same time, it is important that all the stakeholders involved in the operative service process understand the key cost and value drivers, as pointed out by the OEM project manager after a troubleshooting session:

> Our after-sales logistics people are not yet very familiar with this new service concept. We need to continue active dialogue with them to help them understand how the service works.

Altogether, the findings of the paper extend the view of the management control implications of the digital twins (see e.g. Saunila *et al.*, 2022), also outside the factories and assembly lines, especially to the guidance and communication among the parties involved. Furthermore, the findings provide possibilities to unveil and manage several different cost implications of the new service processes, so far under-researched in the servitization literature. More broadly, digital twin of a service can serve as basis for setting KPIs for the new service businesses as an extension to the management accounting and service literature (Laine *et al.*, 2012a; Lindholm *et al.*, 2017; Tenucci and Supino, 2019). All such implications deserve, however, much more attention as the digital twin of a service will be further examined in the new studies on the topic.

Concluding remarks

The paper provides empirically grounded insights regarding the possibilities of using a digital twin of a service in developing new service businesses. As its contribution, the paper extends management control and service literature and shows how new service business development could be supported with the help of the animations representing the digital twin of a service. First, this paper is among the first attempts to understand the digital twin of the service. Indeed, as reflected upon the case, the paper is unique in providing financial and control implications of digital twins also in the context of service. Second, this paper responds to the need articulated in the servitization literature to support the development of the new service businesses with management control tools and techniques.

Methodologically, the paper takes advantage of a rather unique, valuable interventionist case study. During the process, the role of the researchers as active participants moved from facilitating the service development to ensuring communication of the service process and its cost implications, eventually to fine tuning processes to ensure cost effectiveness. Such features of the empirical approach enabled the rich set of findings presented in this paper.

Finally, the article is not without limitations. It primarily serves the purpose of initiating the idea of the digital twin of a service, and thus, it paves the way toward further research on the digital twins of services in the future. Such research may take place in both conceptual studies and empirical papers using cases and industry-level surveys.

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