Development approach for value-creating service process twins based on service design methods

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***Abstract*—Adopting the digital twin concept in the industry has revealed its potential for value-creation in production and operations. At the same time, the idea of a digital twin is also being discussed in many other business areas. One of these is after-sales service, where the digital twin is attractive from two aspects. On the one hand, as a source of knowledge to better understand the customers' problems. On the other hand, digital twins may help manage service operations themselves. However, building such a service process twin with limited resources and capabilities is not trivial. Moreover, managing service operations transparently can be complex and demanding. Therefore, it is essential to focus on the solutions that generate the most value for customers and providers. Based on literature research and previous projects with similar problem settings, this paper presents a method to build such service process twins. Thereby, service blueprints and agent-based simulation play a significant r ole. T he p resented s ystematic a pproach h as been tested and continuously improved in two projects with companies in different industries. However, current research showed room for improvement concerning the detail level of service blueprints and their interrelationship with the simulation models.**

***Index Terms*—Service Process Twins, Service Blueprints, Service Operations, Symbiotic Simulation, Agent-Based Simulation**

I. Introduction

The ongoing digitization of the industry holds countless opportunities. Therefore, it is easy to get carried away pushing technologies without considering the value they create for the customers. One of these promising technologies is the digital twin (DT). Combining different existing technologies, the DT is one of the key approaches in the fourth industrial revolution [1]. First mentioned by [2] the definitions of DT have changed, were interpreted, and as well adapted by different fields over the last years [3]. However, there are some points were most of the researchers and the industry agree upon [4]. First, there has to be a virtual entity representing it for a physical entity. Typically there is some physical environment reflected by a virtual environment. Specific parameters are exchanged between those elements of the DT, whereby the fidelity measurement defines the amount, and their accuracy [4]. However, all non-physical entities are left out of account by this definition. Therefore, definitions like the ones of [5] or [6] include physical, non-physical entities, and even the possibility of twinning all kinds of entities. These definitions take a broader view of the concept of DT and thus leave more room for possible applications. Looking at DT from a service engineering point of view, according to [7] it is crucial to differentiate between different types of twins regarding their use case. To distinguish between DT of physical entities (equipment twin) and processes (process twin) becomes necessary to clarify the DT's usage [8]. In recent years, there have therefore been an increasing number of publications dealing with the use of DT in the business process environment [9] for example are discussing the management of tasks and resources, and [10] about the usage of DT in smart farming. Also, [11] describes the linkage of processes and simulations in so-called symbiotic simulations. Research also shows that the costs of creating and operating a DT can be enormous [12]. For this reason, [13] suggests focusing on the core problems in the company when creating DT and not dealing with all problems at the same time with a holistic DT. In order to develop such value-creating process twins based on business questions, one needs a methodology. This paper presents one possible approach to building such process twins.

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II. Background

The methods and approaches presented in this paper are based on existing literature from different research fields. Generally speaking, this literature can be divided into two areas: on the one hand, there is the service engineering literature, and, on the other, the DT literature. This section will provide a short overview of our presented approach's techniques.

In our approach, we make use of the concept of service ecosystems [14]. Service ecosystems show the interconnection of the different actors in an environment and how they exchange value. This exchange occurs based on the assumption that one actor alone can not operate in isolation as he is missing relevant resources. Therefore, it needs to participate in resource integrating systems [15]. Additionally, we also use service blueprints to document and understand processes in the organizations. Firstly proposed by [16], the service blueprint diagram shows all relationships between the necessary components of a service. The components consist of the

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customer touchpoints, business processes, and all the actors and materials needed to provide a service. All the actions from the first customer touchpoint to the point where the customer leaves are shown in chronological order from left to right [17].

When we talk about DT in this publication, we have a particular way of interpreting the concept. We are basing our understanding on the publications of [6] and [4]. Whereby [18] lays the foundation for us concerning the connectivity of the DT (Fig. 1).

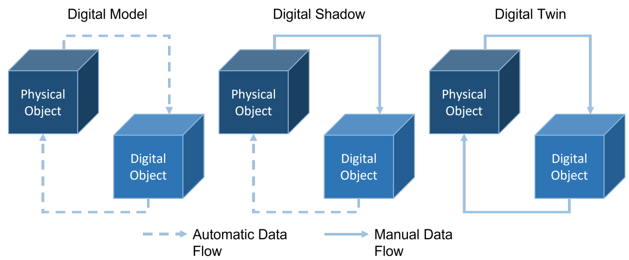

Fig. 1. From digital model to digital shadow [18]

However, since we can refer too little to these two definitions concerning services, we use and build on [10], [11], [19] for service simulations and use their definition for process twins. Regarding simulations and digital twins, we adhere to the view of [20] that DT is the next stage in the evolution of simulation technology. For this reason, we speak of an *equipment twin* when representing a physical product or system, and of a *process twin* when representing a process or intangible system [13] as depicted in Fig. 2.

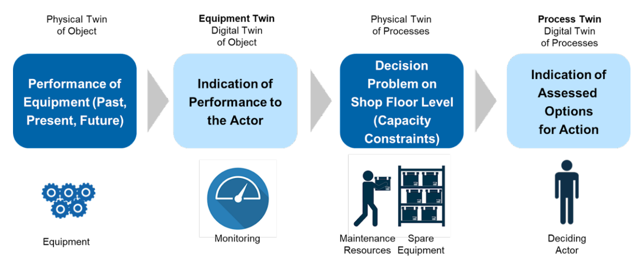

Fig. 2. Equipment Twin vs. Process Twin adapted from [13]

III. Methods

As already described in section (I), this paper aims to create a new methodology to develop new process twins. The focus thereby lies on the research questions: *How can the creation of process twins be supported with methods from service engineering?*, and: *Which methods from the service engineering environment are best suited for this purpose?* In order to be able to answer these research questions, part of this paper builds on newly arranged work already published in the context of various projects. Research on this topic started as part of an Innosuisse project in 2019. Four universities and six business partners investigated the use and structure of DT in various sectors of the economy, resulting in several publications [7], [8], [13], [21]. Using the expert knowledge in this consortium, we developed the methodology from use case to use case. With each iteration, we were able to eliminate minor weaknesses and better highlight the methodologies strengths.

IV. Use Cases

Within the scope of two projects, we created several use cases to better understand the creation of service process twins. We will present two of them, including the lessons learned in this paper.

A. Use Case - Smart Ships

Within the Innosuisse project 35258.1 IP-SBM, we developed this first use case for smart ship management. The use case is based on the business problem of Shiptec, one of 6 industrial partners in the project. Shiptec is a shipyard that designs, develops, and builds inland water vessels in Switzerland located at the Lake of Lucerne. For example, ships for public transport, tourist activities, ships for the transport of goods, and government and rescue boats. In addition, they offer related services such as strategic maintenance planning or short-term technical operations [22]. Furthermore, they aim to achieve zero emissions for their ships. Therefore, one of the business questions was: *How to reduce the ecological footprint of a fleet in operation?* We were certain the answer to this business question would create value across different levels of organization at Shiptec. For this reason, we surveyed and examined Shiptec's service ecosystem depicted in figure 3.

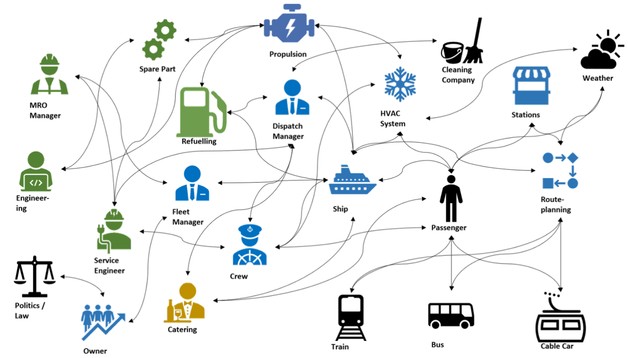

Fig. 3. Ecosystem Map of Shiptec [22]

After we had captured the ecosystem, we decided to divide the main business question into two sub-problems inside the ecosystem. The first is the planning of service operations on the ships, which are carried out directly by service technicians, and the second is the optimization of route planning based on the ships' fuel consumption. In detail, we discussed this division of the overall business problem into smaller sub-problems in detail in [13]. The consequence of splitting is that several models have to be created. However, from our point of view, this is an advantage because we can reduce the complexity and divide the goal of a digital twin into smaller sub-steps. In the case of Shiptec, we created two different models. Firstly, a model for the simulation of the service technicians and the service operations processes they are situated in (Fig. 4), and secondly, a physical image of a ship's propulsion system to simulate fuel usage in operations (Fig. 5).

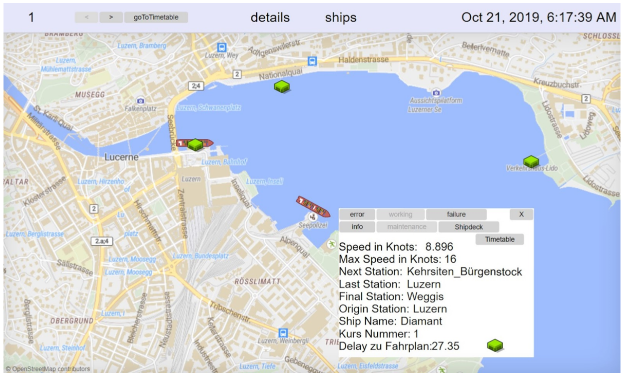

Fig. 4. Simulation of ecosystem system in GIS environment [22]

The second model is an equipment twin that can directly simulate fuel consumption based on the sensor data from the ship (Fig. 5). Whereas the first is a process twin. In which we mapped the business logic and simulated the influence of the different actors on this logic (Fig. 3). However, our goal was to connect these different types of DT so that they can mutually benefit from the information. In other words, by combining them, more complex business questions could be answered without making significant new investments in new models.

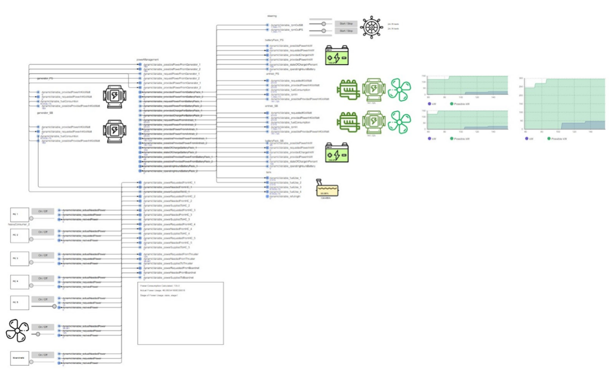

Fig. 5. System dynamics simulation of propulsion system [22]

We drew some important conclusions from this use case. Firstly, how important it is to clearly define which business questions are to be answered at the beginning. This allows for a focused approach with clear goals in model development, leading to shorter lead times and visible value creation for the actors.Furthermore, it became evident that we would need to better understand the processes inside the companies to develop process twins faster.

B. Use Case - Smart Waste

The second use case we present in this paper was developed within the Innosuiss project 46283.1 IP-EE. It is a use case in the smart waste domain. This use case aimed at developing an intelligent waste management ecosystem based on the dense network of waste bins in Switzerland. This was done with the help of sensors located inside the bins that measure the fill level and then transmit the telemetry data into the companies platform, where it will be used for process optimization [21]. The project aimed to look at the problem holistically, and combine the technological advances with process improvements in the waste management ecosystem, to increase the efficiency and effectiveness of the waste management processes. To achieve this, three main parts had to be done: 1) improving the existing sensor unit in the waste bins to collect raw data, 2) processing the resulting data with the help of statistical data analysis into information, 3) redesigning the existing decision-making process based on the knowledge generated by the process twin [6]. This paper will focus on the third part of and look at how we developed the process twin for the waste management ecosystem.

As with the first case (IV-A), we first defined the business question. This task was done by conducting several interviews and observation of the daily work of the actors in the ecosystem. We built the customer profiles of route planners and collection coordinators based on this information. The business goal for communities with already installed sensors was to *define the optimal route for collecting the waste bins based on the data from the sensors in the waste bins using the digital twin.* For communities with no sensors in place, the question is *whether to invest in such a system or not.* The process twin could be used to answer questions on ecological and economic and the impact on the organization itself concerning the service processes of the communities [21].

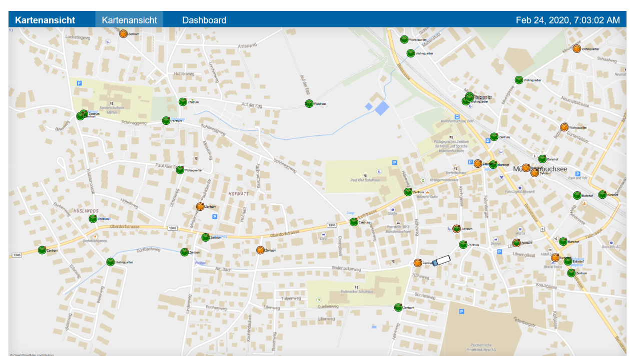

Fig. 6. Simulation of smart waste management ecosystem

We built service blueprints for the relevant processes based on the ecosystem analysis to better understand the processes and have something in hand to discuss with the relevant actors. The usage of such blueprints to support process understanding was one of the learnings from the first use case IV-A. Based on the service blueprints, we created a simulation of the smart waste ecosystem in an iterative development process (Fig. 6). With the help of this DT, we can run through various what-if scenarios and provide decision-makers with recommendations that facilitate their work. Furthermore, through dashboards (Fig. 7), it is possible to monitor the different parameters that can show the new system's value to the customers.

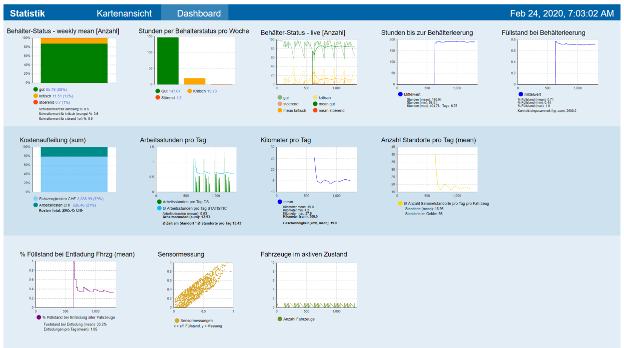

Fig. 7. Dashboard of smart waste management simulation

The lessons we learned from this case were that creating a service blueprint between creating the ecosystem map and the model for the DT can simplify its creation. This is because ambiguities in the process flows can be clarified quickly. Furthermore, it can also be explained to people without a technical background what happens in which sequence. Furthermore, in this use case, it also became clear how important it is to integrate one's system or DT into the existing ecosystem. Valuable external tools are often already available, which can improve the DT and offer the customer even better solutions in cooperation with other partners [6].

V. Results and Discussion

Based on the use cases, we developed a first approach to be used in the future development of process twins in the service context. We are also working on integrating process twins into service ecosystems to increase the value for users further.

A. Resulting development approach for process twins

The resulting development approach of this multiple case study is a development approach (Fig. 8) for service process twins with the help of tools from service engineering. The approach is built on four subsequent steps: 1) Problem definition, 2) Ecosystem analysis, 3) Service blueprint, 4) Process simulation, and 5) Decision support. Each step is also value-creating on its own, so the additional benefit of such a approach is derived from the improvement of the process towards the service process twin. Particularly in a process as time-consuming and often expensive as the creation of DTs, we have found that this focus on value creation is particularly worthwhile. In the following, we show in detail which methods we apply in which step of the methodology.

1) Problem definition: In this first step, we capture the business questions that need to be answered [23]. For this, we use classic ideation approaches from service design. It is essential to consider customer-centricity and determine which interactions within the company or between the company and the customers generate value. Once the business questions have been defined, they can be analyzed in the ecosystem.

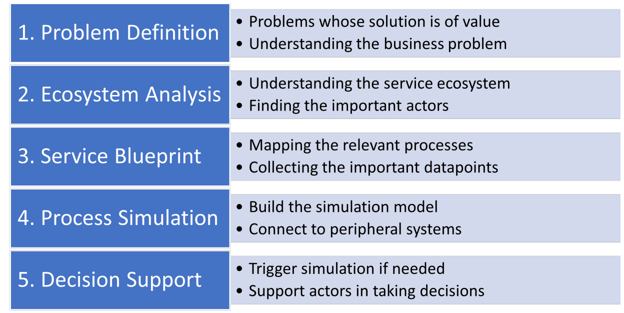

Fig. 8. Development approach smart process twin building

2) Ecosystem analysis: In the second step, we map the service ecosystem in which the company operates. In doing so, we record all important players and assets to understand the overarching business processes and the exchange of value propositions. Then, based on this service ecosystem, we start to model the relevant systems in more detail with the help of service blueprints.

3) Service blueprint: We go one step further by creating service blueprints for the relevant services in the service ecosystem. Service blueprints allow us to understand better the processes, people, and tools behind a service to model them later on. Furthermore, capturing the service blueprint allows us to get an understanding of the availability and quality of the data. It is often the case that we have to bring together data from different silos in order to develop a functioning process twin. For the first prototypes, we do not necessarily need a direct connection to the IT system of the company - raw data that has been imported is also sufficient.

4) Process simulation: We use a mix of agent-based, discrete event, and system dynamics simulations for the process twins models. By using agents that correspond to the actors in the ecosystem, we can continuously extend the complexity of the models and add new functions with little effort. Furthermore, in this step, we turn the simulation into a DT by ensuring a connection to peripheral systems and thus being able to access live data from the company's data resources.

5) Decision support: The last and final step is to integrate the DT into a decision support system. There it will be used by the actors in the service ecosystem. Three different trigger conditions may start the DT for decision support: Operator Trigger, Period Trigger, or Anomaly Trigger [11]. The simulation will then provide the decision-makers with valuable help to better understand the consequences of their decisions.

B. Further integration of process twins

With the presented approach for creating process twins, we link the areas of smart service engineering and process twins, thus creating more value for the customers and the companies by ensuring the solution's usefulness through service design methods.

However, we are aware that we can not solve all companies' problem settings with service process simulations alone.

For this reason, we are currently working on an end-to-end integration of DT in the service and maintenance environment (Fig. 9). However, the resulting end-to-end approach should be adaptable not only for maintenance cases but also for other fields such as logistics or production processes. This end-to-end integration aims to link equipment twins, condition monitoring, and process twins. We want to unite the various value-creating elements in a single concept with this approach.

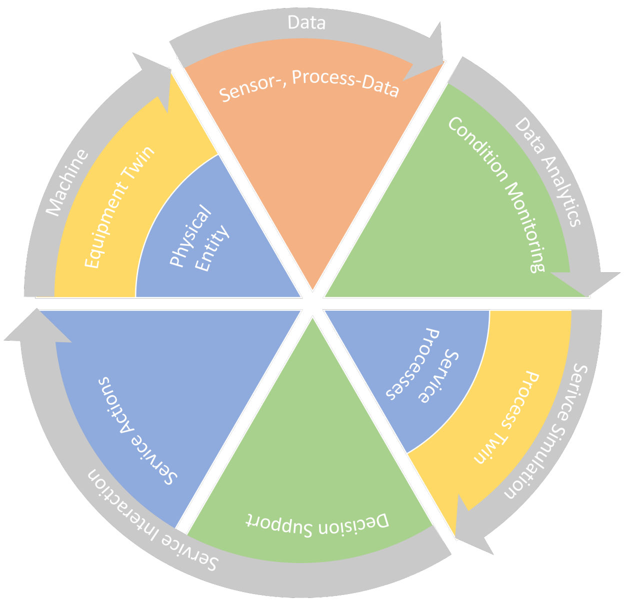

Fig. 9. End to end decision support approach for digital twins adapted from [24]

We introduced this end-to-end approach at the Fourth Smart Services Summit in October 2021 [24]. It consists of six main parts: 1) The physical entity [8], [25], also known as the real system [26]–[28], is the counterpart to a physical product or system. Built on this base is the equipment twin [8]. As mentioned in section II, we distinguish between twins for equipment and processes. Those parts, twin and entity, can deliver data either through sensors or virtual sensors. 2) The sensor-, and process data resemble the collection and storage of the data generated by sensors in the systems and products. Therefore, this data needs to be made available to be analyzed by external systems [29]. This part of the approach ensures that the data is in the suitable form for the following steps. 3) The condition monitoring uses the data collected to add information, by applying knowledge-driven system analysis [30] or data-driven machine learning models [28], [31], [32]. 4) The process twin is based on a service process and then uses the data and information generated in the steps before. Enriched with the help of ERP and CRM data, the process twin helps to create knowledge [19]. This process twin may be triggered by one of the following trigger types: an operator trigger, a periodical trigger, or an anomaly trigger [11]. 5) The integration into a decision support system helps decision-makers make informed decisions based on the knowledge generated in the steps before. In an optimal case, they get an evaluation of possible actions and then take their preferred action based on the result [8]. 6) Finally, the resulting service action has to be applied by the system's operators. In the case of after-sales services, this is normally done by service technicians. Their actions then again influence the machine itself. Henceforth the circle starts again.

1) Test Case - Smart Cutting: We currently test this approach (Fig. 9) in detail within a new Innosuisse project with one industrial partner. This project supports the after-sales service business with the end-to-end approach combining dynamic monitoring, fault diagnostics, and service simulations into a decision support model. We want to help the service organization grow business and reduce costs with this combination. Currently, three teams are working in different fields on the approach. One team is building an equipment twin prototype for parts of the machine. Another is analyzing failure data to understand better the patterns the machine is working in, and the last one is building the process simulation for the service ecosystem. The project aims to show how to connect the different elements of the end-to-end process in a real-world environment and show how successful the approach can be in creating internal and external value.

2) The value of data: Furthermore, we are working on quantifying the value of the data in such systems. This quantification is of particular interest to us as we claim to reduce the cost of DT by applying service engineering approaches and therefore focusing on the relevant elements of the DT to solve business problems. This research is still in an early stage, but we have already published the first results [33], [34]. This research branch aims to add a layer to our end-to-end model, which describes the effect of the model's cost- and value-generating parts.

VI. Conclusion

The subject of process twinning and its development in a service environment still offers room for further research. Furthermore, in our view, the potential of the concept of process twinning, especially when integrated into an end-to-end process, is far from exhausted. By integrating different approaches from equipment twin, data analysis, condition monitoring, and process twin, companies can create new value propositions for their customers. In addition, this integration also helps to build understanding between departments in the companies. Which often operate independently of each other for the potential and problems within their company. However, this is also where the most significant challenges lie. The connection of the individual disciplines requires clearly defined interfaces and a common language. Furthermore, an understanding must be created that the connection to an overall concept creates value for all sub-areas. Therefore, further research in this field will contribute to the understanding and value generation of companies and their customers. Second, we see a significant gap in research regarding the quantified value of the individual elements of such systems. We expect that this quantification of the elements of DT will convince companies, customers, and employees to build and use DT twins in their environment.In summary, we see two main areas of research which should be pursued further:

1) Integrating equipment twins, data analytics, and process twins into an end-to-end process for supporting decision-makers.
2) Development of a framework for quantifying the value of data in such an end-to-end process.

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