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Smart Services Summit

Digital as an Enabler for Smart Service Business Development

Springer

Progress in IS

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Smart Services Summit

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Foreword

Smart Services have come a long way in the last 15 years. Fifteen or twenty years ago, adding services, such as warranties or repairs, was considered the state of the art in product/service diversification. However, digital technology trends have enabled and empowered entirely new business models and value propositions. Since 2000, the price of sensors has dropped dramatically, while at the same time computing power and telecommunications/wireless bandwidth have increased by orders of magnitude. Combined with Internet connectivity and new approaches to data science, we have the recipe to move, as Allmendinger and Lombreglia put it, from “reactive” (fix things when they are broken) to “proactive” (fix things on a schedule) to “preemptive” (fix things before they break based on data).

These technological innovations allow smart services that create value up and down the supply chain. Producers gain value from operating and customer use data that feeds back into new product development, and customer organizations reduce the number of suppliers and the complexity and costs of downtime. Furthermore, smart services enable new business models and new sources of revenue for producers, from servitization subscription models to data aggregation and selling of analytics insights.

Innovation in the smart service area is emerging, representing the interplay between traditional, open, and platform plays, but in essence, innovation in this space occurs in the “smartification” of products, new ways of sourcing and analyzing data, and applying services and integrated solutions in new sectors. For example, collecting data from people via crowdsourcing platforms has become much more sophisticated in the last 10 years, not to mention approaches for collecting data from smart devices. Applying the insights from data analytics is finding its way into new areas beyond the typical servitization and predictive maintenance of heavy equipment into policing, traffic control, personalized health, financial services, and fleet management, among other areas.

Innovation in this space is extremely difficult for a variety of reasons. Part of it has to do with any information technology exercise in companies, that is, change management is difficult, senior leadership does not fully embrace digital transformation, the information technology function is often put in charge rather than senior management, and companies often ignore the fears of employees being made redundant via new technology adoption.

That brings us to this timely book, which provides an overview of emergent approaches in smart services, not only mainly in the business-to-business (B2B) space but also highly relevant for business-to-consumer (B2C) and open to integrate with B2C approaches. What is clear is that companies in all sectors need to experiment with digitally enabled smart services, and those that do not may find themselves with irrelevant legacy skills and/or uncompetitive products and services. This book surfaces the latest thinking on the role of digital technology in creating and capturing value from smart services. I hope that readers will absorb its lessons and apply them to their own challenges to prepare their organizations for a digital future.

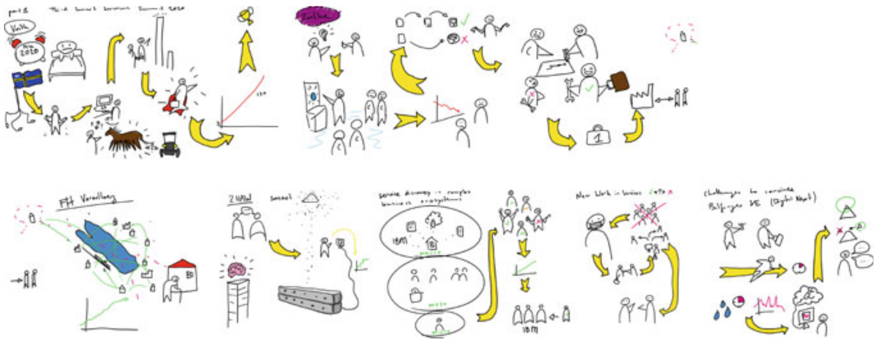
London, UK
December 2020

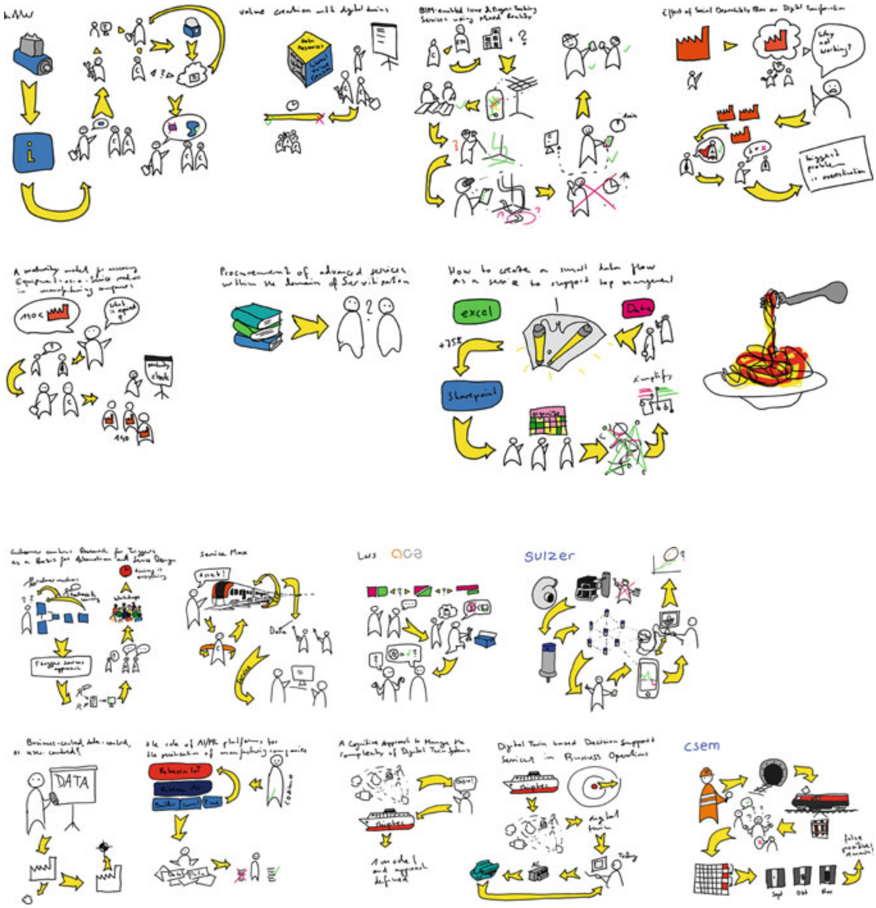
Christopher L. Tucci

Preface: data innovation alliance—Expert Group Smart Services

The data innovation alliance provides a significant contribution to make Switzerland an internationally recognized hub for data-driven value creation and is supported by Innosuisse.

The Day in Graphics





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Academic Contributions

The contribution to the academic community for the Smart Service Summit was to provide a forum for emerging research in the area of Smart Services. The conference's goal was to go beyond the technology and to consider the non-technical aspects that are important with digitally enabled value propositions and the underlying business models. The academic contributions were directly challenged by industrial presentations to allow for an active discussion of future research directions. Given the dynamic nature of digital technology and the ongoing evolution of Smart Services today, this provided a lively discussion and highlighted again the multi-disciplinary approach required for Smart Services. To guide the summit, three different panels were developed to provide a framework to shape the discussions:

1. Value system understanding for Smart Services
2. Value propositions for Smart Services
3. Value capture with Smart Services

The academic insights from each part will be described below.

The first part introduces three very different, yet complementary, views that were provided from the papers. All of the papers described multi-actor environments where value creation was distributed widely within the ecosystems and depended on the situation(s). The understanding of these complex systems allows the papers to provide approaches that support performance measures to be identified providing proxies for the value creation for various beneficiaries within the system. Martin Dobler focused on understanding services for Smart Cities, Manuel Holler on buildings, and Linus Bächler on server rooms.

The second part discusses value propositions for smart services with a strong focus on the application of digital technologies as an enabler for new value propositions. As such, the papers are all more application-based than those from the first part; they all provide insights into how new technologies can be integrated to provide improved or new solutions to existing problems. Linard Barth provides a framework for developing new value propositions based on the application of digital twins, whereas Valentin Holzwarth describes a value proposition based on the application of mixed reality technologies combined with building information modeling over the early lifecycle phases. Jonathan Roesler turns traditional good-dominate logic on its head by presenting a rental model ("equipment as a service") predicated on the integration of digital technologies. Oliver Stoll then provided insights to an often-neglected area of the procurement of advanced services, reminding us that in a B2B environment there is always a "buyer" and that there is limited research in this area.

The third part's focus is on value capture for firms providing smart services. Smart service design is focused on creating value for beneficiaries, which is a required prerequisite for any business success. Frank Hannich opened with a paper that described how "trigger" marketing can be successfully automated with service design within SMEs in a B2C environment. While the setting of the summit is centered around B2B markets, there are many lessons we can learn from B2C. The discussion at the summit made evident that both B2B and B2C can learn from each other in many cases. Cosimo Barbieri moved back to a B2B case, showing how machine learning and augmented reality had been demonstrated to support the servitization of firms. Lu presented a cognitive approach to transforming disorganized complexity to organized complexity to improve the digitally enabled services' value capture. This paper was closely linked to the digital twin-based decision support services within an operational context presented by Meierhofer. The asset and process digital twins were integrated to provide decision support. Abrell followed on by questioning the different types of approaches that have been applied in value capture (e.g., business-, user- or data-centric) within the context of big data innovation. He concluded with four positions for future research to improve value capture in the future: actor knowledge; designerly approaches to enhance understanding of tacit needs; use of designerly approach to integrating the perspectives of the actors, the businesses, and data; and, a beneficiary-centric approach to the design of value capture systems based on big data.

Challenges from Industry

In many industrial companies, the term "service" is related to fixing broken products in the field or preventing their failure. Owners of the products cannot afford to have their maintenance personnel trained on repairing every piece of equipment installed. Furthermore, a repair action would probably require in-depth proprietary knowledge that suppliers don't want to give away. The spare parts required for the repair are typically not available on the market and need to be purchased by the supplier as well.

In recent years, the industry has realized the power of the service business. While in the past the business model was often predominantly related to people lending—sending out a service technician when the customer asked for one—more advanced service offerings and business models become the norm. IoT technology has paved the way toward more data collection and more advanced data analytics, where suppliers are capable of better detecting or even predicting failures. Outcome-based service contracts are becoming possible, where more responsibility for the performance of the equipment is shared with the supplier.

Still few companies have figured out the value of "services", i.e., the broader term that defines the service industries. Today still, many offerings are closely tied to the product (monitoring, repair, maintenance, etc.). Few services are offered in addition. The same technology that is today used for condition monitoring could also be used to monitor process performance, energy efficiency, and other KPIs important for the plant's operation. Such services address other value levers apart from uptime and plant availability.

Entering the market with more advanced services that continuously add value to the customer's operations will allow a customer and a supplier to closely interact in constant optimization of the operation.

Selected speakers from the industry presented challenges, approaches, and solutions that represent a good cross-section of the state of the art. Some of the presentations explained the approach taken and the learnings, while others presented interesting service solutions. Some also dove into difficulties that arise when dealing with the real-world boundary conditions of industrial organizations and processes.

Mario Schmuziger from Zühlke shared some insights into innovation processes that he and Dominik Böni had found over years of consulting. Many companies are locked in incremental innovation, steadily improving their offerings to their customer base. However, they often fail to bring something radically new to the market. The authors emphasize the importance of a market view. To push for more radical innovation, they value the role of generalists that can bring together technology as well as the market view.

Philipp Schenkel from Kistler explored the value of information about the installed base. It can not only be harvested to assess the performance of the delivered solutions, but also serve as the base to increase sales. An important component of such a strategy is to have the right data available at the right time, from the service technician recording data in a service intervention to the salesperson analyzing the account and choosing the right offering strategy.

Thomas Sautter from Voith presented some of the challenges in selling digital services and products. The status quo for him was not possible to accept as he had inherited a digital business that he had to integrate into his service business. Integrating the digital business into a "steel" company was the basis of the challenge, but this was coupled to sales which were used to selling from a catalog rather than building solutions around customers' problems. To overcome the barriers that exist, solution-selling champions were identified within each of the regional sales teams and supported directly with engineering or product managers with the target of closing deals with digital content. Ongoing coaching and regular sales calls supported this new approach to selling in the firm. The objective is to disseminate the knowledge to the other regional sales managers. This is anticipated in the longer term to support both new digital solution sales as well as traditional sales.

Andreas Beyer-Köster from Bilfinger presented the challenges that are encountered when convincing manufacturers, operators, maintenance providers, and asset managers to apply Industry 4.0 concepts. Often, manufacturers struggle with the variety of data sources which are not connected. Additionally, the potential that lies in the already existing data and systems is often not recognized. Manufacturers often are surprised to see that projects can be realized fast, e.g., in 4 to 12 weeks. Top management support and cultural change are very important.

Lars Hennecke explored the challenges of the commercialization of smart services that ace Advisor Services had identified. Suppliers have a sizeable service business already today, and introducing smart services may bring some overlaps with what is currently offered to the market. To replace existing service offerings with smart services or to keep partly overlapping offerings on the market, both have their pros and cons.

When introducing smart services, Lars proposes to enter a collaborative relationship, since processes on provider as well as on customer side may be required. He concludes that the commercialization step shall be considered already considered in the development phase and should cover a change management aspect.

Matthew Anderson from Sulzer presented an industrial IoT Monitoring solution "Sulzer Sense". Once established as a service, he shared real-world insights into the customer's business drivers and pain points, and how Sulzer designed a solution to address these needs in a cost-effective manner and provide real value. Important aspects of this were overcoming the challenges of a digital project covering multiple technical disciplines, allowing for innovation and the need for agility, while introducing a new type of service to the business.

An interesting use of image recognition for condition monitoring was presented by Philipp Schmid from CSEM. The asset to be analyzed is not machinery, but rail tracks. Diagnostic trains equipped with cameras continuously traverse the rail network at travel speed (160–200 km/h). The presented AI system classifies real defects from other artifacts (chewing gum, dirt, snow, etc.). Repeated monitoring of the same track combined with advanced fingerprinting techniques helps to monitor the evolution of a defect over time. The solution significantly reduces the number of false positives compared to traditional algorithms that had evolved over a period of 10 years and adds new capabilities of smart maintenance planning.

The value of the asset data was at the core of Coen Jeukens' presentation from ServiceMax. The focus can be shifted from avoiding downtime to maximizing the outcome and the uptime while minimizing cost. This can be achieved by knowing where the assets are, in what condition, and how they are being used. By using the asset instead of owning it, real output value can be achieved. Exploiting the data from the asset can benefit stakeholders from multiple domains, among other customers, marketing and sales, field service, R&D, and many more. Thus, asset centricity becomes a cornerstone of service success.

The conversion of data to usable information and then using the information to support decision-making in pricing was the theme of the presentation from Dominik Kujawski from Regent. The core was the change management from using what looked like random data on pricing to understanding how it could be used to drive behaviors of the sales team. The automation of the preview work meant that he could then focus on the real value of supporting pricing in an environment with over 10,000 SKUs. This helped with consistency in the pricing process and assisting sales to identify new opportunities that they had missed in the past. This was a significant change for the firm and within a few months had been though several improvement cycles. Each improvement cycle provided new insights into the pricing process and the potential uses of the data.

Lucerne, Switzerland — Shaun West
Winterthur, Switzerland — Jürg Meierhofer
Zürich, Switzerland — Christopher Ganz

About the Conference

Following on from the successful Smart Services Summits in 2018 and 2019, we were following with a similar format of short papers and posters to foster closer collaboration between industry and academia.

This year's theme was "Digital as an Enabler for Smart Service Business Development for Manufacturers, Operators, Maintenance Providers, and Asset Managers". The topics covered by the contributions are as follows:

- challenges and solutions for Smart Services;
- the efficiency of delivery within existing value propositions;
- the development of new value propositions to improve competitiveness.

In these topics, the Smart Services Summit covered new and emerging research and was about pushing the topics forward through discussion. Invited presentations from international industry experts framed the summit. These were accompanied by short academic presentations, followed by in-depth discussions.

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Value Capture with Smart Services

About the Editors

Prof. Dr. Shaun West after gaining a Ph.D. from Imperial College in London, Shaun worked for over 25 years in several businesses related to industrial services. He started his industrial career with AEA Technology before moving to National Power, where he developed and sold services to external businesses. After studying at HEC (Paris) for an MBA, he moved to GE Energy Services, modeling and negotiating long-term service agreements. At Sulzer, he drafted the strategy that led to the service division tripling in size over 10 years and executed part of the strategy by acquiring a 220M CHF service business. Now at the Lucerne University of Applied Sciences and Arts, he is the Professor of Product-Service System Innovation. He focuses his research on supporting industrial firms to develop and deliver new services and service-friendly business models. He is a member of the advisory board for ASAP Service Management Forum and a member of the data innovation alliance. He lives close to Zurich with his wife and two children. He climbs, skis, and runs. e-mail: shaun.west@hslu.ch

Dr. Jürg Meierhofer the optimization and design of Smart Services are the red thread through his activities in various industries. He is Head of the "Smart Services" group of the data innovation alliance, Industry 4.0 Coordinator at the Zurich University of Applied Sciences (ZHAW), and a Board Member of the Swiss Customer Service Association (SKDV). After various management positions in service and innovation in several industries, he has been teaching and researching at the ZHAW since 2014. He is director of studies for continuing education in the field of Smart Service Engineering and Industry 4.0, leads several cooperation projects with numerous industrial companies, and regularly writes publications on these topics. He is now leading a project consortium in the topic data-driven services for SMEs in the framework of the IBH-Lab KMUdigital (www.kmu-digital.eu) and co-leading the project focused on the application of Smart Twins in complex industrial application together with Shaun West. Jürg holds a diploma and Ph.D. in electrical engineering from ETH Zurich and an executive MBA from the University of Fribourg. e-mail: juerg.meierhofer@zhaw.ch

Dr. Christopher Ganz is Group Vice President, Head of Solutions and Standards at ABB Future Labs, responsible for the conception of solutions for the future needs of future customers of ABB, as well as for standardization strategies for ABB Future Labs. His focus areas are autonomous industries and industrial artificial intelligence (AI). Having joined ABB in 1995, he was involved in developing the company's digital strategy and is a valued member of the ABB Future Labs management team.

Prior to his current role, Christopher was Group Service R&D Manager, supervising cross-division projects in the area of service and digital technologies, including remote services and Internet of Things (IoT). Before that, he was Research Program Manager leading a corporate research program in control and optimization and Manager Research & Development and Product Manager in ABB's power plant control unit.

Christopher holds a doctoral degree from ETH Zurich with a focus on Automatic Control and an undergraduate degree in electrical engineering from the same institute.

His academic and professional credentials have made him a renowned speaker on digital technology topics worldwide.

Value System Understanding for Smart Services

Smart Service Development in Public-Private Settings—Assessment Methodology and Use-Cases in the Lake Constance Region

Martin Dobler, Hanno Kalkhofer, and Jens Schumacher

Abstract Under headings like 'Smart Government' and 'Public Private Partnership' (PPP)- i.e. the development of services in cooperation with private, industrial service providers—municipalities are launching ICT and digitalisation initiatives aimed at the holistic deployment of digital, public and private smart services. Even where geographical proximity and similar socio-economic conditions of the municipalities are often present, a systematic exchange of methodologies, service design approaches, and best practices is missing. In this paper, we describe the how service science is approached in the public sector, especially in cooperation with private as well as academic partners and in co-creation settings (quadruple-helix). Furthermore, we present existing approaches in procurement and approaches we designed for service development in Smart Government and Smart Cities settings in the Lake Constance Region. Key Performance Indicators (KPI) and two use-cases of the region round of the paper.

Keywords Smart government · Smart cities · Smart service development

1 Introduction

1.1 Smart Cities, Smart Governments, and Smart Services

With the Europe 2020 strategy the European Commission has set numerous goals, which aim at achieving smart, inclusive and sustainable growth in Europe. At the core of Europe 2020 is the pursuit of innovation as the union's competitiveness is depending on innovative, holistic services and products. Hereby, the services and

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products in question have to tackle major societal challenges, including climate change, energy efficiency and emission reduction (*Smart Cities and Communities—European Innovation Partnership,* Communication C(2012) 4701 final). When looking at the Strategic Energy Technology (SET) Plan (Albino 2015; Directorate General for Energy 2018), we find that over 40 demonstration cities were planned until 2020, which are all supposed to accomplish ambitious goals. Similar to sustainability and green building challenges, the ageing demographic in European countries is demanding unique approaches towards healthcare. Smart services and health care solutions are considered one opportunity to ease the burden on governments and cities, especially since the advent of new service fields that emerged under the consideration of new technologies—mainly ICT based—such as Smart Care for at-home care (Thomas et al. 2014) or Ambient Assisted Living (Sun et al. 2009).

Finally, services that are provided directly to citizens similarly undergo a transition towards more ICT based solutions. Smart identification services for citizens, such as the Schaffhausen eID+ (Kanton Schaffhausen, n.d.) in Switzerland or the e-ID (A-Trust, n.d.) in Austria are just some examples. It is especially noteworthy, that blockchain technologies in Smart ID use-cases are predestined for the development of multi-stakeholder, public-private ecosystems and services derived therefrom—ranging from services offered by municipalities like the provision of legal paperwork over services of private insurance and banking providers like credit score documentation to payment services in local shops.

Therefore, our research activities based upon the research project Smart Government Academy for the Lake Constance region aim at

- development of high-level requirements for innovative, integrated solutions in energy, health care, Smart ID, and ICT, both on business and policy level, thus enabling the derivation of meaningful frameworks and KPIs for Smart Government
- derivation and development of cooperation and recommendation frameworks for territorial knowledge, data-enabled services and entrepreneurship, extended by the development, acquisition and publication of a comprehensive KPI set, specifically targeting the needs of European regions as laid out by the high-level requirements and Smart Government assessment
- stimulation of the market for data-enabled services and products—thus supporting entrepreneurship and providing recommendations to policy makers for collecting new sources of data and form the basis for a Smart Government index.

1.2 Terminology and Previous Work

In order to create comparable KPIs and assessment methodologies for Smart Cities and Smart Government services, individual goals have to be broken down into their overall dimensions, high level goals and inherent technical dimensions—e.g. Smart ICT, blockchain, Big Data and the Internet of Things (IoT).

Best practices have to be interconnected with the performance measures for services, always accompanied by the scalability component of the practice. They can be categorised according to the characteristics present in the European Commission' study on Mapping Smart Cities in the EU (Manville et al. 2014): Smart Governance, Smart Economy, Smart Mobility, Smart Environment, Smart People and Smart Living.

2 Service Development in PPP—Smart Cities and Smart Government

2.1 *Smart Cities*

A Smart City is a place, where "digital technologies translate into better public services for citizens, better use of resources and less impact on the environment" (Smart Mobility and Living (Unit H 5), 2020; Milenković et al. 2017). A key role in this respect is played by the management of large amounts of data as their "context-related analysis and combination (…) allows self-learning algorithms to make increasingly precise statements about certain facts, groups, or even single individuals, enabling the automation or execution of certain tasks in much more efficient and citizen-friendly ways" (Guenduez 2018).

The technological focus may not distract from the holistic approach of smart cities, whose thematic fields might at times be "more social and organisational than technical, substantially associated with multiple diverse stakeholders and high levels of interdependence" (Pereira et al. 2017). A smart city is additionally about creating and fostering connection and interaction between its stakeholders (governments, scientific institutes, companies, citizens and NGOs—sometimes referred to as Quadruple-Helix of actors or Public Private People Partnership) in order to use their potential to find innovative solutions for complex problems.

2.2 *Smart Government*

Smart Government is a dimension in the overarching concept of a Smart City along others like smart economy, smart environment, smart living, smart mobility, and smart people (Purnomo et al. 2016). This also applies to the previously common notion of e-government that improves information, communication, and transaction processes between the government and all of its stakeholders (Schedler et al. 2013). A government that acts smart is characterised by "activities that creatively invest in emergent technologies coupled with innovative strategies to achieve more agile and resilient government structures and governance infrastructures" (Gil-Garcia et al. 2014). Moreover, it seeks to adopt an open style government which integrates "stakeholder participation and collaboration on all levels and in all branches of the governing process" (Scholl and Scholl 2014), and generally turns "government tools from an office-centric mode to a citizen-centric mode" (Milenković et al. 2017). From a technological point of view the concept of smart government especially outlines the role of Big Data. The data is obtained using intelligent networks and smart objects which are equipped with sensors, actuators and a communication unit attached to an unambiguous identity on the Internet (Lucke and Große 2017), thus can be "identified throughout its life and interact with the environment and other objects. Moreover, it can act in an intelligent way and independently under certain conditions" (González Garcia et al. 2017). Examples for smart objects range from wearables like mobile phones and smartwatches, smart-home-devices like motion detectors and automatic blinds, stationary devices like surveillance cameras/intelligent street lighting, and mobile devices like drones and unmanned vehicles (Lucke 2018). While the e-government "has been criticized for being largely focused on improving government services" (Hansson et al. 2018), a key aspect of a smart governments is its radical openness. Similarly, open data mends the traditional separation between public organizations and their stakeholders (Janssen et al. 2012).

A smart government acts not only as a producer and buyer of services, but also as a service innovator and promoter of an innovation ecosystem as it proactively provides a suitable environment for user-/business-driven and open innovation (Jussila et al. 2019). One example is the offering of prototyping environments to academic and industry partners (Ubaldi et al. 2019). Hereby, open data is used to "enable the public, entrepreneurs, and their own government programs to better leverage the richness of federal data through inputs into applications and services" (Pereira et al. 2017).

Innovation management for Smart Government within the context of this paper is understood as strategically moving into uncontested markets (e.g. Blue Ocean Strategy (Kim and Mauborgne 2015)), formulation and documentation of goals and needs, as well as differentiation between innovation types (frugal innovation, proactive innovation, high-speed/low-risk innovations and others) (Govindarajan and Trimble 2010).

3 Indicators for Service Prototypes in the Public Sector

3.1 Technology Maturity and Key Performance Indicators

Performance measurement and KPI frameworks are set up to clearly quantify comparable, properly defined target values, which are meaningful to its intended audience as they need to drive towards the benefits that are expected to be delivered. In Smart

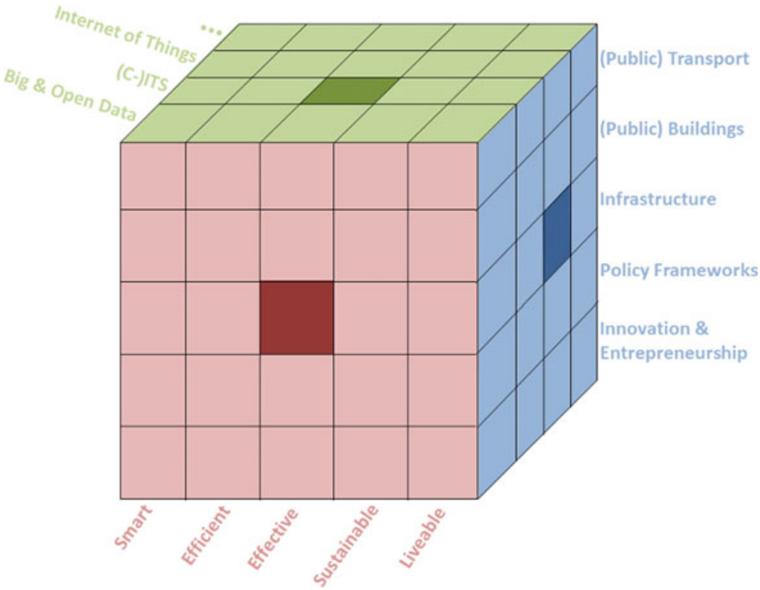

Fig. 1 High-level dimensions for performance measurement

Government, alongside the common policy goals, we have a broad range of stakeholders and intended audiences, depending on individual viewpoints, fields of expertise and area of operation. To this extent we include a set of components in our framework, shown in the Service Development Cube (Fig. 1). The multi-dimensionality is hereby broken down into its high-level dimensions. Firstly, the inherit pretension of Smart Government, namely the requirements of being smart, efficient, effective, sustainable and liveable. Secondly, the area of operation is taken into consideration. This includes transportation solutions—from public transport, inter-modal person transport and goods logistics -, Smart Care, citizen services and sustainability, as well as its supporting infrastructure. Finally, the dimension contains the context of its national and international policy frameworks, as well as its approach towards innovation and entrepreneurship. Lastly, the technological dimension rounds off the measurement cube, taking into account numerous ICTs from the necessary foundation, e.g. Big & and Open Data, or the Internet of Things, but also specialised technologies like Blockchain solutions, geo-information systems, open data, or inclusive web portals. With these dimensions we are laying out the preliminary groups of indicators, which then are enriched with specific internal and external stakeholders, assessment methodologies, value ranges and best-use scenarios (e.g. lead vs. lag indicators), as well as the linkage to scalable and targeted best-practices.

The partnership between public authorities, private companies and citizens, i.e. Public Private People Partnership (PPPP), and their targeted innovations is the lowest level of the Service Development Cube and consequently the foundation upon which all other levels are built. Creating an economical sound broad-ranging ecosystem for

PPPP is a significant challenge, which must incorporate public procurers, city and transport planners, policy makers, citizens, technology providers and the companies taking the entrepreneurial risk to create pioneering and innovative solutions. The approaches KPIs are therefore setting the measurement and comparability of entrepreneurial support and innovation as a key component of its analysis, and tracks time-to-market, cost-to-market, fitness for market, and novelties for the market (Fig. 2).

The service development takes place in the strategic outline that can be seen in the assessment pyramid in Fig. 3, whereas the vision is the top level (i.e. EC challenges for Europe), strategy (i.e. funding instruments, call topics, and key initiatives)

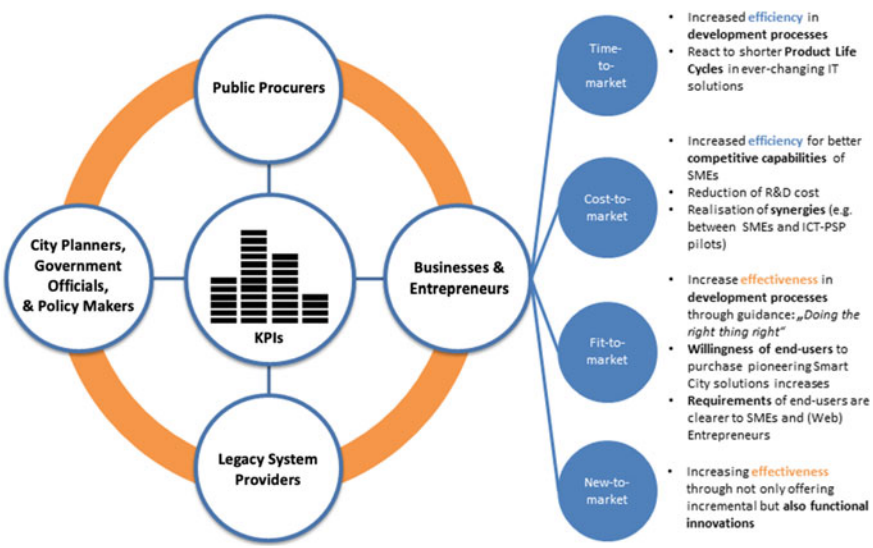

Fig. 2 Categorisation of KPIs for entrepreneurial support in Smart Government ecosystems

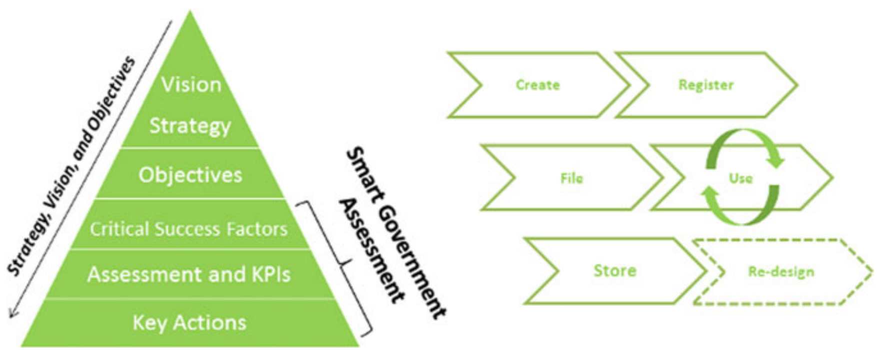

Fig. 3 Services assessment pyramid and phasing of innovation and service tracking

is therefrom derived, and concrete objectives are defined for individual smart solution providers. We see ourselves herein as a research partner which assesses critical success factors and KPIs, besides defining key actions in the sense of recommendations and best practices for smart solutions. For all the elements targeted by the pyramid, its approach foresees a phasing in which the elements are created, registered, filed, used, stored and re-designed, if needed. The re-use of the elements is a key goal, hence promoting the transferability of the one smart solution approach to other municipalities and generating a framework which makes the services comparable within the Lake Constance region.

4 Smart Service Development Use-Case Analysis: Smart Care and E-ID Applications

4.1 Schaffhausen's EID+

The continuous increase in the supply of online services is accompanied by a rise in the importance of electronic identification (e-ID). This issue is covered in regulation No 910/2014 of the European Union, which argues that "building trust in the online environment is key to economic and social development. Lack of trust, in particular because of a perceived lack of legal certainty, makes consumers, businesses and public authorities hesitate to carry out transactions electronically and to adopt new services" (*On electronic identification and trust services for electronic transactions in the internal market,* Regulation 910/2014). Private sector involvement has increased significantly in recent years, especially for higher value applications with banks being the main players (Müller and Windisch 2018).

In 2017, the canton of Schaffhausen launched its own e-ID, the eID+ , which was developed in a PPP with Procivis, a swiss start-up providing the required technology. In this way, the canton targets the development of a unique selling point in terms of innovation and technology in the competition among business locations. The eID+ identity system—which is based on blockchain technology—enables citizens to access official services directly via smartphone. The app guarantees data privacy control and users can decide for each service respective data recipients and have the option of digitally signing documents. The data is protected by strong encryption including password-based and/or biometric procedures (Kanton Schaffhausen, n.d.)

In the sense of a Smart Government co-creation, citizens were involved in a "co-design process, to ensure a solution design that benefits the public stating the needs in the first place" (Andermatt and Göldi 2018). In the research project Smart Government Academy for the Lake Constance region the University of St. Gallen analyses processes and shows how service delivery is improved from the users' perspective. The University of Applied Science Vorarlberg in turn examines, which requirements the eID+ needs to fulfil in order to be accepted by the private sector. As it can be noted: "technology is only the customer facing front-end of a complex set of organizational structures, policies, and processes that are designed to provide particular services" (Rose and Grant 2010).

4.2 Dornbirn Smart Care

For some time now, population forecasts have confirmed that the aging of Austria's population continues to progress. Currently the percentage of over 65 years of age in Austria's total population is about 19%. Twenty years from now, in 2040 this percentage is forecasted to rise up to 26% (Statistics Austria 2020; Austrian Conference on Spatial Planning 2019). In 2030, up to 72,900 additional staff in the health-care sector will be needed—compared to 2017 (Federal Ministry of Social Affairs, Health, Care and Consumer Protection 2019b). The shift from multi-person to single-person households, the decline in fertility, and child mobility (Grossmann and Schuster 2017) are additional challenges. In the current care provision report of Austrian's Federal Ministry Republic of Social Affairs, Health, Care and Consumer Protection, a strong focus lies on homecare, especially on Ambient Assisted Living (AAL) (Federal Ministry of Social Affairs, Health, Care and Consumer Protection 2019a; European Parliamentary Technology Assessment 2019).

The city of Dornbirn sought to understand whether the connection between intelligent systems and existing human resources can ensure a self-determined life in old age within one's own four walls. Based on a study of several focus groups, a specification book was developed, and service and support scenarios were prioritised which can serve as a reference for future policy making. Participants consisted of service providers and service recipients as well as representatives of the city administration. The initial results in our use-case mapping of Smart Care potential for the City of Dornbirn concluded two challenges. Firstly, there is no sufficient consideration for the application of intelligent technological systems by most actors in the outpatient care as well as by the end users. To tackle the issue, the stakeholder groups have now planned to set up a regional physical consulting and service centre in combination with a showroom for AAL technologies.

Secondly, efficient coordination of care and nursing institutions is unanimously seen as a key potential for the development of services for smart care in the region. The potential therefore lies in care management which can defined as "the establishment, planning and management of a largely binding, standardised and coordinated cooperation of professional and voluntary actors in the region who offer assistance and who can be coordinated for individual cases" (State Government of Vorarlberg 2019).

5 Conclusion and Outlook

Under headings like Smart Government, Smart Cities, and PPPP, municipalities are launching ICT and digitalisation initiatives aimed at the holistic deployment of digital, public and private smart services. Even where geographical proximity and similar socio-economic conditions of the municipalities are often present, a systematic exchange of methodologies, service design approaches, and best practices is missing. In this paper, we describe how services can be developed in the public sector, especially in cooperation with private as well as academic partners in co-creation settings, sometimes referred to as quadruple-helix. We present approaches we designed for service development in Smart Government and Smart Cities settings in the Lake Constance Region, especially those developed in the research project Smart Government Academy for Lake Constance Region. After an initial presentation of the KPI framework, innovation management methods, and phasing approaches, we conclude the paper with two exemplary use-cases conducted within the research project. In next steps, we plan to refine the KPI set as well as the Service Development Cube and adapt the results for a generalisation which supports the replicability and scalability for further use-cases in the region but also on a European level.

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Smart Dust for Smart(er) Industrial Product-Service-Systems: Three Strategies and Their Application

Manuel Holler, Benjamin van Giffen, Linard Barth, and Rainer Fuchs

Abstract The nascent technology of smart dust—miniaturized sensor networks—promises high value to advance industrial product-service-systems. While previous studies have identified smart dust as source for product and service innovation, the pathways from an initial offering to smart dust-enhanced product-service-systems have received scant attention. The present work in the scope of a Swiss National Science Foundation project on the economic potentials of this technology aims to conceptualize and apply strategies for smart dust-enhanced product-service-systems. This conceptual research resulted in the three pathways (1) product-driven strategy, (2) service-driven strategy and (3) holistic strategy which could be successfully mapped to the use case "Monitoring of structures". In closing, this emerging technology helps to make industrial product-service-systems more customer- and user-oriented as called by recent voices. To science, we introduce smart dust in the field of product-service-systems and offer a first systemization of pathways, thus contribute to the product-service-systems engineering knowledge base. To practice, we provide useful approaches to be applied at a strategy level to push the servitization in manufacturing forward.

Keywords Smart dust · Industrial Product-Service-System · Industrial PSS · Strategy · Application · Conceptual research

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1 Smart Dust for Industrial PSS

In the past years, product-service-systems—broadly speaking integrations of products and services—have been playing a pivotal role in the industrial economic sector (Baines et al. 2007; Meier et al. 2010). Thereby, digital technologies (e.g., smart connected products and corresponding smart services) have promoted the field in research and practice (Hänsch Beuren et al. 2013; Lerch and Gotsch 2015). Continuing this line of digital innovation, the nascent technology of smart dust (Gartner 2018; Ilyas and Mahgoub 2018) promises high value to further advance product-service-systems. By definition, smart dust represents an "autonomous sensing, computing and communication system that can be packed into a cubic-millimeter mote to form the basis of integrated, massively distributed sensor networks" (Warneke et al. 2001, p. 2).

Comprising the whole IoT technology stack from sensor to service, these motes can be installed in the application range of industrial assets to expedite sensing to the next level (Ilyas and Mahgoub 2018). Reverting to related literature, recent empirical works (Holler et al. 2020a, b) explored the economic potentials of smart dust in industrial settings. More precisely, Holler et al. (2020a, b) showed opportunities across the whole lifecycle, from beginning-of-life (e.g., advancement of requirements engineering) over middle-of-life (e.g., enhancement of logistics monitoring) to end-of-life (e.g., augmented retirement planning). While these previous studies have identified smart dust as source for product and service innovation (Holler et al. 2020a, b; Ilyas and Mahgoub 2018), the pathways from an initial offering to smart dust-enhanced product-service-systems have received scant attention. Accordingly, we express the following research question: *[RQ] Which strategies could industrial companies pursue to exploit smart dust-enhanced product-service-systems?* The present work in the scope of a Swiss National Science Foundation project on the economic potentials of this technology aims to conceptualize and apply such strategies. We proceed with methodical details, bridge to the strategies and their application, and finish with a conclusion.

2 Three Strategies and Their Application

To address the introduced question, we employ conceptual research (Hirschheim 2008). Specifically, we selected an established matrix framework (Baines et al. 2007; Meier et al. 2010) to conceptualize the strategies. The creation process itself is informed by two main data sources as recommended by Hirschheim (2008): On the empirical evidence side, we include various case studies (Yin 2003) from the DACH MEM industry within the mentioned research endeavor. On the knowledge base side, we draw on scientific literature (Webster and Watson 2002) from both relevant streams on smart dust and product-service-systems. The target group (Hirschheim 2008) for our strategies are product, service and solution managers in industrial companies. For the iterative conceptualization, we continuously referred to established concepts (e.g., product-service-continuum (Baines et al. 2007), product/service development (Ansoff 1957)). In sum, we chose dimension 1 as "Product" and dimension 2 as "Service" because both empirical evidence and knowledge base showed that smart dust affords product and service innovation alike (Holler et al. 2020a, b; Ilyas and Mahgoub 2018). Furthermore, these dimensions were differentiated into the states "No product/service", "Existing product/service" and "Smart dust-enhanced product/service" as industrial enterprises typically start with an existing offering striving to complement and improve it (Lerch and Gotsch 2015).

Figure 1 visualizes the three strategies for smart dust-enhanced product-service-systems. Within the nine quadrants an "Existing product" (Q1/0), an "Existing service" (Q0/1) or an "Existing product-service-system" (Q1/1) represents the starting point in the form of an already available offering. Starting here, two basic approaches are possible: On the one hand, one might pursue a product-driven strategy (horizontal arrows) to achieve a "Smart dust-enhanced product" (Q2/0) or a "Smart dust-enhanced product-service-system (product-driven)" (Q2/1). On the other hand, one might also take a service-driven strategy (vertical arrows) to reach a "Smart dust-enhanced service" (Q0/2) or a "Smart dust-enhanced product-service-system (service-driven)" (Q1/2). Finally, adopting a holistic strategy (diagonal arrow) leveraging both previously described approaches creates a "Smart dust-enhanced product-service-system (holistic)" (Q2/2) exploiting both advantages. We included the grayed

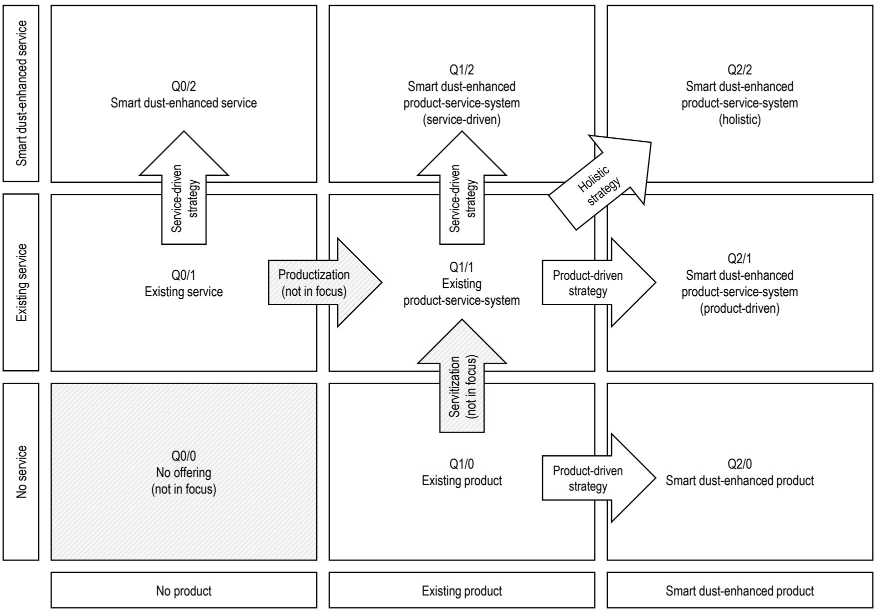

Fig. 1 Three strategies for smart dust-enhanced product-service-systems

out quadrant "No offering" (Q0/0) and the well-discussed productization and servitization strategies (Baines et al. 2007) for the sake of completeness, but these elements are not in the focus of our work. In the aggregate, industrial companies can adopt the pathways (1) product-driven strategy ("better product", horizontal extension, two manifestations), (2) service-driven strategy ("better service", vertical extension, two manifestations) and (3) holistic strategy ("better product and better service", diagonal extension, one manifestation) to leverage smart dust-enhanced product-service-systems.

To illustrate the conceptualized strategies, we draw on a practically and scientifically relevant use case (Ilyas and Mahgoub 2018), selected upon its typicality for the industrial economic sector. Satyanarayanan (2003, p. 2) describes this case "Monitoring of structures" as follows: "If you added a handful of smart dust to every batch of concrete as it is mixed, the resulting buildings would essentially have a nervous system built into every structural element." Starting from the status quo of a general contractor providing a product (e.g., high-rise building, Q1/0), a service (e.g., predictive maintenance, Q0/1) or a well-integrated offering of both (Q1/1), smart dust-based innovation can be made product- or service-driven: First, product-driven, infusing smart dust into the building structure helps to design more load-oriented and customer-centric high-rise buildings (Q2/0 resp. Q2/1), based on a better understanding of the building mechanics. Second, service-driven, integrating smart dust also enables a more accurate and effective predictive maintenance (Q0/2 resp. Q1/2), grounded on a multiplication of measured points. Lastly, combining both approaches in the holistic strategy offers the optimum to the company and its customers (Q2/2). While we selected a specific use case for the in-depth illustration of the framework (Fig. 2), considerations on further product-service-systems in bordering sectors indicate its generalizability.

3 Which Strategy to Pursue?

In this work, we aimed to conceptualize and apply strategies for smart dust-enhanced product-service-systems. This conceptual research resulted in the three pathways (1) product-driven strategy, (2) service-driven strategy and (3) holistic strategy which could be successfully mapped to the use case "Monitoring of structures". The reflections accomplished show that executives have different options: The product-driven strategy involves next-generation product development (e.g., mechanics-based functionalities) or improvements on the spot (e.g., data-driven functionalities). The service-driven strategy entails improved (e.g., predictive maintenance) or novel (e.g., monitoring of concrete ageing) services, which could not be realized without the use of smart dust. The holistic strategy, mirroring the product-service-system thought at best, certainly promises the most advantageous, however also the most effortful offering. In closing, this emerging technology helps to make industrial product-service-systems more customer- and user-oriented as called by recent voices (Dreyer et al. 2019).

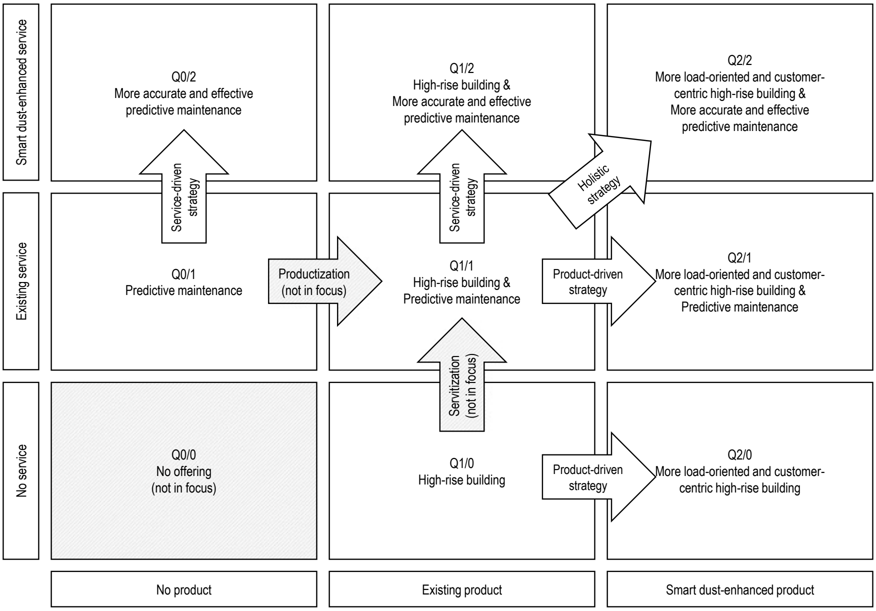

Fig. 2 Application of the three strategies for use case "Monitoring of structures"

First, to science, we introduce smart dust in the field of product-service-systems and offer a first systemization of pathways, thus contribute to the product-service-systems engineering (Cavalieri and Pezzotta 2012) knowledge base. Second, to practice, we provide useful approaches to be applied at a strategy level to push the servitization in manufacturing (Meierhofer and West 2019) forward. Although our typical example could be mapped, further validation with real-world cases (Ilyas and Mahgoub 2018) is necessary to support the theory-building effort of this manuscript. Beyond, only sensory capabilities stood in the center of this work, hence the impact of actuatory abilities (i.e. micro robots) (Holler et al. 2020a) may be considered in future research.

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Service Discovery in Complex Business Ecosystems

Linus Bächler, Shaun West, and Jörg Schanze

Abstract An abundance of frameworks and methodologies are concerned with designing services catering to the needs of specific actors. But how might the potential for such service creation be identified in the first place? And what would the dimensions of the value be, which the service enables? These questions are explored in the case of data centre infrastructure management (DCIM). To scrutinize and answer the questions, literature is reviewed, interviews with eight actors within the ecosystem conducted, and the findings applied in defining the service ecosystem of DCIM. The results are a definition of the actors within the ecosystem, the resources they integrate, what enables and constrains this resource integration, and the service exchange and value cocreation resulting from it. In the service system, value cocreation potential is found to be realized by either cocreating existing value in novel ways or cocreating unprecedented value altogether. This is achieved by integrating novel actors, integrating previously unused resources—or rearranging existing ones, or enhancing or disrupting institutions enabling, or constraining the resource integration. The value dimensions are found to be immediacy and time. The former refers to the proximity of any service exchange to the beneficiary and the latter to when value is experienced by any beneficiary. This is important because the essence of cocreated value must be known to replicate, change, or enhance it. Finally, a replicable process is defined, with which value cocreation potential might be identified and used to lead into a service design process.

Keywords Value cocreation · Service-Dominant logic · Business ecosystem · Service design · Service systems

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1 Introduction

IBM (2016) points out the hardware-centric view of many information technologies (IT) organisations with an accompanying focus on "[…]optimising individual infrastructure components" (p. 3) of data centres (DC). Siloed solutions to increase partial DC efficiency have resulted in costly and complex DCs, struggling to compete with cloud-based IT services. Data Centre Infrastructure Management (DCIM), too, is often seen as solution, i.e., a product applied in a specific use case with a great variety of vendors, each promoting their own methodology in managing cooling, power supply, and other infrastructure, making up a DC. These approaches often lack a consideration of the essential value enabled by a product's functionality.

This case is exemplary of the challenges faced by businesses, experiencing changes to the ecosystem within which they operate. It therefore offers an opportunity to investigate the following research questions (RQ):

RQ (I): How can value cocreation opportunities within a complex service ecosystem be identified?

RQ (II): What are the dimensions of value?

2 Literature Review

Of relevance for RQ (I) is, that the discussion of DCIM focuses on intended functionality of a product and less on the service surrounding and value enabled by it (see Brown and Bouley (2012), Cole (2012), Harris (2015), Meyer (2016), and Levy and Hallstrom (2017a, 2017b) for examples of this product-centricity) But value is the driving motivation for any market activity, according to Service-Dominant (S-D) logic (Vargo and Lusch 2004, 2016). It is cocreated by multiple, resource-integrating actors and their exchange of service, which is enabled or constrained by institutions (Wieland et al. 2017) and institutional arrangements (Wieland, Vargo, and Akaka 2016). These elements, according to Vargo and Lusch (2016), form service ecosystems. It follows that by understanding specific ecosystems, i.e., the actors, resources, institutions and institutional arrangements, and service exchange, within (as oppose to solely product functionality) one could identify potential changes to the system which result in novel, improved value cocreation.

Considering RQ (II), value itself is determined by a specific, beneficiating actor within the system. It only occurs, however, in use (Akaka and Parry 2016). This means that to formulate a compelling value proposition (Osterwalder and Pigneur 2010; Osterwalder et al. 2014), an understanding of an entire service over time (Prohl and Kleinaltenkamp 2020) needs to be established. Additionally, value seems to be created on different levels of abstraction (Akaka and Parry 2016; Frow and Payne 2019): on the levels of individuals, a group, and number of groups; or in dyadic, triadic, and network exchange (Chandler and Vargo 2011). It can further be argued that all value is not equal, as categorisations (Ekman et al. 2016; Yang et al. 2017) are possible.

3 Methodology

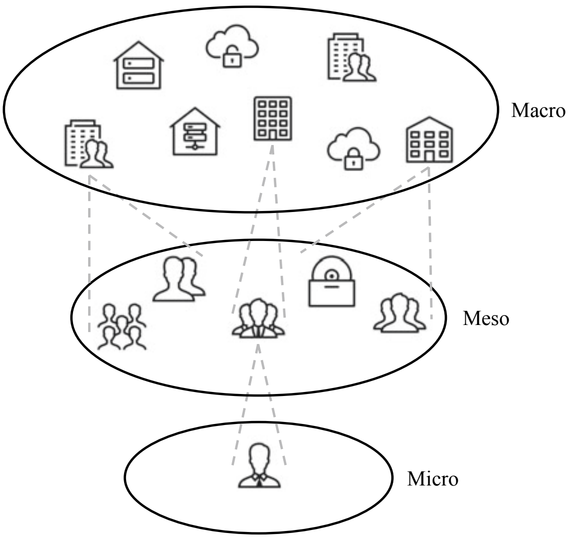
A case-specific literature review, firstly, provides the elements to describe a macro level ecosystem of the DC market. This is done by reviewing contemporary, secondary sources: mainly textbooks, peer reviewed papers, and industry publications.

Then, primary research is conducted to establish the meso and micro level of the ecosystem. This is done mainly through interviews with eight actors (previously identified on the macro level) with qualitative and quantitative components and complemented by the study of literature alluded to in these interviews. Figure 1 offers an abstraction of the resulting three-layered ecosystem.

Finally, a concept of an actual service offering is conceptualised by combining identified values, pains, and jobs in actor profiles and utilizing these profiles to define services, aiming for the cocreation of new value within the ecosystem.

The fitness of these services—and by extensions the fitness of the applied methodology—is tested by subsequently implementing the services in the scope of a four-month project.

Fig. 1 Ecosystem overview



4 Results and Initial Analysis

Results from the case-specific literature review allow for the construction of a macro level view of the ecosystem. It consists of actors (firms, regulatory bodies, etc.), the resources they integrate (data management capabilities, norms, etc.), institutions and institutional arrangements (labour laws, communications standards, etc.), and service exchange enabling value cocreation (increased application availability, lowered environmental impact, etc.).

Results from the primary research, based on interviews with actors identified on the macro level, are used to describe the ecosystem's meso and micro level. For instance, the DCIM-software vendor (an actor on the macro level) is segmented into application development, project management, etc. on the meso level. Subsequently, these actors are further subdivided into actors on the micro level, e.g., individual sellers or project managers. Each of these actors are again defined through the resources they integrate, the institutions and institutional arrangements enabling or constraining this integration, and their service exchange and value cocreation with other actors.

Upon construction of the three-layered ecosystem, actors with high potential for value cocreation (DC managers, DCIM-software vendors, etc.) are described through defining their jobs, pains, gains, and the value they experience. These elements are then utilized to conceptualize services, enabled by other actors, which aim for aiding in jobs, alleviating pains, enabling gains, or contributing to the cocreation of experienced value.

The implementation of the services in the form of a consulting project between three actors (DC manager, DCIM-software vendor, and DC consulting firm) confirmed the validity of the prior identified potential for novel value cocreation to be experienced by each of these actors.

5 Discussion of Results

This section discusses what constitutes an actor, how value cocreation in ecosystems occurs, what value dimensions can be observed and, finally, the implications for the RQ.

5.1 Involvement in Value Cocreation

From the initial research, a DC manager can be identified easily as a main beneficiary of services provided by, for instance, a DC consulting firm. It is tempting to just apply traditional service design methods to arrive at a service offering, catering to this specific "user" and only constrained by the abilities of the providing DC consultants.

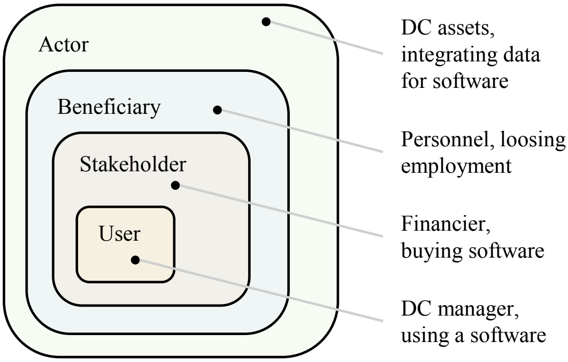


Fig. 2 Nomenclatural overview

However, by describing the ecosystem surrounding these actors, it becomes clear that there is no simple provider-consumer-dichotomy when it comes to the value created. Rather, multiple actors are integrating resources to enable value. And each of these actors, individually, experiences different value in return. Chandler and Vargo (2011) describe this quite fittingly as an Actor-to-Actor (A2A) environment.

These actors do not only encompass individuals, but rather any entity which could integrate a resource, relevant for the service ecosystem. Users naturally fall under this definition as they integrate their skills, time, etc. to use, for instance, a DCIM software. Stakeholders as well, have at some point integrated a resource, i.e., the stake, into the ecosystem but do not necessarily need to also be the user. In the previous example, the financier of the software, for instance, has invested capital and is anticipating optimised DC operations. Stakeholder and user are further similar insofar as they both determine value, albeit in different ways. The return on investment might be more important for the stakeholder, while the user is considering usability. This makes both, the user and the stakeholder, beneficiaries, i.e., determiners of value. Yet, what about someone determining value but not being interested in the success of a service exchange? For instance, DC facility management personnel, integrating their labour into the ecosystem, could be laid off due to automated DC operations. In addition, the software itself, the DC, etc. are all integrating resources into the system but are hardly categorizable as either user, stakeholder, or beneficiary.

The term actor can be applied to encompass all these entities: users, stakeholder, beneficiaries, groups of individuals, or things. It allows for the integration of anything that contributes to the value cocreation. Figure 2 offers a visualisation of this point.

5.2 *Value Cocreation Mechanics*

Having identified the actors involved in value cocreation, an understanding of what it is they integrate is established. The results in this regard could be categorised as capabilities, competencies, or resources (Wieland et al. 2017). But these all are means to the same end: their integration to foster value cocreation. By not only listing the resources being integrated but rather all resources any actor holds, the potential for envisioning new ways of allocating these resources is unlocked. In doing so, not only the conspicuous properties from resources interacting and actors interacting with resources (Peters et al. 2014) must be considered but also inherent properties, present in any individual resource. The added differentiation between operant and operand resource is in this view misleading, as any operant (acting) resource becomes itself an actor integrating a "capability". Furthermore, distinguishing between tangible or intangible, already of little importance under S-D logic, now becomes even more impractical.

The integration and combination of these resources is what enables value cocreation. That which defines the processes wherein this is done are institutions. In this sense, they go beyond generic rules, norms, meanings, and symbols (Wieland et al. 2017) to include, for instance, new technologies, enabling higher network traffic or the architecture of a storage system in the DC, limiting the storage capacity.

Fostering new value cocreation is not only done by breaking established institutions (Windahl and Wetter-Edman 2019) but also by re-iterating them (Wieland et al. 2017). The final service offering results in new value cocreation because it either introduces new practices into the existing DC management, disrupts insufficient ones, or maintains and supports them with the addition of new actors and the resources they integrate.

The ecosystem's levels of abstraction are described in line with Frow and Payne (2019) as micro (individual actors), meso (sub-groups of actors), and macro (groups of actors). This approach seems more practicable, as an approach according to Akaka and Parry (2016) would relegate discussion of dyadic exchange to the micro level. This is because dyadic exchange occurs among any type of actor: individuals, groups, between individuals and groups, etc. But when trying to describe ecosystems, there is hardly only dyadic exchange. Because multiple actors need to be considered to fully understand most value cocreation.

Considering macro, meso, and micro levels allows for a clear orientation with regards to the level of abstraction one is on at any given time. For instance, an interview is an investigation on the micro level. But—the interviewed individuals being representatives of groups of actors—inferences can be made to the sub-group (itself an actor) on the meso level. It further allows for the visualisation of higher-level connections, such as, between two firms, if that level of abstraction is sufficient. But at the same time, it leaves room for closer investigation of exchanges on a lower level, such as between individuals within and across their organisations.

Alternatingly establishing a focus on specific actors to investigate, allows for the application of design methods such as persona or empathy maps, which focus on individuals. But only by focusing on multiple actors and connecting them in a nodal network (Risdon and Quattlebaum 2018) ultimately leads to the complete ecosystem, with certain areas more fleshed out than others, due to the set focus areas. By focusing the investigation on DC consultants and DCIM-software vendor, for instance, shared connections to the DC manager can be identified, which promise potential for additional value cocreation.

If the premise of a single beneficiary, experiencing value, is accepted, the design of a service would, at some point, have to focus on a single actor's jobs. But by incorporating the findings of the defined ecosystem, it is possible to factor in the value these jobs could enable for other actors. A service blueprint, for instance, should therefore not only show the commonly used "supplier" activities behind a line of visibility and the "user's" activities before this line, but include any actor involved in the value cocreation.

5.3 Value Dimensions

When considering the definition of Akaka and Parry (2016), value would be cocreated in dyadic, triadic, and network exchange. However, it is always an actor (individual or group of individuals) determining the value. In a dyadic exchange, for instance, two completely different kinds of value could be experienced. As the value is experienced, it becomes important to understand the beneficiary's activities and contexts. This is part of the reason why the value proposition canvas (Osterwalder et al. 2014) is such a useful aid. But linking the value enabled to a job is pivotal, as otherwise the connection of activity to experienced value would be lost.

Categories, such as formulated by Yang et al. (2017) or Ekman et al. (2016) are just that: categories. Types of values. And not dimensions evident in all value. One dimension which can be inferred from the results might be related to the levels of abstraction, albeit not in the sense of direct vs. indirect exchange. But rather, as the value as experienced by an individual compared to how it is experienced by the group this individual is part of. For example, the value experienced by a user of DCIM-Software might be defined as a highly simplified way of setting up automated event notifications. The same value, on a higher level of abstraction and experienced by the group this actor is part of (the facilities organisation), could become clarity of responsibilities and reduction of errors. On an even higher level of abstraction (the entire company), this value would then translate into increased DC resiliency.

But similarly, if we focus on one actor's jobs, such as those of the DC manager, there are values directly experienced by this actor, because they make their jobs easier. These jobs, now performed better, enable value for other actors, not necessarily part of the same group. The value of one actor might therefore be experienced differently by another actor. As even a group of individuals is defined as just one actor, instead of referring to a value dimension as its level of abstraction, one could refer to it as immediacy; direct value, experienced by whichever actor is in focus, and indirect, presupposing the direct value but experienced by another actor.

Identifying these dimensions of value allows not only for envisioning solutions to enable it by doing the same jobs better. It also leaves room for envisioning different ways of enabling that value. The benefit being, that one already knows that an actor does experience it as value. For instance, a quick IT service provision is experienced as value by the business organisation and currently enabled by a shift of on-premise to cloud-based services. The same value, known to be valued by this actor, can now be envisioned to be enabled by an automated process for IT infrastructure to access computational capacity in an on-premise DC, with the facility organisation ensuring its availability.

Time becomes another important value dimension to consider; while value is only experienced in the moment, the context in which it occurs might shift over time. For instance, the value for a facilities organisation to accurately depict installed assets in a digital model is experienced when locating an asset for trouble shooting and, in a different context, when performing an audit. The visualisation of context across time is, therefore, an aid in identifying value cocreation opportunities.

5.4 Implications for the Research Questions

Following the previous subsections, RQ (I)[1] is answered by the following proposition for a replicable process when faced with the task of finding new value cocreation potential within an ecosystem. And RQ (II)[2] is answered by integrating the identified value dimensions into this process.

In this process, firstly, an understanding of the current ecosystem must be established allowing to go beyond known "customer segments" or "partnering firms". A promising way of doing so is to set up a macro level overview of the market in question. This includes actors such as companies, social groups, governments, and other large entities. To do so, multiple actor-centred ecosystems might be combined into a nodal ecosystem, by overlaying them according to shared actors within. By listing the resources these actors can integrate and mapping occurring interactions, current and potential service exchange is made out.

As this only provides an abstract understanding, the "resolution" of the ecosystem must be enhanced. To do so, a closer investigation of the sub-groups, making up the meso level, and the individuals, making up the micro level, must be established. This could also include inanimate actors such as platforms, software, or anything else integrating resources. The selection of actors to focus on should not be dominated by already established customer segments, but rather allow for the exploration of any actor who might partake in resource integration. As before, introducing actor-centred systems and combining them into nodal systems, allows for a faster arrangement of actors. Additionally, mapping the affiliation of individuals to sub-groups and to groups, fosters a clear structure and understanding across the different levels. The resources these actors can integrate, and the linking of interactions should be visualised once more, as they denote current and potential service exchanges.

Next, an ecosystem consisting of the previously defined macro, meso, and micro level and including actors, their current interactions, and resources which are—or could potentially be—integrated is established. By viewing the resource integration through the lens of actors as beneficiaries, experienced value is identified. This

[1] RQ (I): How can value cocreation opportunities within a complex service ecosystem be identified?

[2] RQ (II): What are the dimensions of value?

includes value experienced by actor "A"—because their jobs are made easier—and value experienced by actor "B", who's value experience is enabled by the enhanced job performance of actor "A". This presupposes an understanding of jobs done and value experienced over time through, for instance, actor-journey mapping.

Lastly, by identifying institutions and institutional arrangements which are currently—or could be in the future—enabling or constraining the resource integration, all elements are present to envision novel value cocreation. This dormant value cocreation is either awoken through the integration of new actors into the system, the introduction of new—or rearrangement of existing—resource integrations, or the enhancement or disruption of institutions.

This ecosystem understanding is then utilised as input for design frameworks, suitable for the definition of concrete services. The allocation of value, to jobs and actors and how they interconnect, allows for a more precise definition of value propositions, which are still aimed at one specific actor. The service design itself is further enriched by the fuller backlog and better understanding of potential beneficiaries and value cocreators.

6 Conclusion

This research paper set out to answer how value cocreation opportunities within complex business ecosystems can be identified and what the dimensions of such value are. The methodology to do so investigates the ecosystem of DCIM: reviewing literature on the broader DC market, interviewing actors within it, and assessing the jobs DC managers must perform in order to keep things running. In doing so, an ecosystem description is derived which informed a service design, leading to the conceptualization of services.

The results shed light on the actors within the ecosystem, how they experience value, what resources they (could) integrate, and the resulting service exchange. The results further identify what enables or constrains this exchange of resources. Value cocreation potential in this system is found to be realized by either cocreating existing value in novel ways or cocreating unprecedented value altogether. This is achieved by integrating novel actors, integrating previously unused resources—or rearranging existing ones, or enhancing or disrupting institutions enabling or constraining the resource integration.

These insights are summarized in a process intended to be employed for defining ecosystems in other cases and thereby identifying the value cocreation potential within. This approach further allows for a subsequent service design to be more thorough due to a better understanding and wider range of possibilities.

The value dimensions are found to be immediacy and time. The former refers to the proximity of any service exchange to the beneficiary: a service might be tailored to cocreate value experienced by one beneficiary, but indirectly cause value (positive or negative) to be experienced by another actor not partaking in the dyadic exchange. Time, on the other hand, denotes when value is experienced by any beneficiary. This is important, as the cause of value cocreation must be known in order to replicate, change, or enhance it.

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Value Propositions for Smart Services

Value Creation with Digital Twins—Framework Validation and Analysis of Further Development Priorities

Linard Barth, Matthias Ehrat, Manuel Holler, and Rainer Fuchs

Abstract This paper presents results of an ongoing research project to explain the systematic value creation with digital twins. Herein a formerly proposed digital twin reference framework is validated, its usefulness in practice is evaluated and development priorities are derived. Therefore, the framework was presented to and discussed with experts from practice. The evaluation of the quality of the framework, its benefits in practice and the applicability for innovation process phases were collected with an online questionnaire consisting of open questions and quantitative ratings. Qualitatively, the study unveiled the systematization and holistic perspective as main strengths and the complexity as major weakness of the framework. Quantitatively, the framework proved to be useful as it provides benefits for practice, especially in the early stages of innovation processes. Finally, development priorities and directions were derived to improve and adapt the framework towards the created insights to foster its applicability in practice.

Keywords Digital twin · Value creation · Conceptual framework · Validation · Practical applicability

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1 Introduction

The development and progress in information and communication technology will transform traditional products into smart products allowing to offer novel smart services (Dawid et al. 2016). Herein, the digital twin (DT) concept is regarded as a key technology for creating value with smart services (Barbieri et al. 2019).

However, the lack of a shared conceptual framework for DTs with an unambiguous terminology (Schleich et al. 2017) complicates cross-functional discussions. Additionally, the definition of digital twins has been enriched over time, from a digital representation of a physical asset to an evolving digital profile of the historical and current behavior and all properties of an asset, where an asset can be anything of value for an organization (Malakuti et al. 2019). In contrast to original definitions which are narrower (Holler et al. 2016) this understanding includes for example also software or processes used to create value via services for different internal and external stakeholders and actors working with digital twins. For the consideration of this broader view focusing more on the value creation, an integrative approach of internal service provision, market-side service usage and comprehensive data provision and architecture is required (Barth et al. 2020).

The authors therefore proposed an ontology and a conceptual reference framework to discuss and analyze the main value creating dimensions of DTs in a previous publication (Barth et al. 2020). The research questions and objectives in this previous study were (a) « Which dimensions are used to classify and structure DTs in academic literature? » , (b) « What are the fundamental differences or specifications within these dimensions? » and (c) « How do these different specifications relate to each other? » . The objective of the research was to find classification systematics that are (a) representing the entire spectrum of DTs, (b) universally valid in all DT related domains and (c) applicable in research and practice.

The resulting digital twin conceptual framework (DTCF) shown in Fig. 1 requires further research to evaluate and validate the framework regarding its application in practice and research, as well as to examine further refinement and development priorities. This paper grounds on the previous publication (Barth et al. 2020) and presents the research approach for the evaluation of the DTCF and initial results.

2 Methods and Objectives

As the objective of the ongoing research project is to integrate and extend existing theories in a new conceptual reference framework as a useful artifact for practice, a proven design science research framework serves as overarching structure for the mixed method approach (Hevner et al. 2004). The step of creating the rigor knowledge base was addressed by conducting a systematic literature review according to vom Brocke (2009) and Webster and Watson (2002) regarding the state of the art of digital twin definitions, taxonomies, dimensions and concepts depicting entities and

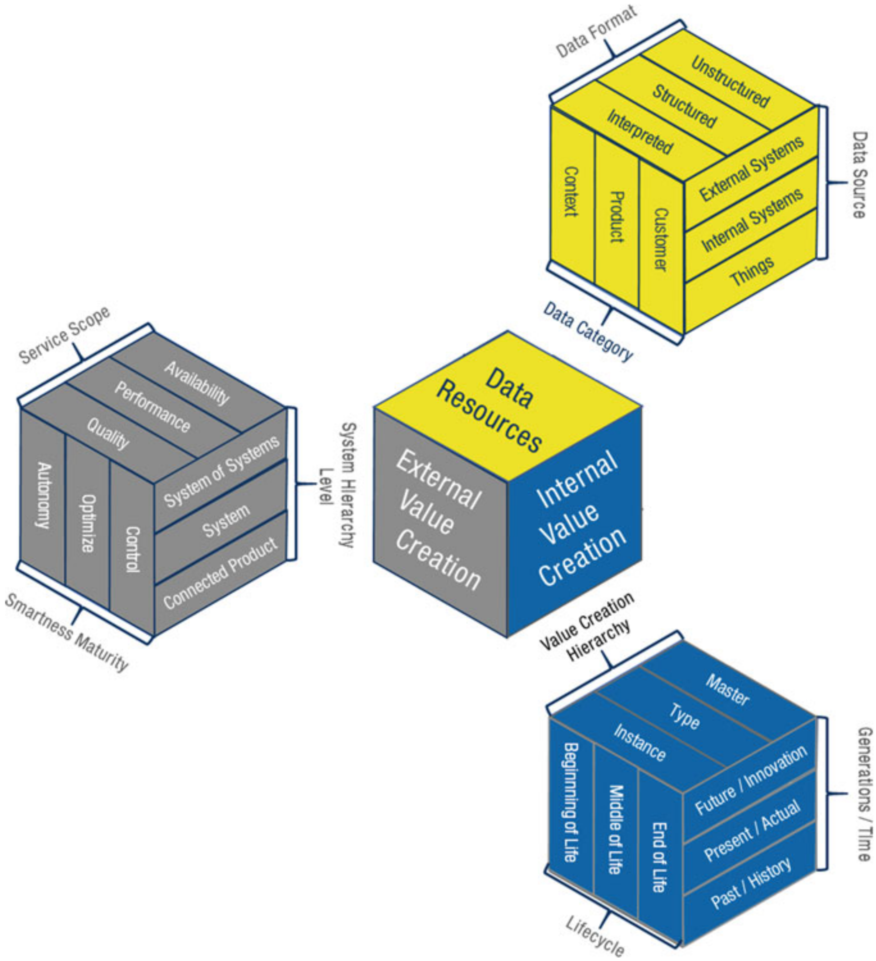

Fig. 1 Digital Twin Conceptual Framework (Barth et al. 2020)

relationships between these definitions. The findings from the literature review were assessed and refined within several iterations supported by semi-structured interviews (Schultze and Avital 2011) with academic individuals and focus groups (Morgan 1988). The interim result is the DTCF as seen in Fig. 1.

The next step according to the overarching design science research framework by Hevner et al. (2004) is the validation and further development of the created artifact by studying its relevance and applicability in practice, thus evaluating its usefulness.

2.1 Objectives

The main objective of the research at hand is thus the evaluation, validation and investigation of further development priorities for the DTCF as proposed by the authors in a previous publication (Barth et al. 2020). The following objectives are addressed:

1. Evaluation and validation of the conceptual framework quality.
2. Evaluation and validation of the applicability and usefulness in practice.
3. Investigation and assertion of the development priorities for refining and adapting the terminology of the elements and their visual/graphical representation to enhance the applicability in practice.

2.2 Research Approach and Methods

To address these objectives, a series of DTCF presentations and discussions were held with experts from various companies that use DTs to create value. The procedure consisted of three steps

1. Presentation of the DTCF to a set of stakeholders within the company to create a basic understanding and to ensure a rigor preparation of the next steps
2. Comprehensive discussion of the applicability of the DTCF based on use cases from the companies along the following guiding questions:
   a. How would you define the current status of value creation with digital twins in your company referring to the DTCF?
   b. In which dimensions and specifications of the DTCF your company seeks to improve its value creation with digital twins in the near future?
   c. In which dimensions and specifications of the DTCF do you see the biggest long-term potential for value creation with digital twins for your company?
3. Collecting feedback from the workshop participants
   a. by means of an online questionnaire with open questions, focusing on improving the terminology and graphic representation
   b. and completed by a utility value analysis focusing on the usefulness and applicability in practice, as well as the quality of the DTCF as a conceptual framework.

30 presentations were conducted with one up to five participants. Not all participants filled out the questionnaire, in total 42 responses were collected. The respondents' job titles and industries are listed in Table 1.

Table 1 Sample job titles and companies

Jobtitle categories	N = 42					
	Job Titel and Company N/A = 4	Industrial goods	Services	Consulting	Medical	**Total**
	Product Manager	10	5	1	1	**17**
	Project Leader	2	2	2	1	**7**
	R&D	3	1	0	1	**5**
	Business Development/CEO/Sales	2	2	4	1	**9**
	Total	**17**	**10**	**7**	**4**	**38**

3 Results

In general, the feedback during the presentations and during the subsequent discussions was very positive. Many company experts stated that the framework represents their own perspective on the topic very well and that they like the structured approach and holistic perspective.

3.1 Qualitative Results: General Findings

The online questionnaire began with a set of open questions. The following chapter names the most frequent answer categories per question and qualitatively describes the answers given.

Q1: In your opinion, what are the greatest strengths of the DTCF?

The systematic structure and segmentation in three main dimensions, especially the separation of internal and external value creation met broad agreement. The comprehensive and holistic overview of the value creation with digital twins was mentioned by 22 participants (answers include “holistic”, “perspectives”, “overview”, “comprehensive” or equivalent terms) as a strength of the framework. It seems as this is perceived valuable as it helps to “subdivide complex issues into individual subareas” and helps to detect correlations and links between topics often discussed in isolation. Or as one participant stated: “One is forced to look at all components and connections”. Further strengths mentioned in connection with the holistic and comprehensive view of the framework are e.g. “compact summary of all essential features” or “the DTCF can very well be used as a checklist to check whether all relevant issues have been addressed”.

Another strength of the framework, mentioned by 15 participants (answer includes “structure” or “structured”), is the clear and consistent structure resulting from the segmentation into three main dimensions and their corresponding specifications. This enables the DTCF to be applied as “a discussion guide for a rather complex topic” or as a “possible tool for systematic screening and categorization of opportunities.

Q2: In your opinion, what are the biggest weaknesses of the DTCF?

The holistic approach and comprehensive overview of the framework seems to be also one of its biggest weaknesses. 13 participants (answer includes “complex” or “complexity”) stated that it is too complex as it contains so many specifications with interconnections and therefore “is difficult to keep in mind”. Furthermore, the three-dimensional representation, which leads to 27 sub-areas in each dimension, does not seem to be intuitively understood by many, as two participants explicitly stated. However, one participant stated, that the representation is very descriptive, once comprehended.

The gap between the theoretical dimensions and specifications to real use cases was mentioned nine times (answer includes “application”, “practice” or “use-case”). This was also noted during most of the discussions, as we were regularly asked to give examples. Even though we were able to explain the individual specifications with a set of examples, we currently lack a single easily understandable and generally valid example, which can be used to explain all dimensions and specifications consistently.

Three participants stated that the meaning of some of the terms is not fully self-explanatory. This was also recognized during the presentations and discussions and might be due to the fact, that most practitioners are only experts in one of the three dimensions.

Therefore, the probably biggest weakness of the conceptual framework is, that it is hardly completely understood without explanation due to its complexity and specialist terms. It currently lacks a single easily understandable example, which covers all dimensions and specifications.

Q3: Which terms are unsuitable? (e.g. unclear or misleading, not precise, too limited, etc.*)*

Even though three participants stated already at the previous question that not all terms are self-explanatory, 11 participants explicitly stated that all terms are known and understandable and eight participants have abstained from the question.

The rest of the feedback is diverse, 15 participants mentioned one or more terms that were not understandable to them or that they consider unsuitable, but only six proposed alternative terms to use. The only part of the framework which was mentioned several times is the “value creation hierarchy” in the “internal value creation” dimension with the specification “instance”, “type” and “master” with eight out of the 15 responses that mentioned specific terms. Especially “instance” and “master” seem to be the terms most difficult to understand.

Another statement on this question, which occurred twice, is that a glossary with synonyms and explanations for each term would be useful to make the framework self-explanatory.

Q4: Are there key elements in the DTCF that you do not consider relevant for value generation with digital twins?

21 participants answered that all key elements in the framework are relevant and another nine have abstained from the question, hence roughly three out of four participants consider all key elements relevant. Five participants stated that they are not able to asses this question, resulting in only seven participants mentioning key elements not relevant in their opinion. Interestingly, five thereof referring to specifications of the data resource dimension.

Q5: Does the DTCF lack key elements that are relevant for value generation with digital twins?

11 participants answered that the framework is not lacking any key elements and another six have abstained from the question, hence roughly four out of ten participants are not missing any key elements.

The feedback of the other participants is very diverse and does not show any clear cluster or patterns. However, some of the statements might be grouped around business model transformation enabled by digital twins, the customer perspective with regard to willingness to pay and willingness to share data, missing granularity regarding processes and supply chain, as well as some feedback regarding the data resources, e.g. data security or tools to structure and enrich data. Three participants stated that they are not able to asses this question.

3.2 Quantitative Results: Framework Quality

To validate the quality of the conceptual reference framework, the participants were asked to rate seven different quality criteria of artifacts (Sonnenberg and vom Brocke 2012) developed within the design science research approach.

The rating with scores of different criteria to validate the quality of a conceptual framework shown in Fig. 2 suggest that the DTCF is considered very complete and capable of covering different areas of application, as this criterium received the best rating with the least deviation. Additionally, the level of detail and the internal consistency received high ratings, but with a notable higher variance of ratings by the participants. Not surprisingly the conceptual framework is also regarded as suitable for standardized and normed comparation of different use cases. The criteria regarding the suitability to depict real applications (practical suitability), degree of self-explanation (comprehensibility and plausibility) and intuitive use (simplicity and applicability) received the lowest ratings, however still above the rating of five, which represents a “just sufficient” fulfilment of a criterium.

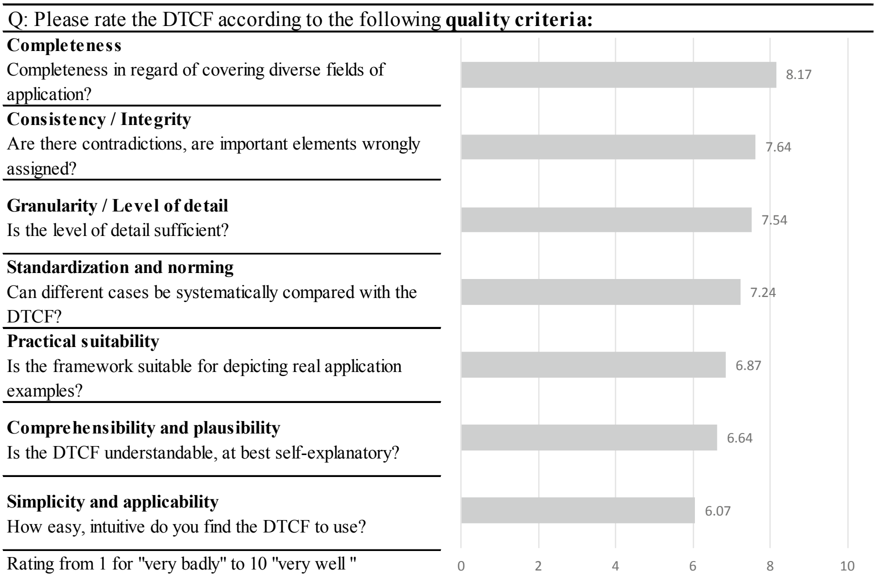

Fig. 2 Framework quality rating (N = 42)

3.3 *Quantitative Results: Applicability and Use in Practice*

The questionnaire asked participants whether they would consider using the DTCF in practice, followed by a question to explain why they would use the DTCF or not. As seen in Fig. 3, roughly four out of five answered that they would consider using the DTCF in practice. The answers to the follow-up questions are very similar to the responses to Q1 (Strengths) and Q2 (Weaknesses).

Deeper insights result from the evaluation of different benefits in practical use as shown in Fig. 4. As a conceptual model must be developed in such a way as to provide a system interpretation easily understood by the user of the model it should satisfy fundamental objectives defined according to Kung and Solvberg (1986). The respondents were asked to rate five fundamental objectives of conceptual models,

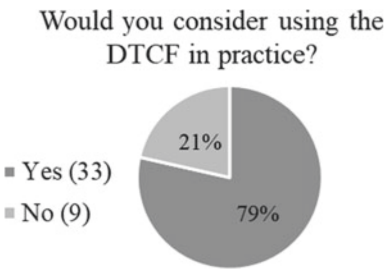

Fig. 3 Proportion of practitioners who would use the framework in practice

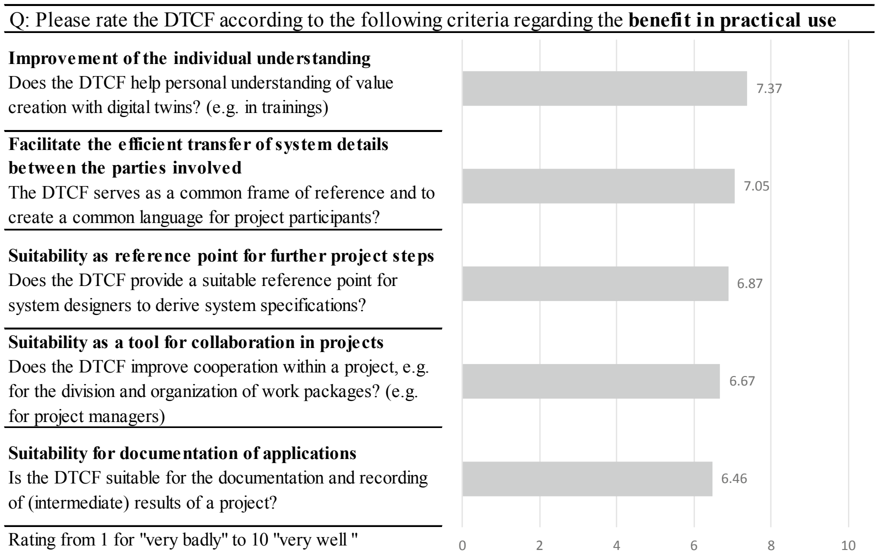

Fig. 4 Benefit in practical use rating (N = 42)

each specified as a benefit in practical use by a corresponding question with a clear reference to the DTCF.

Improvement of the individual understanding received the highest rating, followed by the benefit of facilitating systems details transfer. The suitability as reference point received the third highest rating, while the suitability for documentation of applications received the lowest rating.

This is in line with and supports the findings from the qualitative questions and helps to interpret the findings of the evaluation of the suitability of the DTCF to be used in different phases of the innovation process, as shown in Fig. 5. As presumed based on the statements on strengths and weaknesses and the evaluation of benefits

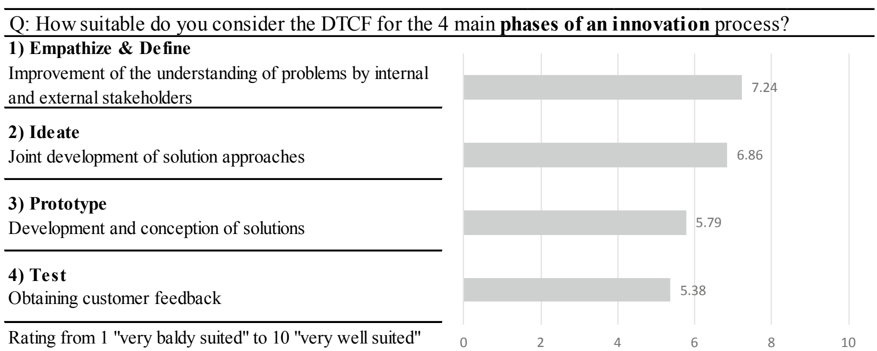

Fig. 5 Rating of suitability of DTCF for innovation process phases (N = 42)

in practical use, the DTCF is perceived to be better suited for the early stages of innovation processes, with steadily declining ratings from phase one to four.

As shown in Table 2 the suitability of the framework to be used in the phases 1 and 2 was rated significantly higher than in the phases 3 and 4.

"(1) Empathize & Define" as well as "(2) Ideate" were rated more suitable than "(3) Prototype" with **high significance ($p < 0.01$)**. The suitability for the first two phases "(1) Empathize & Define" and "(2) Ideate" was also rated more suitable than "(4) Test" with **high significance ($p < 0.01$)**. The means of the other pairs are not significantly different.

4 Conclusion

In this working paper, we set out to (1) validate the conceptual framework quality and (2) evaluate the applicability and usefulness in practice in order to (3) derive development priorities for the Digital Twin Conceptual Framework.

Qualitatively, the study unveiled the systematization and holistic perspective as main strengths and the complexity as major weakness. Beyond, with the exception of minor amendments regarding the terminology (e.g., value creation hierarchy) and scope (e.g., business model transformation), the framework was considered as useful. The respondents considered the DTCF to be useful to foster completeness and holistic perspectives in projects, e.g. by using it as a checklist to ensure that nothing was forgotten and to unveil synergies and connections between partial projects.

Quantitatively, regarding the framework quality, the dimensions completeness, granularity, and consistency showed the highest ratings, whereas the simplicity exhibited the lowest figures, which in turn reflects the qualitative statements. Referring to the applicability and usefulness in practice, the framework is considered most suitable for improving the individual understanding, facilitating systems details transfer and as a reference point, while the suitability for documentation received to lowest rating. Thereby, the DTCF is particularly useful for early stages of the innovation process (i.e. Empathize & Define).

Besides minor points for improvement like nomenclature changes, two approaches to further develop the model are conceivable. For one, the weaker elements could be enhanced, for another the strong components might be made even better.

To science, we contribute a validation, and hence an empirically grounded model for the value creation with digital twins. We therefore overcome many built, yet not validated models (e.g. Enders and Hoßbach 2019, Uhlenkamp et al. 2019). To practice, such a useful artifact offers benefits for the design and the use of digital twins in a variety of industries.

While the mixed method approach in general is beneficiary for the scientific quality, a limitation emerges from the rather small, non-representative sample size. Another simplification is grounded in the perceived value, as the actual value can only be studied in the accompaniment of digital twin activities for months or years.

Table 2 Significance test on paired suitability for project phases

Paired differences N = 42	Mean	Standard deviation	Standard error of mean	95%-confidence interval		T	df	Signifi-cance (2-sided)
				Lower value	Upper value			
(1) Empathize & Define (2) Ideate	0.381	2.527	0.390	−0.407	1.169	0.977	41	0.334
(1) Empathize & Define (3) Prototype	1.452	2.881	0.445	0.554	2.350	3.267	41	0.002**
(1) Empathize & Define (4) Test	1.857	3.310	0.511	0.826	2.889	3.636	41	0.001**
(2) Ideate (3) Prototype	1.071	2.403	0.371	0.323	1.820	2.889	41	0.006**
(2) Ideate (4) Test	1.476	2.822	0.435	0.597	2.356	3.390	41	0.002**
(3) Prototype (4) Test	0.405	2.209	0.341	−0.284	1.093	1.187	41	0.242

Note ** $p < 0.01$

In the short term, the further development and adaption of the framework towards the created insights is an obvious step, serving as basis for a large-scale evaluation in the mid-term. To enhance the self-explanation of the framework a consistent example case as well as a glossary might be developed. To foster the suitability of the DTCF to be used in practice as a tool for the early phases of an innovation project, the development of a workshop methodology might be considered. For later project phases, where the DTCF is perceived as less suitable to be used in practice, a deeper analysis might be conducted to understand for which subphases the framework can provide value and which other methods and tools could complement and support the development of specific use cases and applications. Finally, the implementation as software tool might be a long-term direction.

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BIM-Enabled Issue and Progress Tracking Services Using Mixed Reality

Valentin Holzwarth, Sebastian Steiner, Johannes Schneider, Jan vom Brocke, and Andreas Kunz

Abstract This paper reports on a case study in collaboration with an industry partner to explore the value creation potentials of Mixed Reality (MR) in construction. MR is a technology that allows for intuitive interaction with digital data through overlays on the real world, giving immediate access to the data of a construction site to quickly track or resolve possible issues. While prior research identified potential applications of MR in construction, the evaluation of MR in real contexts is lacking. Thus, this paper describes a user study that evaluates an MR-assisted inspection task with the participation of nine construction professionals. The results reveal that the average time needed to track an issue with the Building Information Modeling (BIM)-enabled MR application takes less than a minute, compared to an hour for the standard process. Furthermore, the participants reported that working with the MR application was enjoyable and they would like to use it more frequently. Finally, based on the user study's findings, this paper develops two service concept prototypes that could be implemented by the industry partner.

Keywords Mixed reality · AEC · Building information modeling · Service concepts

1 Introduction

Digitization is one of the most important trends of the 21st century. The transformative force originating from digitization imposes a direct influence on value creation

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in a corporate environment. In consequence, the current top five of the world's most valuable companies rely heavily on digital business models (Miller 2017). Also the Architecture, Engineering and Construction (AEC) sector is heavily affected by digitization, leading to an increased availability of data along project life-cycles and allowing for the creation of novel, smart services (Holzwarth et al. 2019).

However, the construction industry has not yet exploited the full potential of digitization (Gandhi et al. 2016). Schober and Hok (2016) identified four key factors to digital transformation in AEC: (i) Automation, (ii) Digital Data, (iii) Connectivity, and (iv) Digital Access. Mixed Reality (MR) is a technology, which supports the latter three of the four key factors to digital transformation in construction. It allows for an interaction with digital data, superimposed to a real environment. Thus, MR might enable the construction industry to further increase their degree of digitization and therefore improve its productivity. Prior research has already identified potential applications of MR in AEC (e.g., Wang et al. 2013). However, most prior works do not evaluate the potential of MR technology in a real context.

Therefore, the aim of the study presented in this paper is to explore the potentials of MR technology by conducting a case study in a representative real life setting. The case study's industry partner, one of the world's leading AEC suppliers, is seeking to develop MR-based services as a future complementary offering for their customers. This allows for an in-depth assessment of MR technology's potential in an industrial setting.

2 Related Work

This section provides an overview on the different applications for MR in the construction sector. The findings, where to apply MR technology to support construction processes, originate from different literature sources, such as the work done by Wang et al. (2013) on "a conceptual framework on integrating building information modelling with augmented reality". This section also serves as a basis to determine which MR-supported process should be examined during the user study.

MR technologies can be applied in the planning phase as well as in the construction phase (see Fig. 1). The planning phase includes all preliminary work such as the design and planning process, preparation of construction logistics, and any other preparation task. The construction phase describes the time during which the construction and quality control of the project takes place.

The applications of MR presented in this section are focusing on these planning and construction phase processes. Supporting other project life-cycle processes MR, such as tasks for facility management, is also possible and potentially promising. However, this is beyond the scope of this study and therefore not evaluated in more detail but should be mentioned for completeness.

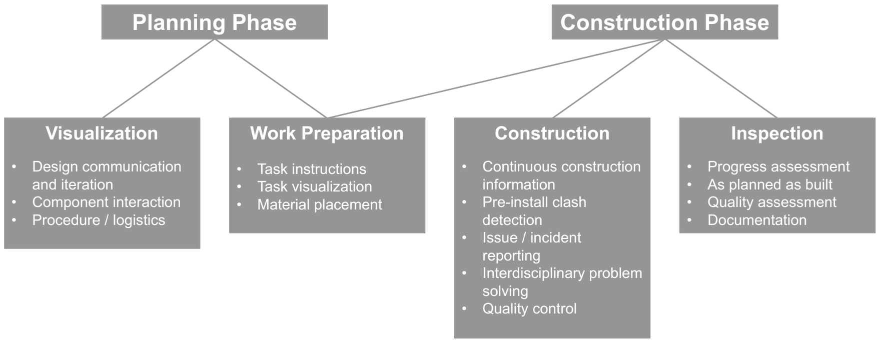

Fig. 1 Applications of MR in construction

2.1 Visualization

The application of MR technology allows for displaying plans and 3D models—so-called Building Information Models (BIM) models—in the real world, either at their original size or at a smaller scale. This facilitates model comprehensibility for non-professionals and allows for visualizing substantially more information than conventional, printed plans. For example, with the MR platform *CityScopeAR*, developed by MIT media lab, collaborative urban design processes can be visualized. This system is used to display additional information about the implications that a planned project might have, such as congestion and construction costs (Noyman et al. 2019).

Another software solution for visualisation, which is available today, is the *Trimble sketch up viewer* which makes it possible to view the projects in a MR environment on a smartphone or with a Head-Mounted Display (HMD). Such software solutions allow the user to view the drawings as miniature 3D representations or in life-size, making them better comprehensible and the experience more immersive (Trimble 2019). Having such possibilities of visualizing plans with MR technology enables better understanding of component interaction, particularly between different planner professions, and it also enables a more interactive way of overall planning.

Additionally, construction logistics procedures can benefit from MR technology by connecting planners and the operating staff through simultaneous access to the same digital model. This enables fast response to unforeseen events or test runs of new logistics scenarios. Through these means, planners can be supported by operative staff during the planning process (Reif and Walch 2008).

Furthermore, MR technology is also considered to be valuable in supporting warehouse planning processes. MR technology can be used to visualize any planned rearrangement in full scale. This enables planners to not only test the plans on the real model but also to model new workflows, which are compatible with the changed environment (Glockner et al. 2014).

2.2 Work Preparation

The second subcategory of the planning phase is work preparation, which is also linked to the construction phase, as planning is also required here. Besides the fact that task instructions and visualizations can be displayed before the task is carried out, other task-related information such as where to place material or machinery in order to achieve the best results can be communicated to the user as well. By that, a deeper connection between the early planning and the on-site preparation can be created, which allows for better accuracy and efficiency.

2.3 Construction

During construction, the execution of tasks plays a key role. The application of MR technology during task execution has been implemented at Boeing in the context of cable routing. Construction information is continuously made available to the user through an HMD, which provides technicians with a real-time, hands-free access to interactive 3D wiring diagrams. This MR-supported wiring process allows for more efficient task execution, which is consequently raising productivity. This has led to a 90% improvement in first-time quality compared to using two-dimensional information on the aeroplane, along with a 30% reduction in time spent on task execution (Boeing 2018). Besides the reported productivity improvements, MR technology leads to a reduced number of mistakes during complex assembly processes (Chalhoub and Ayer 2018).

2.4 Inspection

The final part of the construction phase is the inspection. Here, MR technology enables a facilitated and intuitive access to digital planning data directly on the job site. This enables progress and quality assessment by superimposing the real world with digital plans in an MR environment. The MR environment can be used to access information on the intended construction progress from digital plans more easily and thus enabling “as planned as built” comparisons. Also, the quality with which the features have been installed can be determined by comparing the location and alignment of the real world objects with their digital representations. These different inspection tasks set different requirements for the performance of the MR environment regarding accuracy and information allocation, with the latter being the most demanding for accuracy requirements. Since the user on the construction site has direct access to the digital data, accurate digital documentation of progress, quality and other performance indicators are possible through MR applications during inspection processes. This facilitates the collection and storage of digital data about various aspects of the construction process, which can lead to higher overall efficiency due to a higher data density. Utilizing MR technology in inspection tasks also enables self-inspection functionalities. This encourages job site workers to document their working processes and results on a regular basis. Furthermore, it prevents incorrect actions and helps workers to rectify errors immediately (Riexinger et al. 2018).

3 Methodology

The methodology of the study presented in this paper follows an exploratory, technology-driven approach, starting with an extensive review of MR applications in AEC, with the goal of creating service concept prototypes (see Fig. 2). The literature review summarizes both, the state-of-the-art in MR technologies, as well as prior research on MR applications in the context of AEC. This step results in a long-list of potential use cases. Subsequently, the technology selection evaluates the capabilities of hand-held and hands-free MR technology, regarding features such as calibration and accuracy. This step excludes those use cases that are not feasible due to technical constraints. A workshop with the industry partner adds specific requirements, which are combined with the technology selection's findings. Based on these steps, a user study is conducted, wherein 9 AEC professionals participate. In the first part of the user study, each participant is asked to solve a task supported by an MR application. In the second part of the user study, semi-structured interviews are conducted with each participant, which are transcribed and coded. In these semi-structured interviews, the participants contrast their expertise in AEC with the experience in solving the MR-supported task. Based on the user study's results, two MR-based service concept prototypes are developed: (i) a co-creation service, including a smartphone application to be utilized by involved stakeholders in the construction process, (ii) a full service, requiring only limited stakeholder interaction and collaboration.

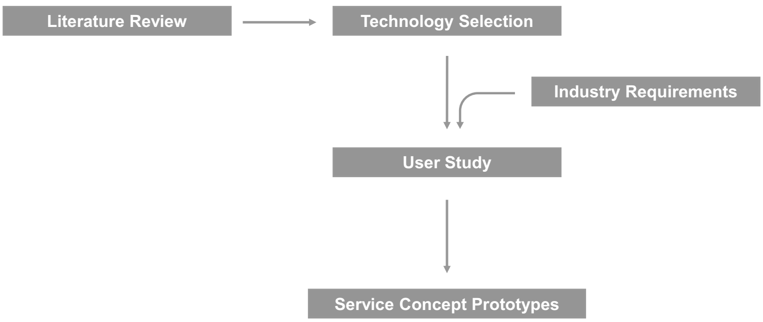

Fig. 2 The methodology of this paper

4 Results

The results of the study in this paper follow the methodology's order, starting with the technology selection and concluding with the developed service concept prototypes.

4.1 Technology Selection

The technology selection identifies and analyzes two categories of MR technologies: (i) hand-held MR technology (e.g. smartphone MR applications) and (ii) hands-free MR technologies (e.g. HMDs). Accuracy (i.e. the offset of the superimposed virtual model over the real object) is essential for certain applications, such as quality assessment. A positional error (i.e. accuracy) of 6.64% at distances between 1.5 and 2.5 m has been reported for the Microsoft Hololens, which is a popular device for hands-free MR technology (Liu et al. 2018). For hand-held MR technology, no literature could be found. Thus, a benchmark experiment was performed, which yielded a 3.28% positional error at distances between 1.5 and 2.5 m for the iPhone Xs, which is a popular representative of hands-free MR technology.

4.2 User Study

The user study integrates the findings of the literature review, technology selection and industry requirements of this study's partner company.

Materials The user study was conducted in a specifically prepared room at the industry partner's facility. For this room, a complete BIM model was available in the AEC software Autodesk Revit.[1] Smartphone-based MR technology was chosen, due to accuracy concerns towards head-worn MR devices. The chosen setup was a state-of-the-art Apple iPhone Xs with the built-in ARKit technology and the MR application Gamma AR.[2] For each participant, task completion time and the number of errors were recorded in the first part of the user study. In the second part of the user study, the participants reported on their experience in semi-structured interviews with a duration of approximately ten minutes. These interviews were recorded, transcribed and coded regarding usability and user acceptance criteria.

The Task During the user study, an inspection task is carried out with each participant in the following way: The participant is welcomed to the study session and informed about the inspection task. Furthermore, each participant is made aware of 5 defects in the study room, which are marked with a colored sticker (see Fig. 3). This was done in order to set the focus on the MR-assisted task and not on the identification

[1] https://www.autodesk.com/products/revit.

[2] https://gamma-ar.com/.

Fig. 3 The MR Application interface (left) and a defect marked with a colored sticker (right)

of defects. On each sticker, the type of the defect is noted. First, the participant has to set-up the MR environment by conducting a set-up calibration of the model. Then the participant uses the MR access to the BIM model of the study room to add the information which is stated on the coloured markers to the digital model (see Fig. 3). These colored markers define five possible defects or other issues that could potentially occur on a construction site. For each of the five defects, it is stated what the defect is and how the information should be added, either by a text, a photo, or an audio recording. This has to be done for all five defects.

This simplified user study setup can be imagined as part of a real world procedure, which can be divided into three parts: In *part one*, an inspector examines the construction site or specific parts of it in the "real world". When the inspector finds an error on a feature, has a general comment or wants to evaluate the progress, the MR environment provides access to the BIM model so that he can add or receive information.

In *part two*, there is no human interaction required. The comments made by the inspector are being uploaded to the cloud. Then the information can be automatically forwarded to the relevant professionals who oversee the specific parts. For example, if the inspector adds a comment on an electrical installation, the electrician will receive a notification and all the information about this installation. Also, all the comments are archived, which generates a timeline that might be used for performance evaluation.

In *part three*, the different technicians get a summary of the affected part (information available in the BIM model), where it is located and what the comments of the inspector are. With this information, they can collect the exact material they need to fix the issue. When arriving at the position which was marked in the ground plan of the building, the technician could again use the MR environment to locate the exact part. After fixing the issue, the MR environment is used again to add a comment to the part, whether the issue could be fixed or if there are any further actions required.

Participants Nine AEC professionals (6 male and 3 female) with a mean age of 27.56 (SD = 6.82) years participated in the user study. They had various backgrounds, such as engineering, marketing, and computer science. All of the participants were daily smartphone users, whereas 5 participants had prior experience with MR technology. Only 3 participants had prior experience with BIM, while 5 participants were unfamiliar with 3D models of buildings.

After accomplishing the inspection task, all participants reported on their experience in semi-structured interviews. These interviews yielded that all 9 participants considered the MR application easy to use, 8 participants would like to use it frequently, and 7 participants stated it would make their work more enjoyable. Furthermore, 2 participants saw the main benefit in process transparency (i.e. cover-ups for defects are impeded due to fast and transparent issue identification processes).

4.3 Service Concept Prototypes

Based on the positive findings of the user study regarding performance, user acceptance, and usability, two prototypes for a MR-based service supporting inspection tasks on construction sites were envisioned:

Co-creation service The service would be provided in form of a digital platform, consisting of a smartphone MR application and a cloud-based issue management software. This service requires value co-creation of all workers and inspectors on a construction site (i.e. the value is created by all involved actors together, instead of one actor creating and the other actors consuming the value). Although the findings of the user study were very positive, it is still doubted, whether all stakeholders would engage in the service. This could not only be due to resistance towards novel technology, but also due to transparency that would impede cover-ups of construction defects.

Full service The full service relies on the same infrastructure as the co-creation service. Here, the service does not require any co-creation. This is achieved by dedicated teams, managing issues and defects on construction sites. This service concept eliminates the disadvantage of the co-creation service, as it does not require the participation of construction site stakeholders. However, the full service would be substantially more costly for the construction project and would be only chosen for special projects.

5 Discussion

The overview of Wang et al. (2013) on applications of MR in AEC served as the basis for this paper. However, it has proven to be challenging to develop a use case that fulfills industry requirements, is technically feasible, and has potential for substantial improvements due to MR support. The inspection of building defects with smartphone-based MR is such a use case. It took the participants on average three minutes and 30 s to complete the task, this is equal to about 40 s per identified issue.

The time was measured including the calibration time but excluding the time it took to restart the application if this was necessary during the user study. Overall, it took the participants 1.67 calibration attempts to set-up the MR environment correctly. This means that 40% of calibration attempts were unsuccessful. Surprisingly, participants were not heavily bothered by unsuccessful calibration and reported high usability and acceptance. However, the accuracy (i.e. the offset of the virtual model) was an issue for 3 participants.

6 Conclusion and Outlook

The aim of this study—exploring the potentials of MR in AEC—was fulfilled. The first substantial finding is that today's technology already seems to be suited to support some of the basic tasks on a construction site. This is most importantly supported by the participants of the user study, who stated that they could even imagine using the MR setup in its current form. Additionally, it is important to note that a regular smartphone could support the MR application which guarantees a high degree of accessibility. The most meaningful finding, however, is not only that this technology is sufficiently mature and accessible but that it is genuinely considered an improvement over a non-MR-supported workflow. Some participants considered the improvement to become apparent during the process itself, but all agreed that the higher quality of data, which was available after using this technology, as well as the time savings due to much faster data post-processing, are undoubtedly the substantial benefits.

Despite these promising results, some problems were also identified. Firstly, it became clear that the calibration success rate has to be improved in order to accelerate the workflow. Secondly, the overall accuracy of the software needs to be improved in order to make more detail-oriented tasks possible and to avoid generating the necessity for users to compensate for software flaws. Further research should be considered regarding the user acceptance on every level of construction work since the scope of our study could not sufficiently cover such a large spectrum. Therefore, conducting experiments with more participants from different backgrounds in the construction industry and directly comparing MR processes with the currently utilized processes on the construction site as well as comparing different MR solutions would be a consequent development of the presented study.

When discussing the limitations of MR technologies, one also has to consider the technology's potential. Current issues pale in comparison to the manifold future possibilities of developing MR technology further. The great variety of possible future applications was demonstrated by the participants immediately being able to think of further tasks on a construction site, which could be supported by MR. All these tasks could consequently lead to a fully MR-supported construction process. In this process, every participating worker could stay well informed through the data provided by such an MR system. In this sense, MR would serve as the key technology to a full digitization of construction sites, possibly introducing one of the greatest efficiency improvements of recent times.

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A Capability Model for Equipment-as-a-Service Adoption in Manufacturing Companies

Jonathan Rösler and Thomas Friedli

Abstract In the light of digital transformation, manufacturing companies are challenged to rethink their business models as technologies, such as the Internet of Things (IoT), that allow innovative product and service offerings. Equipment-as-a-service (EaaS) is a business model that combines both the product and the services needed to maintain and operate the equipment in one offering, whereas the revenue model is based on the actual value (e.g. usage-based, availability-based, outcome-based) provided. Despite high practical relevance, little is known about the required capabilities to introduce and operate such models, as this phenomenon has just started to be explored. Addressing this gap, our study aspires to provide a first understanding of which capabilities are required for introducing and operating the EaaS business model. Based on the insights gathered from interviews with 18 executives from over 14 manufacturing companies that have introduced such offerings, we present a capability model for assessing the maturity needed to introduce and offer EaaS. While bridging the gap between theory and practice, we leveraged state-of-the-art knowledge to help manufacturing companies better understand where they find themselves concerning the capabilities required to introduce and operate the EaaS model.

Keywords Servitization · Business model · EaaS

1 Introduction

Within the increasingly globalized environment of today, manufacturing companies need to stand up to global rivalry. Low-cost production deriving from less developed countries, as well as the increasing commoditization, place the utmost uncertainty upon manufacturing companies' revenue streams and economic margins (Kindström 2010; Reinartz and Ulaga 2008). The importance of services within manufacturing and product-oriented companies are widely recognized to counter this phenomenon (Baines et al. 2013; Ulaga and Reinartz 2011; VanDerMerwe and Rada 1988). The

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shift towards service offerings rather than product offerings is referred to as servitization, the transformation of manufacturers into solution providers (Raddats et al. 2019). Switching away from a product centric offering promises interesting paths to implement innovative business models (Baines et al. 2013)

Our research shows how manufacturers increasingly contemplate moving away from transactional relationships and into relationship-based business models, thus, selling customers the ability to use their product without having to purchase them.

In such business models, the providing company is no longer paid for its service activities, such as materials or repairs, but rather upon the outcome of such activities in a continuous setting, e.g., the number of usage hours or the achieved availability of products. Despite widely acknowledged benefits of providing such an offer to customers (Grubic and Jennions 2018), the fundamental question of how companies can introduce and operate EaaS remains widely unanswered to practitioners. In essence, manufacturing companies face difficulties to design and operate such and similar models (Windahl and Lakemond 2006).

As the implementation of Equipment-as-a-Service (EaaS) requires deep changes within and across organizational boundaries of manufacturing companies, the question regarding how manufacturing companies can introduce and operate such models reveals to be of practical importance rather than only theoretical significance. However, existing studies that address this topic are scarce.

Drawing on the resource-based view (RBV) of firms, our study examines the required capabilities to introduce and operate EaaS. We develop a holistic capability-based maturity model to guide manufacturing companies in their endeavor to introduce and operate EaaS. To achieve this purpose, we follow the maturity development process of Becker et al. (2009) to answer the following overarching research questions:

RQ: *What capabilities are required by manufacturers for the introduction and operation of the EaaS business model?*

The remaining of this paper is structured as follows: first, we will present key literature. Secondly, we will outline the methodological approach adopted, including details regarding data collection. Third, we will introduce our proposed maturity model for EaaS. Lastly, we finish by further elaborating on the implication of our findings and present a brief conclusion.

2 Theoretical Background

Shifting away from transactional and product-oriented approaches to outcome-based contracts (Ng et al. 2013; Visnjic et al. 2017) through EaaS and similar models, such as result-oriented product service systems (Gebauer et al. 2017), or pay-per-use models (Porter and Heppelmann 2015) have been discussed as feasible options for manufacturing companies for decades. Empirical evidence on the successful introduction of such models is, however, mixed at best (Porter and Heppelmann

2015). Whereas examples such as Xerox, Rolls Royce, GE, or Hitachi are often seen as "success stories", the majority of manufacturing companies have yet been unable to offer such models successfully.

In recent times, the most prominent topic within both practice and theory has been how technological possibilities to realize such advanced business models have dramatically increased due to digitalization (Rymaszewska et al. 2020).

The Internet of Things (IoT) is one of the main enablers of these advanced outcome-oriented servitization business models (Becker et al. 2009; Ng and Wakenshaw 2017). The IoT is a system of uniquely identifiable and connected products ('things') generating an internet-like structure that enables a real-time flow of sensing, operation, and location data (Tukker 2004).

Research within this domain has shown that IoT-enabled servitization strategies offer great economic opportunities, closer customer contact, increased sustainability, more stable revenue streams, and improved resource utilization (Kohtamaki et al. 2019; Ng et al. 2012; Reim et al. 2015). Additionally, shifting from product selling to customer problem-solving and outcome provision offers valuable opportunities for customers by mitigating risks and improving operating performance or asset effectiveness (Ng et al. 2012).

However, the shift in processes needed to actuate servitization towards delivering outcomes can be difficult at best, as it requires a significant organization-level change (Benedettini et al. 2015; Story et al. 2017), and many companies lack information to understand the risks associated with such offerings. Moreover, most companies are facing troubles to identify and design suitable EaaS business models and have difficulties in convincing people in the organization to enact such changes towards outcome delivery.

Also, a profound understanding of what and how to organize to achieve an EaaS business model is not always there. There are various further open questions on how value-creating activities are ultimately changing, and which capabilities are required for such changes. In particular, no work on the specific capabilities required for enacting EaaS has been found.

3 Research Methodology

To fill the gaps that emerged from previous analyses, we adopted a three-step research process.

First, we carried out a systematic literature search of servitization-related capabilities using the Scopus database. The search was targeted at scholarly or peer-reviewed research papers. We applied a search combination of servitization ("Servitization"), product-service systems ("product (-) service system*", "PSS"), advanced services ("advanced service*"), integrated solutions ("integrated solution*"), performance contracting ("performance contracting", "PBC"), Pay-per-Use ("Pay-per-Use", "PPU", Pay-per-X"), Equipment-as-a-Service, and other related keywords ("Equipment-as-a-Service", "EaaS", "Machine-as-a-Service", "MaaS", "Product-as-a-Service", "PaaS", "as-a-Service", "XaaS", "aaS", "as a Service"), and capabilities ("capability").

The search conducted between 2000 and 2020 yielded 134 usable articles with review criteria based on the relevance of the abstracts and keywords (first stage) and the content of each publication (second stage). The reviewing procedure included carefully reading, reviewing, and sorting the found articles. These articles were used to derive an initial list of capabilities. Given the employment of a single search engine, no duplicates were found nor excluded.

Secondly, we conducted semi-structured interviews of 90 min with executives from manufacturing companies that were either already experienced in EaaS offerings (12 interviews) or were significantly ahead in piloting these (2 interviews). To refine the model, we asked for their perception of necessitated capabilities for EaaS and validated with them our initial list of capabilities derived from the literature review. We used publicly available information to verify the information given concerning the companies and their offerings.

Third, after formulating the capability-maturity model, we interviewed 15 individuals, academics, and practitioners involved within the topic for their opinions to build support for the model. Each interview was of 60 min. Emails with a questionnaire to guide the open conversations were distributed in advance.

The majority of the responses acknowledged the importance of evaluating manufacturers' capabilities for introducing and operating EaaS and supported the overall structure of the model. Minor adjustments were made regarding the designation of the dimensions. Furthermore, we evaluated the comprehensiveness of the model and validated the results in a self-assessment with the interviewees from steps two and three.

4 Proposed Capability Model

Our model consists of 27 capabilities organized against 8 dimensions (see Table 1) based on the identified requirements and key business activities derived from literature and interviews with field experts: (1) *Organization & Governanc*e, (2) *Value network*, (3) *Data & Analytics*, (4) *Research & Development*, (5) *Marketing & Sales*, (6) *Operations*, (7) *Risk management*, and (8) *Culture.*

For each dimension, the corresponding maturity can be measured on a 5-point scale (ranging from '0 = poorly developed' to '5 = strongly developed') that has been calculated from the average obtained by evaluating the items within each dimension.

To visualize the results, respondents could calculate the average scores for each construct and plot them on a radar chart for their company or business unit. Whenever respondents from the same organization completed the maturity assessment, they could either compare their respective charts or calculate total average scores for each construct to create a shared chart. The tool could therefore be used to compare different business units or companies.

Table 1 Identified dimensions and capabilities of the EaaS capability model

Dimension	Capability
Organization & governance	(1) Fast decision making, (2) Ability to allocate roles flexibly, (3) Efficient process (re-)design
Value network	(1) Identification and analysis of relevant partners, (2) Organizational alignment with network, (3) Ability to co-design processes, (4) Ability to evaluate intermediaries' performance
Research & Development	(1) Ability to design products for service, (2) Ability to design for disassembly, (3) Ability to design for recycling, (4) Ability to anticipate potential causes of product failure, (5) Ability to update/upgrade the product
Data & analytics	(1) Ability to convince the customer to share data, (2) Ability to translate data into value, (3) Ability to ensure data privacy and security
Marketing & sales	(1) Understand the customer's value drivers, (2) Ability to quantify the value provided by the offer, (3) Ability to communicate the individual benefits of the offer, (4) Performance evaluation, (5) Ability to quickly share information among the entire sales force, (6) Ability to design incentives aligned with customer's benefits from the offer, (7) Ability to establish trustworthy relationships with customers
Operations	(1) Ability to solve "digital" complaints and incidents, (2) Ability to quickly react to fast-changing situations
Risk management	(1) Ability to quantify, control, and monitor risks
Culture	(1) Ability to establish a continuous learning culture, (2) Internal communication

4.1 Organization and Governance

Our data imply that moving towards Equipment-as-a-Service requires a fundamental change in the company's system of making and implementing decisions as well as in its organizational structure.

In particular, our interviewees frequently emphasized that they had to completely rethink their decision-making process and operating guidelines for being able to operate their EaaS model successfully. Overwhelmed by this transformation and the frequently occurring organizational resistance, sometimes, companies decided hence to set up entirely new organizational units.

In this context, the undertaking of *efficient process re-design* without significantly increasing costs was one of the most frequently mentioned capabilities in the interviews. Besides, more than ever, the use of cross-functional teams was highlighted as a proven practice to deal with complex and interdisciplinary problems when moving to this new business model. Also, the ability to *allocate roles flexibly* was therefore considered an essential prerequisite for offering EaaS. Finally, as many firms faced great operational hurdles when introducing their EaaS model, *fast decision making* was revealed to be of great importance.

4.2 Value Network

To develop and operate the EaaS model, often, a new level of cooperation and value co-creation with third parties beyond customers is required. Our data shows that manufacturing firms willing to adopt EaaS, therefore, need to develop more intimate relationships with their customers and partners within their respective ecosystems. Consequently, capabilities that relate to coordinating and integrating with these partners, i.e. for billing or financing, become of high value.

In many interviews, the vast number of potential partners who offer or develop solutions aiming to support manufacturing companies with their EaaS model was addressed. This frequently led to a certain complexity regarding the question of which partner possesses the best offering and who could be a reliable long-term partner for the company. Hence, manufacturers need to further develop capabilities that allow the *identification and analysis of relevant partners* for their EaaS model.

Moreover, once such partnerships were established, the experience with such intermediaries was not always satisfactory. Many of these partners, such as platform operators, were often unable to keep their promises or, as financing partners, turned out to be too expensive when scaling up the model. The ability to *evaluate intermediaries' performance* systematically and suitably was thus mentioned repeatedly.

Also, we found that the EaaS business model led to much closer cooperation with partners as well as a deepening of customer relationships. Consequently, manufacturers build up capabilities that facilitate *organizational alignment with the network*. For instance, the majority of interviewed manufacturers have somehow aligned their organizational structure to leverage the efficiencies within their value creation network. Striving for these efficiency gains, many interviewees noted that they had also re-designed their processes tailored to the needs of all partners. Consequently, many companies had to learn to *co-design processes* with all of the actors found within the EaaS ecosystem.

4.3 Research and Development

The EaaS business model is something that cannot be implemented from one day to another. In contrast, manufacturing companies need to optimize their products and services in line with the model and consequently build up the associated capabilities.

For instance, our data indicates that companies have to improve their capabilities to *design products for service*. Namely, to operate the EaaS model efficiently, easy accessibility of components for maintenance must be ensured or products equipped with sensors.

As at times, the cost of recycling is higher than that of purchasing the equipment, the ability to *design for recycling* at low cost is a factor that will become predominant as the provider takes over the ownership of its assets.

Furthermore, the ability to *design for disassembly* was addressed by some companies. For instance, if an EaaS contract expires, the machine must likewise be dismantled or sold on the aftermarket. Our interviews showed how manufacturers often had a lack of such skills or resources. Consequently, it seemed all the more crucial to enable the simplest possible dismantling system.

With products installed at the customer's facility and getting paid on output or outcome achieved with the equipment, another indispensable capability is the ability to *anticipate potential causes of product failure*. Manufacturers highlighted how they often were forced to further develop within their product innovation organizations as well as begin to apply techniques, such as Failure Mode and Effects Analysis (FMEA). This is because manufacturers needed to improve their products to avoid the downtime of equipment.

Besides these capabilities, our interviewees emphasized the importance of being able to take the customer with them in the development process and receive honest feedback. Often challenged by internal resistance, manufacturing companies should therefore go to customers during the EaaS drafting process.

Finally, many interviewees have pointed out the importance of understanding new trends and technologies that they were able to utilize for their offerings. Market intelligence hence often laid the foundation to develop EaaS models.

4.4 Data and Analytics

To successfully operate and offer EaaS models, companies need to expand their current resource base with digital capabilities. Our data indicate that a necessity for this came not only from being able to operate or design better products but also from many manufacturers selling their EaaS model within their core value proposition of improving the customer's operational efficiency via the model.

This translates into having the equipment readily connected, and the data interpreted and turned into value for either the provider or the customer. Both the ability to *convince the customer to share data* and to *translate data into value* were detected.

As it is not trivial to get access to product status data, product usage data, customer process data, and other sources of data, manufacturers emphasized how customers needed to be sure that their data was well-protected. Hence, we found the ability to *ensure data privacy and security* to be another crucial capability within this dimension.

4.5 Marketing and Sales

Designing, selling, and marketing the EaaS business model turned out to be a key challenge within manufacturing companies. Not least because the skills to identify and demonstrate the value of such a business model have not been heavily developed in typically transaction-driven equipment or service sales organizations of manufacturing companies. Additionally, the ability to design a revenue model that takes into account both the provider and customer perspective is challenging.

Manufacturing firms, therefore, need to be able to assess, and thus identify and then quantify, as well as communicate the total value of their EaaS offer. In detail, we found seven capabilities necessary for offering the EaaS business model in this dimension:

First, we found that EaaS providers need capabilities that allow them to develop an intimate understanding of their customers' needs, processes, requirements, earnings logic, and product use. We characterized this as the ability to "*understand the customer's value drivers*". This is mainly due to the different usage behavior of customers and their diverse value drivers, be it productivity, quality, or other factors as shown in our interviews. Manufacturing firms need to be able to connect their value propositions with their customer's needs when drafting their EaaS model. In this context, segmenting customers based on such vale drivers was a common practice observed in the interviewed companies.

Second, our data suggest that the ability to *quantify the value provided by the offer* is of significant importance. Moreover, manufacturing companies should be able to determine the lifecycle costs of the solution as well as to have an intimate understanding of their customer's earnings logic to quantify the total customer lifetime value provided with their EaaS model. Although essential to designing a profitable revenue model for their EaaS offer, usually, we found these capabilities to be not well developed inside the companies in our sample, particularly before moving towards offering EaaS.

Third, when offering the EaaS model to customers, manufacturers need to upgrade their current maturity by being able to *communicate the individual benefits of the offer*, such as compared to the next-best alternative. In particular, the ability to convince customers to decide on the EaaS model, and to agree on the contract duration, the price model, including how to share benefits, emerged as a significant barrier in scaling up this model. Regularly, sales teams of the interviewed manufacturers started to elaborate on the current baseline whenever showing the multiple benefits that the EaaS model offered to their customers. Our interviewees also mentioned that having access to insights about the competitor's offerings and strategies allowed them to better communicate their specific value proposition. Manufacturers should, therefore, develop a profound understanding of their competitor's offering to elaborate on the individual benefits of the EaaS model from a comparative standpoint.

Fourth, manufacturing companies need to develop capabilities that allow them to assess the related costs and contribution margin of their EaaS offer. Our data suggest that many manufacturers had found their initial revenue model to be insufficient, which often meant that the model could not be operated profitably. The ability to design or adjust the price model based on such an analysis is hence a crucial capability, which we named *"Performance evaluation."*

Fifth, as EaaS requires a reconfiguration of the sales approach, manufacturing companies need to develop capabilities that allow them to *quickly share information among the entire sales force.* Our data suggest that most manufacturing companies are quite diverse in the way they sell their products globally. To sell EaaS on a global scale, companies, therefore, need to train their entire sales force, for which information and documents are needed to be shared smoothly across the whole organization. Furthermore, as selling EaaS was typically considered to be of greater complexity, this capability allowed companies to share "best-practices" within their sales teams.

Sixth, companies need to improve their ability to *design incentives aligned with customer's benefits from the offer* with the EaaS model. Our interviewees often highlighted how they had to adjust their sales incentives to be successful within their EaaS. As EaaS is a completely new business model, salesforce had great benefits from selling EaaS at first. Coupled with the customer's success with the model, many sales roles were, however, re-defined from being one-time sellers to customer success related roles, ensuring that customers were satisfied with the offer.

Seventh and finally, our interviewees also highlighted the ability to *establish trustworthy relationships with customers* across the entire organization to convince customers to opt for the EaaS model. More than before, manufacturing companies should keep their promises and focus on facilitating professional customer account management.

4.6 Operations

By taking on maintenance responsibilities from the customers, providers of EaaS models are more than ever required to deliver comprehensively high quality when it comes to service. Managing the value chain of their EaaS offering, therefore, becomes a key task for manufacturers.

Our data shows that manufacturing companies willing to introduce EaaS should be able to *solve "digital" complaints and incidents* with the same quality and speed as "hardware" related complaints and incidents. For instance, if remote monitoring functions were to go offline, manufacturers would need to be fast at fixing such an error.

Moreover, manufacturing companies need to develop the capability to *quickly react to fast-changing situations.* Our interviewees highlighted the difficulties to operate EaaS on a global scale. For which automated business processes, coordinated salesforce, and field service organization, as well as the use of digital field management software, and access to relevant customer data, were all mentioned as key success factors.

4.7 Risk Management

In the past, manufacturing companies only had to take responsibility for the risks associated with the products they sold. However, with the EaaS business model, providing companies take over operational and economical risks from their customers, e.g. by offering a machine for leasing and guaranteeing its availability.

As this is a significant challenge, manufacturers need to build up new risk management capabilities to *quantify, control and monitor risks*. Our data show that these additional risks must first be assessed to determine whether they can be accepted, hedged, and how they need to be priced. For example, if a customer's ability to operate equipment is inadequate, higher operational risks can be a dealbreaker, as availability cannot be guaranteed for a reasonable price. Therefore, the ability to take over risks is based on the company's capability to assess the respective risks of customers in advance. To achieve this, manufacturers also need to utilize gathered information to offer customer-tailored contracts, typically conceived after defined criteria and processes.

4.8 Culture

The culture of a company describes its value system. For EaaS offerings, many cultural related aspects focus on the ability to offer EaaS successfully.

Our data shows, in particular, the need to establish a business innovation-friendly *continuous learning culture,* where different approaches can be tried out and failures can be made. The capability to build such an environment, driven by continuous improvement, a seamless feedback loop system and systematic knowledge management, has therefore been identified as a key to offering EaaS.

Furthermore, manufacturing firms need to develop or expand their capacity for *internal communication.* As EaaS is a new business model in which success cannot be guaranteed, best-practice sharing, as well as communicating openly about success and failure, ensures that the whole organization is "on-board", which was frequently considered as very important to be successful. To ensure this, many manufacturing firms made use of dedicated resources to perform internal marketing.

5 Conclusions

5.1 Implications for Theory

In this study, we investigated the capabilities required for manufacturing companies to successfully introduce and operate Equipment-as-Service (EaaS). In achieving this purpose, we identified these required capabilities, which align to 8 dimensions. In particular, we highlight those capabilities that are unique and critical. In doing so, the study complements existing academic efforts and makes three leading contributions.

First, while previous studies identified servitization capabilities, this investigation specifically addressed the capabilities required to offer the EaaS business model.

Second, we considered capabilities from both the perspective of introducing and operating such a model. In doing so, this research extended the current knowledge base, as specific capabilities for introducing such a model were typically not well emphasized in existing work. Namely, capabilities that referred to the development and sale of such business models were not widely discussed in previous research.

Third, while this work is focusing on the capabilities required by manufacturing firms wanting to offer EaaS, the data suggests that complementary capabilities relating to intermediaries and customers should be built up for the implementation of EaaS models. In essence, our study highlights the ecosystem perspective of EaaS business models.

5.2 Implications for Practice

Our research sheds more light on how companies can successfully provide EaaS offerings and master the necessary strategic and organizational adaptations needed. The study hence suggests several principal managerial implications for manufacturing companies that are considering to offer EaaS.

Most importantly, manufacturing companies need to invest in building up capabilities that mostly relate to the ability to transform and re-configure the resource-base of companies. By doing so, manufacturers need to balance their traditional business model with the EaaS business model.

Also, it revealed that manufacturers need to expand their current capabilities to succeed in communicating with the customer and selling the EaaS model. The latter is because EaaS models require a much thorough interaction with customers in identifying the EaaS value proposition and the value delivered to customers.

Finally, as most EaaS models are based on digital technologies, manufacturing companies are well-advised to expand their corresponding capabilities in this field.

5.3 Limitations and Further Research

As with all research, this study has some limitations. First of all, the development of the model is based on literature and only a limited number of interviews with executives from manufacturing companies and experts, which makes it conceptual. For that reason, further research could involve more interviewees, divided into academics and practitioners, aiming at improving the model consideration of different perspectives. Moreover, we also acknowledge how even though the maturity model has been carefully developed, based on literature and interviews, a testing and final evaluation of the tool with cases has not yet been conducted. Besides, at this stage, some dimensions of the model are so far captured insufficiently and should be supplemented.

Nevertheless, the presented maturity model can serve as an essential part of future empirical and theoretical work. As we pursued the ambition to provide a fertile ground for future research, we suggest further research to explore the various dimensions of our model and their internal interdependencies empirically. On the one hand, this exploration could be carried out expediently in a qualitative research design setting where the potential challenges in the conceptualization of each dimension should be clarified along with their causality relation. On the other hand, we also invite quantitative studies of our framework to measure the above in a broader perspective, which could include examining the effects of different capabilities on the performance of companies.

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Procurement of Advanced Services Within the Domain of Servitization: Preliminary Results of a Systematic Literature Review

Oliver Stoll, Shaun West, and Lars Hennecke

Abstract The development of smart services for business to business applications enabled by digital technologies is on the rise. Services can become very complex in industrial applications; many actors are involved in their development, and value propositions often reflect complexity by addressing many beneficiaries. The challenge of pricing services is still prioritized in service-science because services are often intangible, therefore not as easy to price. With complex value systems emerging from advanced services, it is even harder to describe their value. When developing services, strong emphasis is put on understanding ecosystems and customer needs to create compelling value propositions. The key question for service sales is how much value the offering should capture? The pricing of services can be cumbersome and should be consistent with the value proposition: the promise to solve the customer's defined problems. To maximize value for the customer, the offering should not be under- or over-scoped with features of limited usefulness. Every actor in the buying process has a different view on value, and different situations create different amounts of value. For sales, this is where a careful analysis is essential. But how are the services for industrial applications bought, and how is the value of a service assessed by a customer? Are there any differences between the stated value proposition and the perceived value proposition? This paper aims to investigate models and concepts from literature on assessing the value of services from the buyer's perspective, comparing them to existing sales models.

Keywords Servitization · Advanced services · Service purchasing

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1 Introduction and Background

Servitization in manufacturing is a mature research field (Kowalkowski et al. 2017) which investigates how manufacturers move from selling products to selling "bundles" of products and services (Vandermerwe and Rada 1988). In some of these manufacturing firms these service offerings have become dominant, a shift described by Vandermerwe and Rada (1988) as the "servitization of business". Servitized manufacturing firms with up to 3,000 employees are more profitable than traditional firms (Neely 2008). The impact and the prospect of outperforming competitors through services (Neely 2008; Schmenner 2009; Vandermerwe and Rada 1988) can be a strong motivation for firms to participate in servitization. During the period 2000-2010, servitization led manufacturers to innovate and move from selling products to selling integrated product-service offerings that deliver value in use (Baines et al. 2009). The shift to value-added services and value in use business models (Baines and Lightfoot 2014; Gebauer et al. 2017; Kohtamaki et al. 2019; Raddats et al. 2015) has driven servitization to a more customer-centric approach compared to the tactic of gaining dominance over the customer through servitization (Schmenner 2009). Another emerging approach for assessing the value of services is service-dominant logic (SD logic) (Vargo and Lusch 2008). This concept has emerged more recently in the research field of servitization (Stoll et al. 2020a; S. West et al. 2018a). Putting smart services enabled by digital technologies into an SD logic perspective (value co-creation) may be considered a path to explain the value of smart services (Stoll et al. 2020b; West et al. 2018b). Smart services can be seen as an enabler for advanced service (Baines and Lightfoot 2014), because digital technologies enable firms to provide capability, availability or performance contracts (Kohtamaki et al. 2019).

In servitization, pricing (capturing value) is a recurring topic that presents many challenges (Kindstrom and Kowalkowski 2014; Raja et al. 2020; West et al. 2016). Within marketing literature, Anderson and Narus (1998) provided a useful framework to identify, create and deliver value in B2B environments. Within SD logic literature, Vargo and Lusch (2008) offer a framework to support value identification based around the "value in use" rather than the approach of "value in exchange" from a goods-dominant logic paradigm. There appears to be a limited amount of literature that links value capture with revenue models pragmatically, nor is there significant literature on the fair sharing of value between parties in a value co-creation and co-delivery situation. Some of the recent research proposes to assess the value of smart services (West et al. 2018a) through the lens of SD logic (Vargo and Lusch 2008) and an approach to value capture (West et al. 2018b).

Procurement in firms has been professionalized over the past 30 years, resulting in commoditization of the buying process, which in turn has cut costs in external purchases (Anderson and Katz 1998; Rehman Khan and Yu 2019). The use of alliance agreements in two different markets (Murthy et al. 2016) has shown that a move to different procurement approaches supports situations where collaborative value creation is occurring, still neither provide objective views on the appropriate level of the value share between the two firms.

A recently published paper describing the commercialization of smart services coming from a Digital Twin (Stoll et al. 2020) revealed that the customer's purchasing department was considered a barrier for selling the services. Moreover, Stoll et al. (2020) proposed to investigate further how customers buy services because the tools and mechanisms for buying products cannot be applied to purchasing services (van der Valk 2008). Therefore, this paper aims to investigate: "*how are smart services purchased according to existing theoretical frameworks within the research field of servitization?*" To answer the research question, a systematic literature review was conducted.

2 Methodology

The methodology has been designed to answer the research question by investigating the literature of servitization. In this context, a semi-structured literature review (Snyder 2019) was performed to understand the state of knowledge about purchasing services in this particular research field. Figure 1 shows the procedure followed by the researchers. The search was conducted in the Web of Science (WoS) database and the servitization research area.

The data set was built by searching WoS with the following keywords: TS = (servitization AND purcha*) OR TS = (servitization AND sourcing) OR TS = (Servitization AND "sourcing strategy") OR TS = (Servitization AND procurement) and refined by: WEB OF SCIENCE CATEGORIES: (management or engineering multidisciplinary or business or engineering industrial or engineering mechanical or engineering manufacturing or operations research management science or computer science software engineering or computer science information systems or economics or computer science artificial intelligence or computer science interdisciplinary applications). Data cleaning was done by reading the titles and abstracts. Analysis and validation of the results were conducted by each author individually. This allowed the authors to get unbiased results, and having the data analyzed by practitioners and academics enabled practical and theoretical implications to be derived from the study.

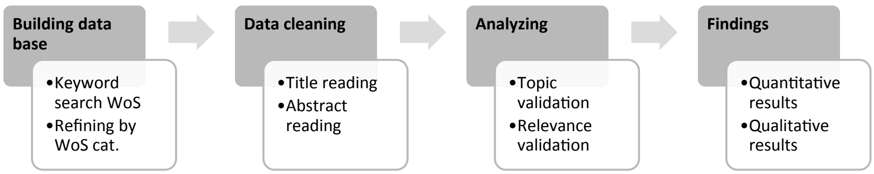

Fig. 1 Process followed by the researchers

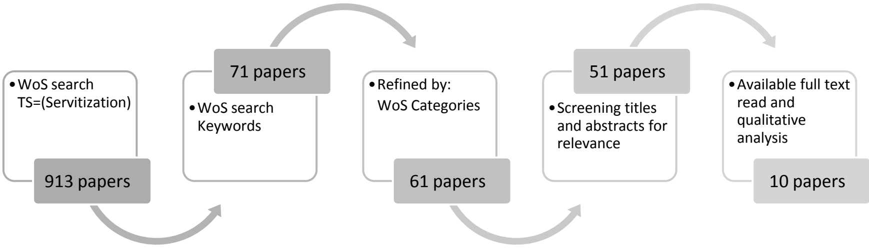

Fig. 2 Results of the systematic review

3 Results

The data set for "servitization" consists of 913 papers published in journals and conferences. The keyword search (see Fig. 2) returned 71 matches. After refining according to the WoS categories 61 references were left. The initial screening process of reading the titles and abstracts lead to rejecting 50 papers as not being relevant and 1 where the full text was not available.

The final set of full texts were read by the three authors independently to assess the relevance of the papers' content to the research question. Table 1 shows the identified papers and the ratings from a consensus score, for the rating a 5 point Likert Scale was used where each author specified his agreement for the relevance of the paper ((1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree).

4 Discussion

Since the impact and the prospect of outperforming competitors through services (Neely 2008; Schmenner 2009; Vandermerwe and Rada 1988) is considered a strong motivation to participate in servitization, it has been surprising that within the servitization research community, minimal studies have been conducted investigating how firms buy advanced services. In the literature, van der Valk (2008) emphasizes that buying goods or services are substantially different processes. Further, that buying services may even be more complicated than buying goods and that the 'interactive character of advanced services has so far largely been neglected in published studies. van der Valk (2008), Liu (2014), Liu and Song (2014), Maiwald et al. (2014) and Tunisini and Sebastiani (2015) however, do highlight the importance of investigating servitization from the buyer's perspective. The authors consider that currently the work of (Liu 2014); Liu and Song (2014) can be considered the leading investigation of the buyer's perspective of servitization.

In this study, after the full reading by the authors, only four papers out of almost 1000 were found to be relevant to answering the research question. Three of the

Table 1 Results from the analysis of full papers

Title of paper	Combined score	Reasoning for score
Towards an operations strategy for product-centric servitization (Baines et al. 2009)	1	Limited links to research question
Making a profit with R&D services - The critical role of relational capital (Kohtamaki et al. 2013)	2	The focus on R&D limits its transferability
Will User Involvement Always be the Case? The Effect of Service Procurement on Customer Perceived Value in Servitization (Liu 2014)	4	Provides insights from a buyer's point of view
Service Outsourcing and Procurement in Service Supply Chain: Perspective of Service Buyers (Liu & Song, 2014)	3	Provides a framework to describe the interactive nature of services and its implication for procurement
The dark side of providing Industrial Product-Service Systems - perceived risk as a key challenge from a customer-centric point of view (Maiwald et al. 2014)	3	Provides insights to procurement and purchasing behaviors
Innovative and networked business functions: customer-driven procurement (Tunisini and Sebastiani 2015)	4	Insights to the role procurement could play
Should everybody be in services? The effect of servitization on manufacturing firm performance (Crozet and Milet 2017)	1	Limited link to research question
Supply Chain Management Integration in Maintenance and Repair Services Sector (deSouza and Haddud 2017)	2	Limited link to research question
Territorial servitization: Exploring the virtuous circle connecting knowledge-intensive services and new manufacturing businesses (Lafuente et al. 2017)	1	Limited link to research question
Capturing and enhancing provider value in product-service systems throughout the lifecycle: A systematic approach (Matschewsky et al. 2020)	2	Limited link to research question

publications are conference proceedings, and one is a paper in a journal. The two publications from Liu were published in the proceeding of the 13th Wuhan International Conference on E-Business. The work of Liu has gained little to no attention since the citation count on WoS is zero. However, the authors consider Liu's work as relevant for this study because the author covers SD logic through the characterization of services and emphasizes the importance of the procurement role. To that, a critical view on co-creation (user involvement) is provided, examining the importance of collaboration and interaction needed from procurement (Tunisini and Sebastiani 2015) for buying services.

The third publication from Maiwald et al. (2014) was published in the proceedings of the 6th CIRP Conference on Industrial Product-Service Systems and has been cited five times, according to WoS. The work provides a different view on how customers perceive risks associated with purchasing product-service systems. This contribution has not been considered directly relevant to answering the research question, but the risk perception of such offerings may be a relevant aspect to consider when researching the purchasing of services. When viewed together it starts to highlight the research gap here, and the importance of linking procurement with the selling of advanced services.

The paper written by Tunisini and Sebastiani (2015) is the only relevant paper published in the Journal of Business & Industrial Marketing. It attempts to describe the role of procurement and how customers' procurement drives client value. Also, the growing integration of procurement and sales was discussed, and how the procurement process starts to interact with the clients business.

4.1 Academic Implications Business

Based on this literature review, there is a research gap on how firms purchase advanced services in the field of servitization. Examining this topic could improve understanding of how to sell services in this context and add to the knowledge base on servitization and value.

4.2 Practitioner Implications

Procurement plays a vital role in many organizations; in some, it has high strategic relevance. With increasing service offerings, the opportunities for firms are growing. However, services cannot be bought in the same way as products.

The procurement process for servitized offers will need to address the interactive nature of services. It may require a higher degree of collaboration of buyer and seller, come with an increased risk of supplier dependency, or require flexibility to address future needs.

Therefore, buying services requires enhanced procurement strategies and capabilities to define, evaluate and drive operational collaboration between buyer and seller to maximize the advantage of a purchased service.

5 Conclusion and Recommendations

This systematic literature review shows that within the research field of servitization, there are no explicit frameworks supporting the procurement of this type of advanced services. The vast majority of the work focuses on the development and sales of advanced services. However, evidence was found that procurement practices differ for services and products. Some aspects of these differences are presented in the papers found. The impact of these papers is meager, either indicating a lack of interest in the servitization research community, or that this study searched in the wrong community. This paper is limited by focusing on servitization literature and WoS as a database, or possibly the keywords used for the search may be incomplete.

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Value Capture with Smart Services

A Customer-Centric Search for Triggers as a Basis for Marketing Automation Service Design

Frank Hannich, Tania Kaya, and Marcel Hüttermann

Abstract This B2C case is about Houzy, a startup and free landlord platform based in Zurich. We used the five trigger sources approach to identify relevant triggers and a gap analysis to create new service design ideas. Our study shows that the five trigger sources approach works well for small and medium-sized enterprises (SMEs) with limited data and resources. We found numerous triggers that generate behavior changes in customers, and we derived service design ideas from triggers not yet addressed by Houzy services.

Keywords Trigger-based marketing · Customer centricity · Marketing automation · B2C · Trigger sources · Service design

1 Introduction—The Houzy Case

Houzy is a platform for home and apartment owners based in Zurich, Switzerland. Through Houzy, property owners can monitor renovation requirements, financial performance, and access many other services. This is free of charge and without obligation (MyHouzy 2020) and is achievable because Houzy has more than 450 partners and investors (Unsere Partner 2020).

Houzy consists of a 29-strong team and is continuously growing and developing new ideas (Das Houzy-Team 2020). As is typical for B2C platform business models, one of the first pressing challenges is generating a large user base, and Houzy has taken big steps towards achieving that. Their principal task now is to retain their clients and intensify service usage and interaction. Consequently, Houzy must offer services that their customers need, at the right time when the need exists—and in

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a largely or fully automated way to be able to scale business. This importance of value in use and the need for perfect timing has led Houzy to consider trigger-based marketing.

2 Literature Review—Customer-Centricity in Marketing Automation Should Be Improved

Automation is one of the most discussed topics in marketing at present (Mero et al. 2020). While companies consider customer satisfaction to be their primary goal, marketing automation initiatives seldom take this sufficiently into consideration. A lack of customer-centricity in marketing automation is evident in definitions as in frameworks describing the process. Indeed, marketing automation has been described as "…the IT-supported execution of recurring marketing tasks with the goal of increasing the efficiency of marketing processes and the effectiveness of marketing decisions" (Little 2001). In more recent definitions, customer-centricity is, at least, mentioned. Murphy (2018) describes a "company-centric automation of repetitive tasks to find efficiencies" (Murphy 2018), and Järvinen and Taiminen speak of the "customer-centric delivery of content to users based on specific rules" (2016). When marketing managers were consulted, a similar picture emerged. According to Adestra's Marketer vs. Machine industry report, "marketers are found most frequently to see benefits of automation in saving time (74%), increased customer engagement (68%), more timely communications (58%), and increased opportunities, including up-selling (58%)" (Adestra 2015).

A well-established framework for describing and analyzing marketing automation processes is offered by Heimbach et al. and depicted in Fig. 1. It describes the main elements of the process in a consistent way. However, the framework uses triggers to define known automated processes and omits any need to identify cases that generate added value for customers or cases where customers initially accept automation (Heimbach et al. 2015; Vargo and Lusch 2008). In terms of customer-centricity and apart from the mentioned element "control performance", the framework does not emphasize the need to generate new data and insights from customer responses, the implementation of feedback, or the learning cycles depicted by the back arrows in Fig. 1 (Effendi et al. 2016).

Therefore, our work is structured as follows:

1. A description of the general customer-centric trigger identification process.
2. The creation of a foundation for customer-centric automation at Houzy.
3. The identification of service gaps for the development of service-design concepts.

One concept that seeks to identify individual customer triggers and react to them in a customer-centric way is trigger-based marketing. Common reasons why companies rely on trigger-based marketing are (Hannich and Hüttermann 2020):

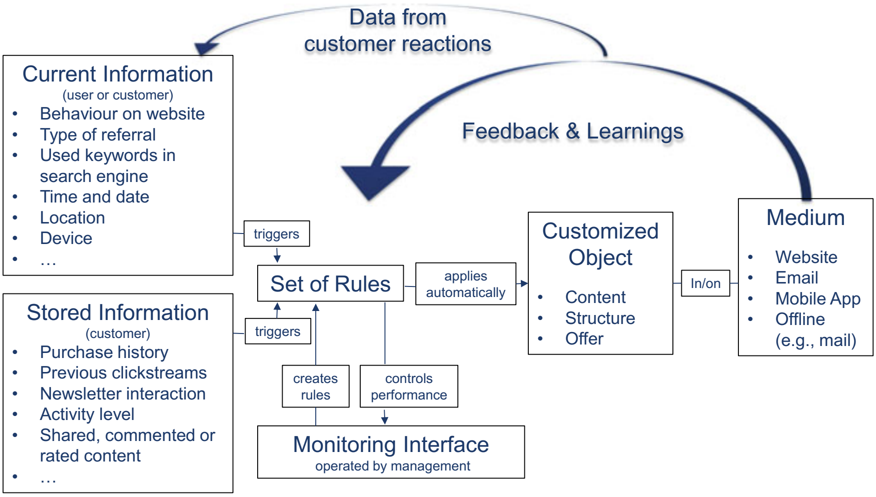


Fig. 1 Marketing automation process; Adapted from: Heimbach et al. (2015)

- to identify incidents and specific moments when marketing automation creates added value for customers,
- to create relevance and wow-effects for customers with personalization, to perfect timing and channel selection, and
- to improve marketing efficiency (compared to mass marketing) and offer better leveraging of existing customer value potential and data.

The concept of trigger-based marketing and an approach for identifying customer triggers are discussed in the following section.

2.1 Trigger Identification by Analyzing Customer Life Cycles

Trigger-based marketing is an essential tool for modern companies as it becomes increasingly important to reach the right customer with the right message at the right time. To achieve this requires a deeper understanding of those moments in time when customer needs alter. Trigger-based marketing follows a life-cycle approach based on recognizing that certain events in people's lives trigger changes in their needs and purchasing behavior (Dyche and O'Brien 2002).

Trigger-based marketing aims to capitalize on four dimensions (Hannich and Hüttermann 2020): (1) the customer, (2) the moment in time, (3) the channel, and (4) the message or content. Consequently, companies that are successful at reaching customers with personalized messages at exactly the right time can significantly improve key performance indicators such as perceived interaction quality or conversion rates. In many cases, but not always, this process is automated and employs an

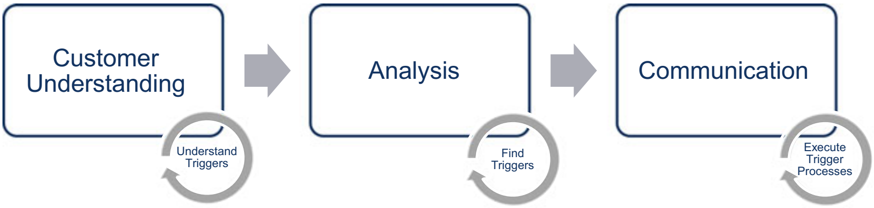


Fig. 2 Trigger-based marketing process (Hannich and Hüttermann 2020)

omnichannel approach. (Belz 2016; Cebulsky and Günther 2015; Dyche and O'Brien 2002; SDV 2017). While the right moment is dependent on the individual, the principal triggers seldom are. From similar preferences concerning the right content, and the channel microsegments can be formed and used in automated processes. The process of trigger-based marketing can be summarized in three steps, as Fig. 2 shows below (Hannich and Hüttermann 2020).

In this paper, the focus is on the initial step, and to ensure that trigger-based marketing is successful, it is crucial to identify the relevant customer life events and the questions, needs, and issues related to them. The following section outlines a five trigger sources approach for identifying these events systematically and in a customer-centric way.

2.2 *The Five Trigger Sources Approach*

The five trigger sources approach can help identify triggers, but the question arises as to which triggers exist and which of these represent events that change customer needs (creating or eliminating them) and behavior.

Research into significant life events begins by looking at customer lives in terms of phase of life models, which are still prevalent in socio-demographic segmentation (Heinonen et al. 2010). Segments such as DINKs, families with small children, or retired people are all derived from this approach, and it is clear that they have differing needs in many respects. There are also obvious events that mark the transition from one phase to another, such as the birth of a child or retirement. Such an event is very relevant to Houzy. The decision to buy a house or apartment as a significant event in the life of many individuals, and often the single biggest investment, triggering a host of other needs and actions. This approach enables to search for additional life cycle models and systematically identify triggers relevant to customers.

The customer relationship life cycle represents a general explanatory model of an ideal time course of a customer relationship developed a similar way to the product life cycle (PLC) (Strauss 2011). When identifying the right triggers, it is necessary to understand the customer life cycle from the entry touchpoint up to the exit point (Lambe 2008). Customers are the core of any business, so a company can only succeed if it effectively manages customer relationships (Nguyen et al. 2007). The customer relationship life cycle helps identify triggers such as a first purchase or complaint.

The PLC can be an important source of customer triggers, too, such as the expiry of contracts or guarantees that can prompt additional service needs or other requirements. Additional to the PLC changes of the macro environment can also be triggers that alter customer needs and behavior. A good way to identify these triggers from changes in companies' macro environment is going along the PESTEL model. The PESTEL model lists five fundamental areas, namely the political, economic, social, technical, ecological, and legal (Yüksel 2012). A bank, for example, can analyze which customers are affected by changes in interest rates and initiate meetings with these clients. In the Houzy case, changes in real-estate taxation rates are especially relevant to landlords.

A final source of triggers is the everyday transaction (Hannich and Hüttermann 2020). Triggers based on transactions or single process customer journeys are used frequently in e-commerce settings. In many cases, these are automated reactions to customer behavior, such as orders (and order confirmation) or completion of a transaction triggering feedback requests, or abandoned online shopping carts acting as triggers for retargeting. Another variation is threshold triggers, such as when customer loyalty programs offer special customer discounts or extra services when a milestone is reached. In the following section, the methodology and findings will be described in detail. Afterwards its implications for management are discussed and in the end this paper will be concluded by outlining its limitations and potential for future research.

3 Methodology

The research into trigger-based marketing aims to describe a general, customer-centric trigger identification process and create a foundation for customer-centric automation. Based on this, an effort was made to identify service gaps and derive service-design ideas for Houzy.

To understand customer triggers better, the authors worked in close cooperation with different companies. Between 2017 and 2020, more than 300 managers in continuing education or on Master's programs attended workshops based around their employers or other selected companies. A number of research projects with companies, including the Houzy study, utilized the five sources approach as a guideline for conducting customer interviews and for targeted data analysis. This approach has proven to be quite effective in helping companies identify customer triggers and become more customer-centric.

In this study, user data (mainly observational data from Google Analytics, search histories and behavioral data from Houzy apps based on Hotjar analytics) was analyzed to search systematically for customers' triggers. The subsequent interviews using the five trigger sources with Houzy employees, business partners, and—most importantly—customers then revealed additional triggers.

As an additional step, a gap analysis was conducted to compare the identified triggers with the existing services of Houzy. A gap analysis is generally used to identify missing information by using a conceptual, technical, and organizational base to provide a quick overview of the status (Jennings 2000). However, this methodology does not prescribe a design since it focuses on the basic information needed and identifies the elements of the existing set (Jennings 2000).

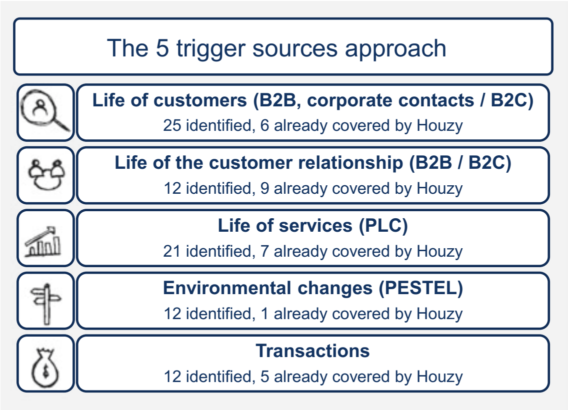
A workshop with Houzy employees and partners was conducted for the trigger gap analysis, where the five trigger source approach was introduced, and participants asked to identify any triggers. In the same week, the five sources approach was again used when holding in-depth interviews with Houzy customers, who were asked about triggers in their lives relating to their properties. Following the interviews and workshop, a list was made of all the triggers mentioned. To identify which triggers were already covered Houzy services were analyzed in a workshop setting using external and internal information with the help of their marketing managers. Through this gap analysis, it was possible to generate new service design ideas.

The design thinking approach for creating service design ideas provides a holistic and customer-centric solution to complex issues using a wide variety of methods based on an iterative innovation process (Eppler and Hoffmann 2012; Uebernickel et al. 2015). In doing so, innovation is driven by a thorough understanding of customer needs and wishes, including their likes and dislikes about the product itself and its manufacture, packaging, marketing, sales, and support (Brown 2008). The gap analysis used here can deliver these insights needed to start design thinking projects.

4 Results and Discussion

It starts by outlining the five trigger sources approach results, which are summarized in Fig. 3, after which the gap analysis findings are described. From the customer life cycle, it was managed to identify 25 triggers. Then every trigger (and the connected

Fig. 3 The five trigger sources approach and Houzy project findings



needs) were compared with the existing services offered by Houzy to determine how many of the triggers found were already being addressed. Where triggers and services match, Houzy may find a way to increase interaction in one of two ways—first, by making it as easy as possible for customers to find the right service when the need arises and, second, by implementing automated processes such as personalized emails or targeted pop-ups.

The life cycle of the customer: When buying and selling customers wish checklists of the most important issues, other triggers include marriage and divorce and Houzy may also require assistance concerning inheritance. Another issue is managing small properties, with customers wanting to manage all their portfolios through Houzy. The most significant gap identified was a proper record of repairs and renovations. Houzy customers like to know the tradesmen employed for a particular job even if it happened many years ago.

The life cycle of the customer relationship: Houzy customers require legal support and advice during both house construction and maintenance. They would also like to record insurance details and be reminded of other relevant issues. Another wish among Houzy customers is car parking and the ability to track vehicle depreciation over time.

The life cycle of the product/service (PLC): The PLC for Houzy customers comprises, garden maintenance and the existing online plant information and care service. Customers would like an improved version of the plant manager app and a timeline in their Houzy account, which draws their attention to house maintenance requirements. One missing service that was found: Houzy customers need a legal advice service (by phone or in-person) covering all aspects of property ownership.

Environmental changes (PESTEL): Blog posts regarding new technologies, materials, and building standards were requested, as well as details of any changes in energy-saving regulations. Customers also wish to be informed about air conditioning systems for hot weather and about what is happening in their immediate neighborhoods, such as town planning changes.

Transactions: Houzy customers want a clear idea of how much certain building upgrades would cost. A room calculator could help here. For example, it could show Houzy customers how much a new bathroom would cost based on its size and proposed fittings. Another issue concerns information regarding e-mobility vehicle provision, which could be delivered in the form of a blog post or newsletter. Since Houzy customers like to have a general overview, a location summary detailing local amenities would also be very helpful.

Figure 4 depicts the gaps between the triggers identified and the triggers already covered by Houzy services. Once identified, this led to a number of ideas for new services, all beginning with a clear customer need.

The issue of e-mobility leads, in turn, to several other needs concerning the buildings themselves, such as solar cells or vehicle charging stations. By answering these questions and offering services based around e-mobility, Houzy has the opportunity to create added value for its customers.

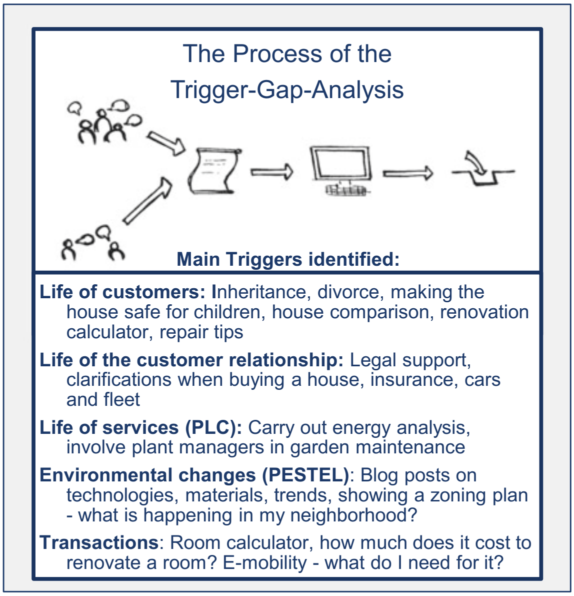


Fig. 4 The trigger gap analysis process

5 Conclusion and Brief Recommendations

It was found that the five trigger sources approach worked well for Houzy and should for any small and medium enterprise (SME) with limited data and resources, since it serves as a quick and straightforward way to understand customer needs and the events that trigger them. In addition the approach offers a way to become more customer-centric. However, it works best when used as a guideline for customer interviews and customer data analysis. It is also useful because it identifies which triggers could be served by automated processes. Through the gap analysis, it is possible to create new service design ideas as shown in the Houzy case.

The identified limitations were that this explorative design needs to be tested further especially in other companies and industries. Additionally explorative data analytics methods could be used in cases where there is more data available. Further use of the approach might even reveal other principal trigger-sources that should be included. Despite this, the five trigger sources approach is a sound basis for identifying triggers, as the Houzy case and the numerous management workshops have demonstrated.

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The Role of AI Platforms for the Servitization of Manufacturing Companies

Cosimo Barbieri, Mario Rapaccini, Federico Adrodegari, Nicola Saccani, and Giulia Baccarin

Abstract The paper sheds light on the interplay between the adoption of digital platforms for Artificial Intelligence (AI) and the servitization of manufacturing companies. Through the analysis of three cases that have been deployed with a commercial AI platform to provide advanced services such as health monitoring and predictive maintenance to industrial equipment and infrastructures, we conjecture about how manufacturing companies could benefit from the adoption of this kind of platform in their servitization journey.

Keywords Servitization · AI · Digital platform

1 Introduction

The success stories of companies such as Uber or Airbnb are notable examples of the large diffusion of platform-based businesses, in which the value is created and captured by first enabling demand matching, and then facilitating transactions between customers and suppliers. These businesses are always characterized by the

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presence of an internet-based infrastructure (i.e. the digital multi-sided platform) that, as defined by the literature (Ardolino et al. 2020), enables the interactions among two or more different groups of users (i.e. the different sides of the platform,) through a virtual environment (i.e. an app, a website, etc.). Platform-enabled business does not only concern consumer sectors, where marketplace like Amazon and Alibaba have taken the lead over "brick and mortar" competitors, but also B2B settings in which other categories of industrial platforms are emerging. For instance, Internet-of-Things (IoT) technologies and their applications are experiencing great diffusion thanks to solutions such as Thingworx by PTC or Mindsphere by Siemens. These platforms are used to connect equipment, collect, store, organize and analyze field data (on the Cloud), generate insights, and enable the provision of data-driven, proactive services. The spreading of the mentioned platforms in the form of Platform as a Service (PaaS) can facilitate to a large extent the servitization of manufacturing firms: using an industrial internet platform, the equipment manufacturer can focus on the provision of intermediate and advanced services such as condition monitoring, remote control, preventive maintenance, and customer support, rather than just selling their products and forgetting the needs of professional customers along the product lifecycle. The trend to develop advanced services through the use of digital technologies has been named "digital servitization"(Paschou et al. 2020). Despite its growing relevance, how digital servitization can be implemented in practice remains rather unexplored. In particular, little work has specifically focused on how companies can manage data and information gathered from the field, to develop advanced services. In addition to IoT and industrial internet platform, also Artificial Intelligence (AI) seems to fit naturally with the servitization strategy (Iansiti and Lakhani 2020) and have proven to be useful in this business setting (Paschou et al. 2018). Despite this popularity, it is claimed that most initiatives developing AI do either completely fail or not reach the expected goals: companies find hard "augmenting" the human skills with AI models since there is a paucity of professional competencies such as business analysts and data scientists (Xing et al. 2015). A great help could come from the advent of a new category of digital platforms, namely AI platforms, that are specifically designed to facilitate the development of AI applications (Porter and Heppelmann 2015). Big vendors such as SAS, IBM (Watson), and Microsoft (Azure) are claiming that their solutions can speed up to a great extent the servitization journey of a manufacturing company since it can use AI platforms to develop and deploy diagnostic models that can be trained (and retrained) on the huge amount of data that are so far collected by its installed base. AI platforms include also features that automate—to a large extent—the typical tasks requested in digital servitization, such as data collection, cleansing, normalization, ingestion, selection of the most appropriate algorithms, verification, training, validation, etc. These platforms are usually conceived to support the deployment of the AI models along their lifecycle and with features that help the construction and distribution to the equipment users (i.e. operators and maintenance crew) of dashboards. In this sense, these platforms can be of great help in increasing the diffusion of AI applications and the development of data-driven models and advanced services, in the servitization domain.

Based on the above considerations and since academic research on the role of the AI for servitization is in its infancy, it is of great interest to answer the following research question (RQ): how these platforms could support the servitization of manufacturing companies?

Starting from these gaps, through the investigation of AI applications that have been developed with AI platforms, this paper aims at shedding light on the potential contribution of these platforms to the servitization of manufacturing companies. In line with these premises, the rest of the paper is organized as follows: Sect. 2 presents a short background on AI platforms and servitization concepts, Sect. 3 illustrates the research strategy, Sect. 4 presents the selected cases, and Sect. 5 draws some considerations from the cross-case analysis. The paper ends with some concluding remarks in Sect. 5.

2 Background

2.1 AI Platforms

According to the well-known Magic Quadrant of Gartner corporation Den Hamer et al. 2020), an AI platform needs features supporting at least the following processes: a) collecting and preparing data; b) building models; c) deploying those models along the lifecycle (through dashboards). These features, according to the CRISP-DM method (Wirth and Hipp 2000), are characteristic of a data mining project, since they are means for the data understanding and preparation, modeling, evaluation, and deployment phases. Other premium features relate to the level of automation of the different coding tasks (e.g. simple/low efforts/one-click features, etc.), and the ease-of-use. The market leaders in this domain (e.g. SAS, RapidMiner, KNIME, etc.) have different AI algorithms for classification, regression, prediction, clustering, as well as functionalities for automating building and testing models.

2.2 Servitization

The term servitization refers to the shift of manufacturers from selling products to offering product-service solutions, where more and more services are tightly coupled to the product to increase the value potential of this new offering (Baines et al. 2007). The interest in this topic is growing among academia, business, and government because it is thought that a move towards servitization is a mean to create additional value-adding capabilities for traditional manufacturers(Baines et al. 2009). It is considered a strategic alternative to product innovation (Carlborg et al. 2013) and standardization (Baines al. 2009), a way to meet increasingly more heterogeneous needs while exploiting scale economies from high-volume production (Hart 1995;

Baines and Lightfoot 2014). This transformation is having a deep impact on the business of the manufacturing sector. Nowadays, the application of digital technologies can further advance servitization, by enabling more and more sophistication of the service offerings (Carlborg et al. 2013) and the development of new service-oriented business models (Brax 2005). Notable cases have already shown this potential and the rationale for such a shift, and also smaller companies are increasingly interested in the adoption of digital platforms to collect and elaborate field data from their installed base, to include advanced services like predictive maintenance or pay-per-use models (Ardolino et al. 2018; Fu et al. 2018). This trend has been named "digital servitization", that is "the development of advanced services and/or the improvement of existing ones through the use of digital technologies by enabling new digital business models, finding ways of co-creating value, generating knowledge from data, and improving a firm's operational performance" (Paschou et al. 2020).

3 Research Strategy

We use case-based research (Yin 2015) since there is little knowledge on this topic, and this research is explorative and early-stage. In particular, we evaluate the impact of AI platforms application in the development of advanced services in different cases, manufacturing companies belonging to different sectors.

First, the selection of the AI platform based on the requirements previously explained, in relation to the -known Magic Quadrant of Gartner corporation (Den Hamer et al. 2020). We selected an AI platform that has been developed by a niche software company and that is currently used by a network of professionals, consultants, and data scientists. We had the opportunity to receive a demo of one AI/ML platform and to enter in touch with the platform provider that also showed a clear interest to be involved in this research.

Then, for the selection of the use cases, with a retrospective approach, semi-structured interviews have been conducted—to provide deeper insights (Barriball and While 1994)—with the platform provider to investigate representative use-case, that have been selected based on the following criteria: (a) the application should have been developed with a clear business purpose (e.g. reducing costs of maintenance, predict performance/ degradation, reduce downtime, etc.); (b) its triggers should have been clearly identified (for instance, partly funded by public R&D frameworks, a change in regulations, a requirement of the customer's customer, etc.); (c) the process from its beginning to the deployment of (even preliminary) results (e.g. a dashboard to the end user) should have been completed; (d) the contexts should have been mostly related to industrial equipment and productive plants (B2B settings) to be maintained and supported along their life cycle; the OEM as well as the owner/operator of the equipment should have either been involved in, or have triggered or commissioned the project; (e) any cultural, organisational and technical challenges faced during the project should have been reported, in order to shed lights on how the corresponding obstacles had been overcome, being these obstacles related to the different stages (data preparation, model building, etc.).

In the end, the results of the findings have been shared and discussed between the authors to highlights the most relevant patterns and draw conclusions.

4 Cases Description

The cases have been selected based on the criteria stated in the previous section, among the customers that have developed advanced services thanks to the AI platform (i.e. Rebecca AI) of the platform provider. This platform has been designed to enable end-to-end management of AI solutions, from data collection (through databases or IoT) to machine learning model development, implementation, validation, and deployment in the production environment (see Table 1). It consists of three main modules ("apps"), namely (a) Builder, (b) Innest, and (c) Frame. (a) Rebecca Builder allows the user to build and train intelligence efficiently and seamlessly, without the need to code. This is composed of three further submodules, respectively "Dataset", "Flows" and "Model". In the "Dataset" workspace, data can be visualized and compared in predefined visualization tools that enable interactive data cleaning operations. Filters can be applied to the raw data to obtain the most suited dataset for model training and evaluation. In the "Flows" workspace, several machine learning algorithms can be implemented to solve supervised (regression and classification) and unsupervised (dimensionality reduction and clustering) tasks, by explicitly selecting their hyperparameters or by adopting a grid-search approach. In the "Model" workspace, the model performance can be evaluated on a test dataset through dedicated visualization tools and performance metrics such as the mean absolute squared error (MAPE) and the mean squared error (MSE) for regression, or precision and recall for classification. The best performing model can be published in the (b) Rebecca Innest module where it becomes available to be deployed in the production environment. Models published in Innest can be connected to the data streaming in real-time through Rebecca IoT, and the model prediction visualized in (c) Rebecca Frame module. Standard visualization can be enriched with tailored dashboards and data experience functionalities, and it is possible to set customized alerts based on the model output.

Table 1 Rebecca modules and sub-modules in relation to CRISP-DM method phases

<table>
<tr><th>Rebecca modules</th><th>Rebecca sumodules</th><th>Corresponding phases of CRISP-DM method</th></tr>
<tr><td rowspan="3">Builder</td><td>Dataset</td><td>Data preparation</td></tr>
<tr><td>Flows</td><td>Modeling</td></tr>
<tr><td>Model</td><td>Evaluation</td></tr>
<tr><td>Innest</td><td>–</td><td rowspan="2">Deployment</td></tr>
<tr><td>Frame</td><td>–</td></tr>
</table>

Below we briefly present three cases where AI has been applied to support service operations (in particular for predictive maintenance) through the Rebecca platform earlier described.

4.1 Case A

Case A is a public company responsible for the management, maintenance, and administration of the railway infrastructure in Italy. One of the main issues related to this task is to constantly monitor the railway health state and predict the likelihood of faults to implement predictive maintenance and improve safety. The solution, prototyped in Rebecca Builder, made use of real-time data related to different parameters representing railway geometry and collected by an IoT acquisition system. By incorporating information about the warnings generated by operators trained in detecting anomalies, a fault prediction algorithm based on an artificial neural network and XGBoost (a Python module) was implemented and trained for each parameter, allowing to predict the generation of a warning 14 days in advance a possible fault. Through Rebecca Innest, the models were deployed for several lines, and Rebecca Frame was set to send a notification to the maintenance manager whenever the algorithm detects an anomaly in the railway.

4.2 Case B

Case B is one of the leading companies in Europe in the supply, production, and sale of electric power and gas, in the energy and environmental services, and the exploration and production of hydrocarbons. B needed to implement a system to monitor the health status of several assets of an energy production plant (such as gas and steam turbines, heat recovery steam generators, auxiliaries, heat exchangers, condensers, and cooling towers) and to act proactively to reduce management costs, improve plant reliability and optimize the maintenance operations. A monitoring system installed on the plants was responsible for data collection. For each asset, Rebecca Builder was first used to perform data cleaning and then to implement a regression model to predict the output (such as output temperature in the example of the gas turbine modeling) through a feed-forward neural network algorithm. The grid search functionality was used to achieve the best model hyperparameter, and model validation was performed by looking at MAPE metric and control charts, such as the residual and the cumulative sum control charts (CUSUM). The implemented models achieved a precision of over 95% and an MPE $< 2\%$. Through the data experience of Rebecca Frame, the output of the 41 models representing the whole plant could be monitored through dedicated alarms and control charts representing in real-time the difference between the real and predicted output for each asset, thus allowing the operator to spot anomalous system behavior due to possible faults or degradations.

4.3 Case C

Case C is a global leading company for low carbon emission power generation and distribution. C needed to implement predictive maintenance for a wind farm consisting of 18 wind turbines. Using Rebecca Builder, AI models have been built based on 5-years historical monitoring data and maintenance events. Data preprocessing on the dataset workspace showed that 40% of maintenance hours were spent to resolve four machine failure types, thus helping in identifying the most critical components (i.e. generator, slip-ring, and bearing). Model training was carried out with a feed-forward neural network with one hidden layer and the optimal number of neurons was selected through the grid search functionality, by setting the selection criteria based on the lowest MSE. The resulting performance control models were deployed in Rebecca Frame and used to describe the degradation of each component, thus anticipating failures. Control charts were visualized to plot the error between real output value and predict the output value for each component. As an example, the degradation of the slip-ring was characterized by an increasing trend of residuals, up to the time of replacement, thus demonstrating the capability of this model to detect anomalies.

5 Discussion

The description of the three cases focused on the application of AI to the understanding of failure mechanisms and predictions to anticipate maintenance activities. The cases, therefore, allow discussing the purposeful adoption of AI platforms to develop advanced services. All the three companies analyzed provide, through their equipment, services to customers. Case A is in charge of maintaining the railway infrastructure, Case B and C produce energy that is then sold to the customer. The role of AI algorithms in the three cases can be viewed in the light of understanding the functions of the above-mentioned technologies: they provide internal (to the company) and external (to the customer) benefits in a servitization path. In particular, the case applications aim at increasing system availability and safety (from an external viewpoint) and improving service efficiency (from an internal viewpoint). These results are reached by monitoring the systems and component status, understanding and anticipating potential failure, this way improving maintenance planning capabilities on one hand, and reducing maintenance cost and increasing its effectiveness on the other. The case applications are primarily focused on the detection of anomalies and unwanted behaviors in the usage of the equipment, starting from usage data.

6 Concluding Remarks

Among the digital technologies that are increasingly changing the competitive landscape, AI is becoming the new operational foundation of business, defining how the company drives the execution of tasks (Iansiti and Lakhani 2020). It is not surprising therefore that great interest has emerged both in the managerial and academic communities to explore how AI, coupled with more affordable digital technologies, can enable the ongoing strategic transformations in the manufacturing industries, such as servitization. By analyzing three application cases of AI in the domain of product health status assessment and predictive maintenance based on an AI platform, we have investigated the linkages between the adoption of AI digital platform and servitization, therefore advancing knowledge on this topic. In particular, we understand from the cases that companies through the adoption of AI platform achieve external or internal benefits (such as the increase in systems availability or improving service efficiency) through the purposeful exploitation of the functions related to AI platforms.

Moreover, by illustrating the application of an AI platform to three cases, this paper discusses the functions these platforms may have in enabling servitization and what motivates or obstacles their utilization in practice. We conclude that AI platforms can be a fundamental factor in this process since as described above, they enable functions (e.g. data collection, cleansing, normalization, ingestion, selection of the most appropriate algorithms, verification, training, validation, and visualization) by facilitating the manufacturing companies dealing with the top challenges of AI adoption (Goasdaff 2019), such as the need for highly skilled professionals.

Thus, this paper also has implications for managers since they can use the results illustrated to more consciously evaluate the adoption of AI platforms as an enabler of the servitization transformation in their particular context.

Anyway, the research comes with some limitations, mainly related to the fact that our results rely on the application of a specific AI platform, limiting the extent to which the results can be generalized. Future research should thus analyze how different AI platforms in different contexts can be used by companies to servitize their business. Also, more use-cases and a more structured analysis of the results should be considered in order to answer more comprehensively to the research question.

This research appears as one of the first attempts to address the practical implications of AI platforms in servitization, and we hope that this research will inspire other researchers to contribute within this field which we are convinced will significantly advantage both scholars and practitioners.

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A Cognitive Approach to Manage the Complexity of Digital Twin Systems

Jinzhi Lu, Xiaochen Zheng, Lukas Schweiger, and Dimitris Kiritsis

Abstract During the entire lifecycle of system development, various digital twins could be developed to support different systems engineering activities, such as verification and validation. The increasing complexity of digital twins leads to a challenge to manage the consistency, changes and traceability across the entire lifecycle. In this paper, a semantics modeling approach is provided to formalize the digital twins using systems thinking. The semantic models represent the information of each digital twin and the interrelationships among them. Using the semantic models, system developers are enabled to promote the cognitive capabilities of digital twins, which in return will provide more potentials for decision-makings based on digital twins. Finally, the feasibility of the proposed approach is evaluated through a case study in the Swiss Innovation Project IMPURSE.

Keywords Digital twins · Complexity management · Semantics modeling · Cognitive twin

1 Introduction

Since the system complexity is increasing, different digital twins are provided by system developers in order to describe different architectural views of stakeholders and to verify their concerns (Tao et al. 2017). Such amount of digital twins bring new challenges to the system developers: (1) Requirements (why do we need to build them?); (2) Concepts and solutions (How to build them?); (3) Decision-makings (How to improve the cognitive capabilities of each digital twin in order to make them support decision-makings better); (4) Complexity management (How to manage their

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complexity?). Previous research (Gharaei et al. 2020) has investigated the application of systems engineering approach in identifying the requirements of digital twins development. Various modeling techniques are available to support creating and modeling digital twin models, such as Modelica (Scaglioni and Ferretti 2018). These models are widely used to support decision-makings aiming to promote efficiency of system development. However, a large number of digital models make model users difficult to understand how they support system development when managing the complexity of digital twins.

In this paper, we focus on the complexity management of digital twins and expect to find a solution to promote the cognitive capabilities of digital twins in order to support decision-makings. First, during the entire lifecycle of system development, an approach is expected to identify all the entities of digital twins. Then, the complexity of digital twins requires to be formalized as the basic ontology concepts for its management. Finally, these ontology concepts can construct knowledge graph models for management activities during system development.

In order to manage the complexity of digital twins, a semantics modeling framework is proposed to empower the development of semantics models for digital twins based on systems thinking. Real systems and system lifecycle are considered to provide a scope for semantics modeling. Through systems thinking, digital twins and their interrelationships can be identified. Based on the concepts created by systems thinking, semantics models could be developed to describe the information of digital twins and their interrelationships. In order to evaluate the proposed approach, a case study from Swiss Innovation Project IMPURSE is provided to build the semantics models through systems thinking. Through the semantics models, the proposed approach identify the information for digital twins and their interrelationships and manage their complexity.

The rest of the paper is organized as follows. We discuss the related work and propose the research methodology in Sect. 2. In Sect. 3, the semantic modeling approach based on systems engineering is proposed. In Sect. 4, a case study from Swiss Innovation Project IMPULSE evaluates the availability of our approach. Finally, we offer our conclusions in Sect. 5.

2 Related Work

Digital twins are considered as one of the key enabling technologies in the Industry 4.0 era. It is empowered by various existing technologies such as 3D modeling, system simulation, digital prototyping etc. (Boschert and Rosen 2016; El Saddik 2018). In recent years digital twins and its enabling technologies have been evolving explosively (Tao et al. 2017). With the wide application of digital twins in different domains, heterogeneous models and architectures of digital twins have been developed due to the lack of unified design and development platforms and tools (Qi et al. 2019). During the development of a complex system, various digital twin models might be involved which contain different specifications, protocols and standards.

Semantics technology and systems engineering are considered as promising solutions to manage the complexity of heterogeneous systems (Cho et al. 2019). In a previous study (Lu et al. 2020), the concept of Cognitive Twins was proposed by integrating semantics technologies and systems engineering with traditional digital twin concept to manage heterogeneous models from different domains. Although the idea of cognitive twins is promising, many challenges need to be addressed to fully realize its vision. One of the challenges is the increasing complexity with more digital twin models involved.

Studies specifically focused on the complexity management of digital twin models are quite rare. However, in some relevant domains, such as manufacturing, complexity management has been attracting many research efforts. For example, the authors of (Efthymiou et al. 2012) identified and synthesized the research done in the manufacturing systems' complexity domain; and investigated the approaches based on a theoretical analytical framework that provide a quantitative analysis of manufacturing systems complexity. Efthymiou et al. (2014) studied the fluctuation of critical manufacturing performance indicators to assess the complexity of a manufacturing system. To mitigate the ever-increasing complexity of large-scale engineered systems, systems thinking (ST) has been utilized in many studies (Frank 2012; Greene and Papalambros 2016). Systems thinking supports to analyze how a system interacts with the other components of the larger system of which it is a part (Kenett et al. 2018). Kasser and Mackley (2008) proposed an approach to apply systems thinking and align it with systems engineering. They identified a set of perspectives and defined a systems thinking perspective set of views for a system. A case study was performed in their study to apply the set of perspectives to the Royal Air Force Battle of Britain Air Defence System which proved that the set of perspectives could facilitate the modeling the complex system.

Previous studies have verified the effectiveness of using semantics technologies and systems thinking to manage the complexity issues of complex systems. Therefore, in this paper, we propose a cognitive approach enabled by semantics modelling to manage the complexity of digital twin systems following the systems thinking methodology.

3 Systems Thinking Supports Cognitive Semantics Modeling

In this chapter, we first introduce the overview of the whole approach. Then we explain how systems thinking support semantics modeling in order to manage the complexity of digital twins.

3.1 Overview

As shown in Fig. 1, systems thinking is proposed as a core technique to support semantics modelings for complexity management of digital twins. Systems and system lifecycle are considered as two inputs of systems thinking in order to define scope for semantics modeling. Then semantics models are developed in order to identify digital twins' information and to describe the interrelationships between them.

– **Real systems** refers to the target products which the digital twins are developed for. The real systems provide data for digital twin development and digital twins provide information to the real systems.
– **System lifecycle** refers to the entire development processes of the real system. It provides the scope for digital twin development. Also, digital twins provide decision-makings for system lifecycle.

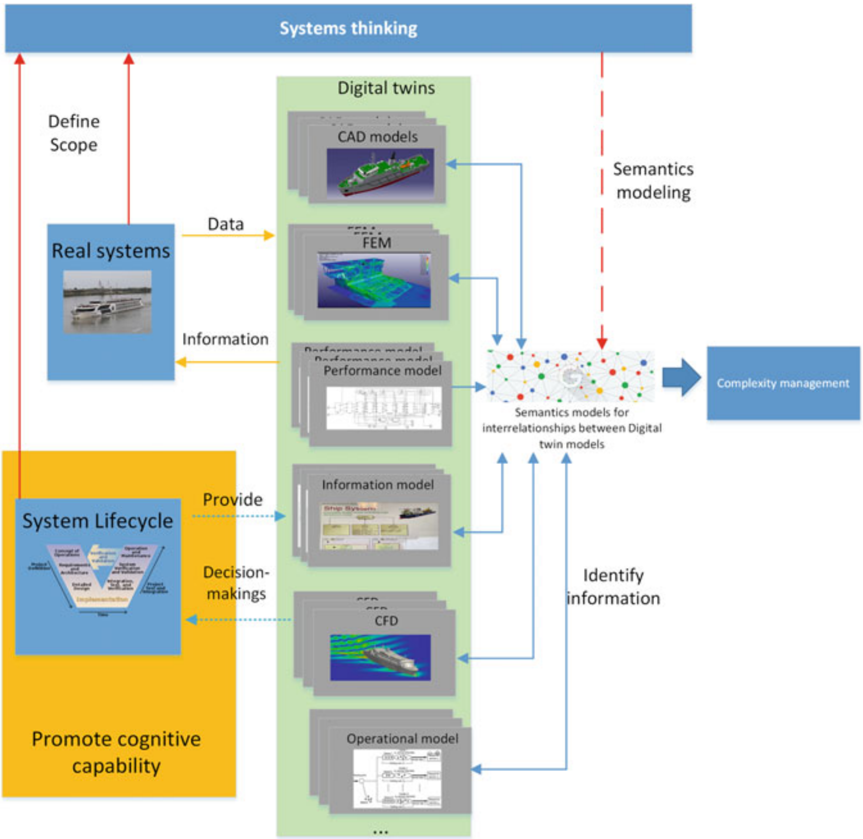

Fig. 1 Cognitive semantics modeling for complexity management

– **System thinking** refers to one approach to identify digital twin models in the scope developed based on real systems and system lifecycle.
– **Semantics models** refers to one virtual asset to describe information of digital twins and their interrelationships.
– **Cognitive capabilities** refers to the set of mental abilities or processes that are part of nearly every decision-making action while system developers are awake during decision gates. They has to do with how system developers understands the system or system development and decision-makings in it.

3.2 Systems Thinking and Semantics Modeling

Systems thinking is an approach for understanding a system nature by identifying the entities and their interactions within the system boundary (Haskins 2014). Obtaining inputs from real systems and system lifecycle, several steps are required to implement in order to construct systematic concepts related to digital twins and implement semantics modeling:

1. **Identify system scope for semantics modeling**: based on real system and system development, system boundary for digital twins are identified.
2. **Define use cases**: scenario awareness of each digital twin is implemented. Considering the real system as target system, during each work task in the system development process, architectural views (ISO/IEC 2007) of the real systems are identified. Then the scenario including such architectural views are captured.
3. **Identify Digital twins and their key information**: in each scenario, required digital twins are identified with their key information which is considered to be important to system developers.
4. **Identify interrelationships between digital twins**: in each scenario or across scenarios the interrelationships between digital twins are identified, such as *copy*, *reference*.
5. **Implement semantics modeling**: based on the digital twin concepts and their interrelationships identified from the previous step, semantics models can be developed.
6. **Evaluation of ontology logicality and completeness of semantics models**: to evaluate the semantics models, we verify them for completeness and logicality using SPARQL and SWRL query (Lu et al. 2020).
7. **Develop a tool prototype for complexity management of digital twins**: development of a tool prototypes based on proposed semantics models.
8. **Prototype evaluation**: after a thorough evaluation of the complexity management prototype, a new round of semantics modeling is started.

3.3 Semantics Modeling for Complexity Management

Based on the complexity definition in Goldstein (2001), we define the complexity of digital twins in system lifecycle as follow:

Definition 1 It is a characteristic making digital twins difficult to support decision-makings of system development, in particular, in terms of understanding all relevant interactions among digital twins, system lifecycle and real systems in the defined boundary.

The complexity includes two types (Weaver 1991; Shank 2013): (1) disorganized complexity, referring to a system with thousands of disconnected parts, operating in random, whose interactions are chaotic and unpredictable. (2) organized complexity, referring to a system wherein the interactions between the myriad parts are anything but accidental: these functions allow the overall entity to interact with other entities in a wholly intentional basis.

In this paper, we expect the complexity management of digital twins enables to transfer the entire digital twins in the system lifecycle from disorganised complexity to organized complexity in order to promote the cognitive capabilities of digital twins. Thus, we define several types of interrelationships between digital twins in order to describe the complexity more clear. These interrelationship types are defined based on previous research (Lu et al. 2018):

- **Reference**—refers to one interaction to track the versions of the related digital twins.
- **Control**—refers to one interaction that digital twin can control another.
- **Co-simulation**—refers to one interaction that real-time data exchange between digital twins and physical systems.
- **Model transform**—refers to one interaction that one digital twins is generated from another by model transformation.
- **Trace**—describes that traceability links of data between different digital twins.
- **Copy**—describes that one digital twin is copied from another.
- **Refine**—describes that one digital twin is refined by another.
- **Verify**—describes that one digital twin can verify another.
- **Satisfy**—describes that one digital twin can satisfy another.

Through these interrelationship definitions, digital twins can be organized as one whole system with organized complexity. Using developed knowledge management systems based on the semantics models, all the digital twins can be managed.

4 Case Study

In order to verify our proposed approach, we adopt a shiptec scenario to build ontology in order to manage the complexity of digital twins related to the Shiptec scenario. Shiptec is a shipyard located in Luzern, Switzerland. They design, develop and build

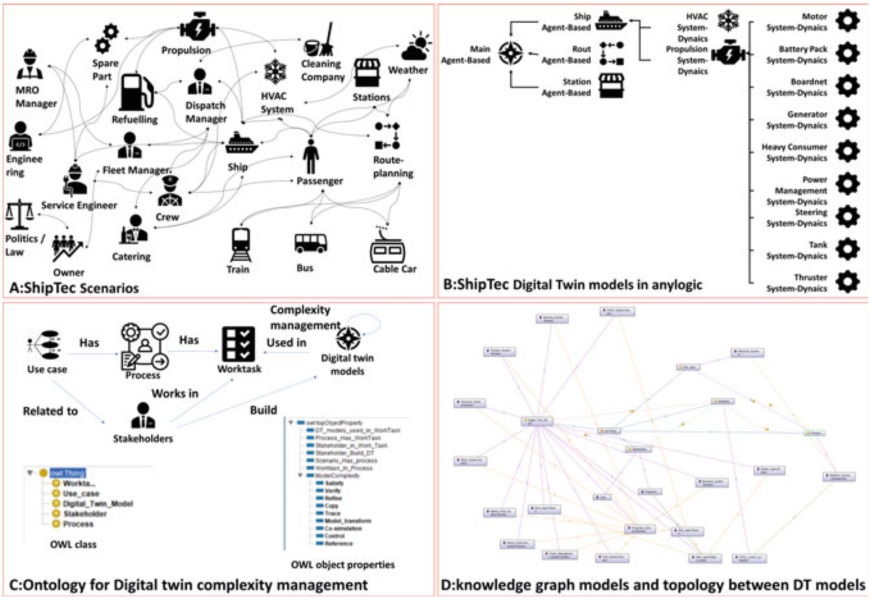

Fig. 2 Shiptech case study: **a** Shiptech ecosystem; **b** Shiptech models in anylogic; **c** Ontology definitions; **d** topologies between DT models

inland water vessels for professional applications. Moreover, Shiptec is an associated company of the navigation company of Lake Lucerne (SGV Holding AG). The shiptec expects to understand the system of systems perspective of their products and promote their product performances based on the their ecosystem (Meierhofer et al. 2020), as shown in Fig. 2a.

The digital twin models were developed to support Shiptec and their partners for decision-making for system design and the operations of the ships. They were built in AnyLogic (Borschev and Anylogic 2008) using agent-based and system-dynamic elements, as can be seen in Fig. 2b. In order to manage the complexity of digital twins in the Shiptec scenario, ontology entities are built which are shown in Fig. 2c, Finally, the knowledge graph model was built in Protégé (Stevens and Hancock 2004), which is shown in Fig. 2d.

4.1 *Digital Twin Models of Shiptec*

Figure 2a describes the ecosystem of Shiptect (Meierhofer et al. 2020). It shows the interaction between the different stakeholders and their interrelationships. This ecosystem analysis was done to better understanding the complex system around Shiptecs business. By mapping the ecosystem of Shiptec, the system boundary for the digital twin could be identified in accordance with the modeling process introduced in Sect. 4.2. The following actors of the ecosystem displayed in Fig. 2a, were defined out of scope for the use case: (1) Cleaning Company, (2) Weather, (3) Passenger, (4) Train, (5) Bus, (6) Cable Car, (7) Politics, and (8) Catering. The remaining stakeholders are beneficiaries or agents of the developed digital twin.

With this defined scope, the use case was identified, and the digital twin models were built to support the relevant stakeholders in the ecosystem. The digital twin should help the stakeholders by presenting them with multiple options to solve a question concerning operational processes and the possible consequences of their choices. The digital twin in the case of Shiptec consists of an operational and a performance model. The operational model simulates the ships driving on the lake according to their schedule is placed in a geographic information system (GIS) network. This part of the model is mainly built as an agent-based model. The operational model can function on its own. It can support service technicians and the dispatch managers by providing knowledge about specific scenarios, such as ship malfunctions. In addition to this purely operational model, a technical performance model was added. The aim of this model of the propulsion system of one ship was to support the crew, the service technicians, the dispatch manager, as well as the owner.

The whole model of Shiptec consists of 15 agents. The top-level agent is the main-agent. In it, all the following agents are placed and interact with each other. The main agent provides the GIS map network in which the ships, routes, and stations are placed. Inside this network, the ships moving according to routes from station to station are simulated. The ships, routes, and stations are modeled agent-based. There are various routes with different operating hours and destinations (stations) simulated in the model. Each route sizes multiple stations on its course as well as a ship. The vessels, on the other hand, have different parameters that are different depending on the type of the ship. Not all of the vessels, for example, have sufficient size for all routes on the lake of Lucerne. Therefore, in the case of a failure of one ship, it is not trivial to find a working solution for a replacement. In addition to this operational modeling of the ship operations on the lake, the ship agents include a performance model of the propulsion system and the heating, ventilation, and air conditioning (HVAC) system. Both of those models are built as system-dynamic models and simulate the performance of the ship. As can be seen in Fig. 2b the model of the propulsion system is described by nine agents. Those agents are system dynamic and simulate the performance of one particular part of the propulsion system. In combination, they are able to predict, for example, fuel usage during a trip. This helps the dispatch manager to plan more ecological as well as economic routs for the ships. It also helps to prepare the refueling process of the vessels on the lake. As each ship has a different propulsion system, this is different for all the ships in the fleet and, therefore, not trivial to find an optimal solution without the data from the digital twin.

4.2 Ontology Definition for Complexity Management

In order to manage the complexity of digital twins in the Shiptec scenario, We define the ontology entities, including: (1) use case; (2) process; (3) stakeholder; (4) worktask; (5) digital twin model. As shown in Fig. 2c, use case refers to one scenario that digital twins are required. Process refers to the operational workflow in the use case which constructed by worktasks. Stakeholders refer to people and organizations who related to the use case. They developed digital twin models for the use case.

In Protégé, the OWL classes are developed based on the ontology entities. The object properties are developed to describe the interrelationships between entities. Moreover, interrelationships between digital twin models are also described based on Sect. 4.3. Through the OWL modeling, individuals of owl models representing all the digital models are built in order to describe the topology between digital twin models in Fig. 2b with object properties. Finally, the visualization of the individuals is demonstrated in Fig. 2d.

4.3 Discussion

Through the case study, we found the interrelationships between digital twin models are described based on the developed ontology using the OWL model. Thus, in the use case, the complexity between digital twin models is changed from disorganized complexity to organized complexity, because the interrelationships between digital twin models, use cases, process, work tasks and stakeholders are described. Based on the knowledge graph model, consistency management, complexity management, traceability management, and knowledge management can be implemented for digital twin models with more promoted cognitive capabilities. From the case study, the proposed approach includes several contributions as follows:

– A system thinking approach is provided to develop semantics models for managing the complexity of digital twins.
– Through the system thinking approach, systems and system lifecycles are integrated in order to support consistency, traceability and change management of digital twins.
– This approach provides one solution to construct cognitive twins in order to support decision-makings of system development (Lu et al. 2020).

5 Conclusion

This paper proposed one cognitive semantic modeling approach to support complexity management of digital twins. The semantics modeling approach can describe the information of each digital twin and their interrelationships. Through the semantics models, system developers can identify their required information with more powerful cognitive capabilities. From the IMPURSE case, we find the semantics models indeed capture the expected information from digital twin models and provide potentials for their complexity management. Future works focus on a tool prototype which will be used to manage the complexity of digital twins.

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Digital Twin Based Decision Support Services in Business Operations

Jürg Meierhofer, Lukas Schweiger, and Lukas Schreuder

Abstract With the advent of servitization and against the background of progressive digitalization, industrial value creation is increasingly shifting to service interactions at the customer interface. Companies are focusing less on selling goods and more on creating service values. The goods remain important as carriers of service values. The concepts of the Service-Dominant Logic (S-D Logic) prepare this shift in conceptual and theoretical foundations by providing a new perspective that puts the co-creation of values in service ecosystems at the core of the conceptual design. Service delivery is significantly supported by the increasing capabilities of digital and data-driven tools (Lusch and Nambisan, 2015). In business-to-business (B2B) environments, the benefits of services manifest themselves primarily in business-relevant decision making. By using data, the consequences of decisions can be better predicted, reducing uncertainty for management and increasing the quality of decisions. This paper examines the modeling of decision support by digital twins in business processes with a consistent focus on service value creation for the human actors in the system. For this purpose, decision making is modelled as a multi-stage process that can be represented by different elements of digital twins. The conceptual study is accompanied by an implementation in a real company case study. This case shows how the elements of digital twins interact to create service value and what kind of data is required to create this value.

Keywords Smart services · Digital twin · Decision support

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1 Introduction

In business-to-business (B2B) environments, services are applied to provide value to both external partners (i.e., customers) or internal users (i.e., employees) of a company. In these types of situations, the benefit of services is manifested primarily in the support of business-relevant decisions. Business decisions are very frequent in operational processes and are accompanied by the inherent uncertainty about their consequences. This poses major challenges for operational management and is a major pain, which represents significant potential for the application of systematically designed data-driven service ecosystems. Data-driven management means taking such decisions supported by data—for example, process data, data created by customer assets, or data from other actors in the ecosystem: by using data, consequences can be better predicted, which reduces management uncertainty and increases the quality of decisions. The Digital Twin as an adequate data-based representation of real objects represents a concept that has the potential to provide value for data-driven decision support.

The research underlying this paper aims at understanding, modeling and optimizing how value is created by Digital Twin-based decision support services in operational processes, in particular—but not exclusively—in manufacturing companies. For this goal, the process of decision taking and its support is described through the lens of service science and Service-Dominant Logic, thus enabling a business value-oriented perspective—characterizing decision taking processes in operational environments and modeling their impact on value creation on a combined quantitative and qualitative basis.

2 The Evolution of Servitization of Manufacturing Towards Data-Driven Industrial Services Based on the Digital Twin

The concept of servitization of manufacturing moves industrial value creation from the goods perspective to the service perspective, where value is created in the interaction between providers and beneficiaries (Kowalkowski and Ulaga 2017; Lightfoot et al. 2013; Vargo and Lusch 2008). In this transition from goods to services, the concept of so-called product services systems (PSS) has emerged (Oliva and Kallenberg 2003; Tukker and Tischner 2006) where products deploy their value via services.

With the emergence of digitalization and the internet of things (IoT), service value creation by data-driven services is a topic of increasing importance in industrial environments, leading to the concept of the industrial internet of things (IIoT) or Industry 4.0 (Thoben et al. 2017; Weimer et al. 2016). Data-driven services enable so-called advanced services, which are output-oriented services, where the customer gets a promised level of output for an agreed price. Data science (also referred to as advanced analytics, machine learning, artificial intelligence etc.) represents an enabling factor for providing advanced services (Paschou et al. 2020).

The Digital Twin is defined as a virtual representation of a connected physical equipment that represents in real-time its static and dynamic characteristics (Romero et al. 2020). It has the potential to add value to many applications and, in particular, to industrial processes and thus attracts increasing interest of practitioners and scholars (Barbieri et al. 2019). There is a wide range of understandings and definitions of the Digital Twin and its applications (Tao et al. 2018). In the literature, the Digital Twin is mainly discussed as a technical tool that has diverse interpretations (Meierhofer and West 2019) which vary widely depending on the industry and implementation field (Tao et al. 2018).

The research streams of industrial services, data-driven services and Digital Twins converge in the field of decision support services. The Digital Twin can be considered as an implementation of data-driven services that enable the exploration of scenarios and alternatives and thus support decision taking in business environments (Kunath and Winkler 2018). Therefore, changing the perspective and conceptualizing the Digital Twin as an approach for value creation from a service perspective is a promising new research direction (Barbieri et al. 2019).

3 Decision Through the Lens of Service-Dominant Logic

According to Service-Dominant Logic (S-D Logic), considering service as the fundamental purpose of economic exchange, value is created by actors integrating resources to create new so-called operant resources which create benefit for other actors (Vargo and Lusch 2008). The support for decision taking can be considered from this perspective as a way of creating benefit for the decision taker. The resources integrated are: (a) the expert knowledge of the human actors in the system, (b) the data created by the actors, in particular by the equipment, people and processes that are to be managed, (c) the analytics applied to this data, (d) the decision taking process based on the integration all these resources.

This process of integrating knowledge and data from their raw formats up to supporting decisions is based on (Holsapple 2008). The structure is comparable to the DIKW (data-information-knowledge-wisdom) scheme based on (Rowley 2007). According to (Holsapple 2008), the traditional conception of decision taking has to be differentiated from the knowledge-based conception, which—according to S-D Logic terms—integrates knowledge resources other than pure data from the systems.

4 Industrial Decision Support Systems Supported by Digital Twins

Decision Support Systems (DSS) are information systems that help users in their decision activities, which can extend to highly automated decision taking. The steps of the decision taking process are described in (De Almeida and Bohoris 1995; Dong and Srinivasan 2013; Holsapple 2008; Power 2004, 2008; Sala et al. 2019) and can be simplified to: 1. Describe the set of possible actions or alternatives. 2. Evaluate these actions. 3. Select the preferred action. This can be followed by additional steps for recording and analyzing the decision and using it for improving future decisions.

Step 2. of the simplified decision process points to the application of the Digital Twin, in particular Digital Twin-based simulation, which allows to explore the variants and evaluate their consequences. This is supported by (Sala et al. 2019), which states that simulation is a very common decision support instrument, in particular for decisions in maintenance and capacity planning in product-service-systems. Several industrial application cases of Digital Twins are described in the literature. (Kunath and Winkler 2018) elaborate how a Digital Twin of the physical manufacturing model is applied to scheduling, the calculation of delivery dates and dynamic pricing as well as the dynamic administration of supply processes. In (Zhou et al. 2016) the application of agent based simulation for service technicians is described for conducting experiments with variations of the number of technicians or the service policy—e.g., the number of maintenance periods after which the equipment is replaced. (Huynh et al. 2010) discusses the application of Digital Twins of machines or equipment for decision support and (Xia et al. 2009) takes into account a Digital Twin of processes.

Operational decisions are taken in the interplay between the product (the equipment) and the operational processes. The Digital Twin of the equipment gets data (e.g., a health condition or a performance indicator) from the physical equipment, i.e., a machine. However, this is considered raw information for better understanding, but does not support the actor taking decisions. Based on the information from the Digital Twin of the equipment, the additional step with the Digital Twin of processes can support decision taking along the lifecycle as shown in Table 1 (Meierhofer et al. 2020; Meierhofer and West 2020):

In the MOL phase, for example, an actor managing an asset takes decision by trading off resource constraints, e.g., between maintenance – requiring available

Table 1 Support services provided by the process twin across the lifecycle

Beginning of Life (BOL)	Middle of Life (MOL	End of Life (EOL)
• Process design decisions • Capacity design decisions • Automation (vs. manual) design decisions	• Capacity vs. demand decisions • Quality decisions • Maintenance decisions • Skills development decisions	• Process redesign decisions • Re-skilling workforce decisions • Process design for recycling or refurbishment

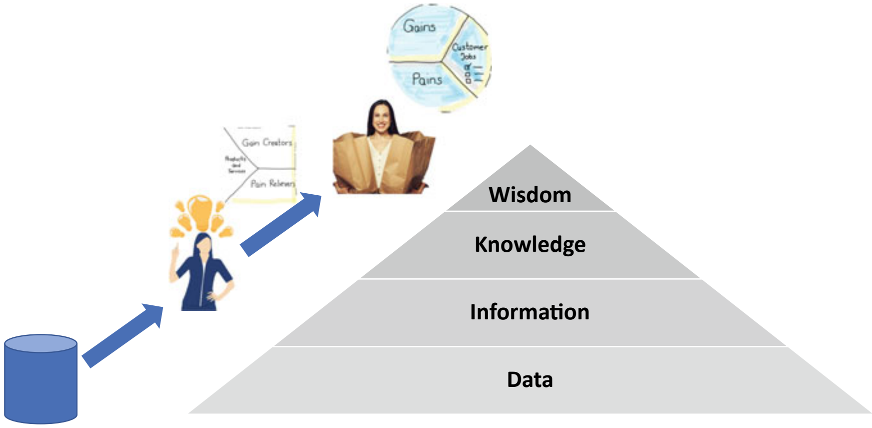

Fig. 1 Enriching raw data to information and knowledge and integrating it with human knowledge to support decision making

maintenance resources, or replacement – requiring available spare equipment, or any point on the continuum between these two extremes.

In the industrial sector, this typically boils down to the concept of data-driven management in operational processes. Data-driven decision support is an essential part of this. Here, operational decisions are made on the basis of data: by using data (for example, internal process data or customer data), consequences can be better predicted, which reduces a management pain and increases the quality of decisions. This process, which turns raw data into good decisions, can be visualized by the so-called DIKW pyramid (Fig. 1): information is created from digital raw data by interpreting it in context. Knowledge, however, is only created through analysis. Combined with management knowledge, this results in the balanced assessment ("wisdom") required for the decision, on the basis of which digital (data-driven) products develop their business benefits in interaction with the users.

5 Case Study: Application for Decision Support in Ship Operations Processes

5.1 Introduction to the Shipyard Case

Shiptec is a Swiss shipyard located in Lucerne which designs, develops and builds inland water vessels for professional applications. These include ships as public transport, tourist activities, ships for the transport of goods as well as government and rescue boats. Shiptec offers all related services, from strategic maintenance planning to short-term technical operations. Shiptec has extensive experience in the holistic analysis and design of energy and drive systems and is a leading engineering company to reduce the ecological footprint of fleets or to gradually achieve zero emissions. Shiptec is an associated company of the navigation company of Lake Lucerne (SGV Holding AG). The SVG Holding consists of the three members Tavolago AG (gastronomy), SGV AG (navigation company) and Shiptec AG mentioned above.

Passenger transportation on inland lakes and rivers was once the fastest means of transport before it was replaced by the cars, busses and trains. With today's need for mobility, the capacities of these transport routes reach their limits. Particularly in metropolitan areas and on main connecting routes, the roads are congested and the capacity limits of the trains are exhausted. The waterway becomes again more important as an addition to existing commuter routes. Because a vessel is a long-term investment of 30+ years, technical evolutions did not happen in the same pace as for private and public transport vehicles, which have evolved heavily over the last decades in terms of ecology, economy and comfort. With the arrival of new and cleaner hybrid and purely electric propulsion systems for inland vessels, it brought many sensors onto the water and made the vessels more digital. This makes it possible to monitor vital ship data in real-time to improve the ship availability, power and fuel consumption and passenger comfort.

The combination of the increasing demand for more and greener mobility on one hand and the availability of modern technology on the other hand creates new business cases previously not deemed profitable for a navigation company and opens new markets for a traditional shipyard. In particular, this situation lends itself to a systematic servitization approach as described in the introduction of this paper. For these reasons, Shiptec joined a research project on smart services based on Digital Twins with the aim of developing a Digital Twin which would support decision making in the existing ecosystem of Shiptec and its partners and co-created the case following hereinafter.

5.2 Ecosystem Mapping

The business system of the vessel transportation is analysed applying the service-oriented concepts provided by the framework of the S-D Logic. To better understand the complex business landscape around Shiptec, according to (Meierhofer et al. 2020) an ecosystem analysis was done. The ecosystem map in Fig. 2 shows the main actors and their connections. In the case of Shiptec, multiple actors were identified. The inner core of this ecosystem and its actors is depicted in Fig. 2.

During the mapping of the ecosystem, different interactions between actors have been investigated. The actors which are colored in green are members of Shiptec. The blue ones are members of the SGV and the golden one from Tavolago. The black ones are external actors that influence the ecosystem. Out of this service ecosystem, several actors were selected to build new services around Digital Twins for them. For framing the procedure according to the concepts of the S-D Logic, practical methodologies of service design approaches were applied. According to (Vargo et al. 2018), service

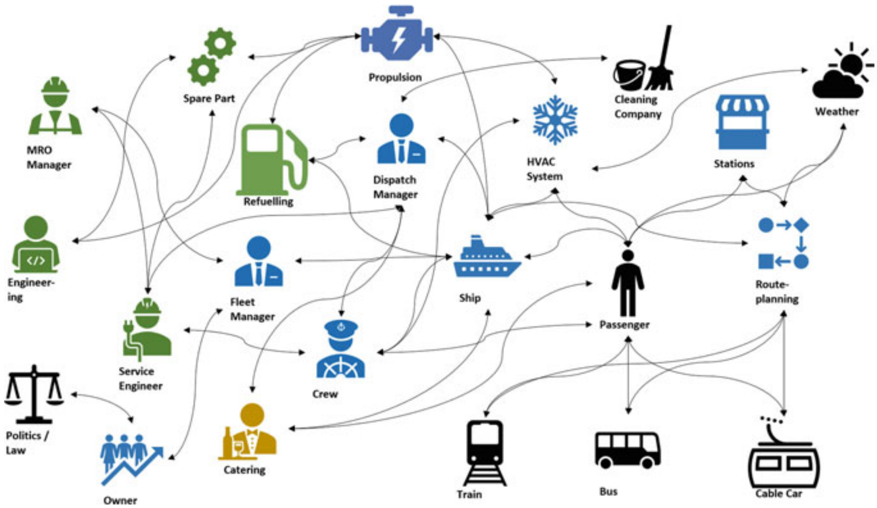

Fig. 2 Ecosystem Map Shiptec

design (Stickdorn et al. 2018) can be considered an operationalization of SDL. In particular, the value proposition design tools (Osterwalder et al. 2014) provide a suitable means to research user insights about the beneficiaries by investigating their jobs, pains, and gains.

The primary beneficiaries are listed below with their jobs, pains, and gains. During the iterative model development, the range of potential beneficiaries was continuously extending. Therefore, there are multiple beneficiaries and not just the one with which the case was started.

5.3 *Primary Beneficiaries*

Along the iterative process of modeling, the four actors described below turned out to be the most relevant beneficiaries of Digital Twin based services.

5.3.1 Dispatch Manager (SGV)

The job of the dispatch manager is to make sure that the right amount of crew is at the right time on the right ship. In addition, he has to create the timetables for the ships and organizes the refueling and cleaning of the ship. His greatest pains are: unplanned breakdowns of ships, high level of fuel usage, paper-intensive communication processes, interfaces between different planning tools, and the integration of theme tours into the regular schedule. The gains of the dispatch manager are: a stable, planned schedule, appropriate capacity (size of ship) timely available given the demand (number of waiting passengers), thus resulting in reduced waiting times.

5.3.2 MRO Manager (Shiptec)

The job of the MRO manager is to plan and organize the maintenance and repair, planned and unplanned, for the customers of Shiptec. His main pains are: missing spare parts and the long waiting time to get these, due to misleading information and missing data from the ships, as well as sending the wrong technician. Also missing appreciation internally as well as from external customers as well as when customers do not have a centralized channel to report failures and problems. His gain is the low failure rate and high availability of the ships. Knowing the ship's health status at any time and knowing in advance when parts are going to break.

5.3.3 Service Engineer (Shiptec)

The job of the service engineer is to repair and maintain the ships at the customer's site. This includes going on board looking for the error and fixing it with little to no information where the error may be located. Prioritize the different error messages and act accordingly. Get in contact with the ship crew to decide if the ship can still be used or needs to be replaced. His greatest pains are: frequently not having the right tools to fix the ships because it was not clear where the problem occurred, too little time to fix the problem on the ship, need to visit the ship several times per error message due to the lack of information.

5.3.4 Owner (SGV)

The job of the owner is to operate a fleet of ships in the most profitable and sustainable manner. His main pains are: ships not operating at full capacity, high fuel consumption, unplanned maintenance events. His gains are reliable planning of recourses and investments, reduction of operation costs such as fuel, spare parts, maintenance, and labor cost.

5.4 *Model*

The model is built to support these primary actors in the ecosystem of Shiptec to support decision making. As a modeling tool, AnyLogic was used, which enables building agent-based, discrete event, and system-dynamic models in the same environment (Fig. 3). The model was co-created with Shiptec in an iterative process. This was done to focus on the jobs, pains, and gains of the primary actors in the ecosystem

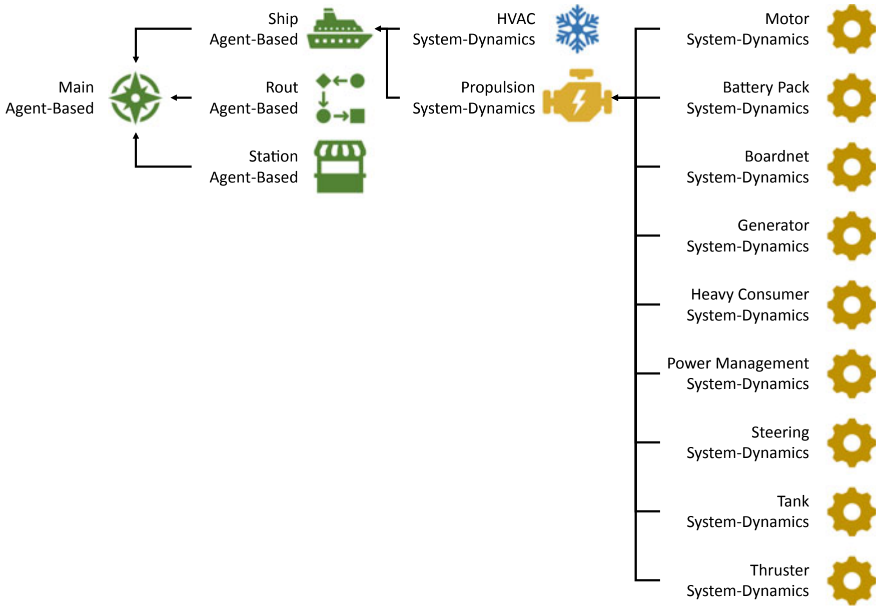

Fig. 3 Structure of final model

of Shiptec. The aim of the model is to support the different actors in the ecosystem with possible options of reactions in situations where complex decisions need to be taken.

5.5 *First Iteration—Operations Model*

In the first iteration, an agent-based operations model was built, i.e., a digital twin of processes according to Sect. 4. The model consists of four agents: Main, Ship, Station, and Route. The "Main" agent is the route environment where all the other agents are placed in and interact with each other. The primary beneficiaries of this model are the Dispatch Manager, the MRO Manager, and the Service Engineer. With the model, different operations states and their implications on the current situation can be simulated. This helps the dispatch manager to take capacity decisions during the operation of the ships on the Lake of Lucerne. For example, the dispatch manager and the MRO manager are able to use the model to calculate the optimal replacement constellation in the event of ship failure. This calculation takes the different routes and ships that are in use on the Lake into consideration. Such calculations can be done in near-real-time or at the end of a day for the upcoming days if a ship needs to go into maintenance. The resulting simulation model is shown in Fig. 4.

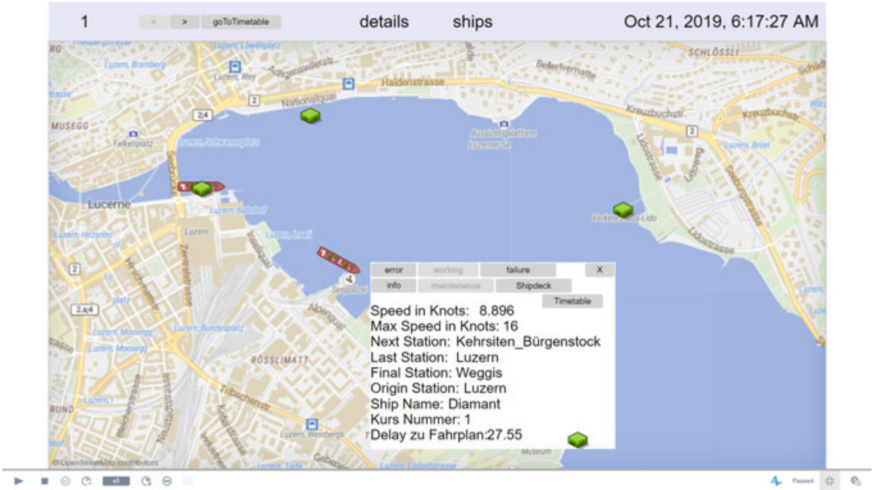

Fig. 4 Print Screen from simulation of the operations model

5.6 Second Iteration—Integration of HVAC

During the first iteration of building the model, it became evident that by adding a simulation of the Heating, Ventilation, and Air Conditioning (HVAC) of the ship the simulation could also support the crew by providing them with information about the development of the indoor climate on the ship. Therefore, the HVAC system of one ship was added to test the approach and to test if it creates value. This represents a digital twin of an equipment according to Sect. 4.. This was done using a system dynamics approach. This addition to the model should benefit the crew as it would be able to simulate the influence of the HVAC system onto the climate on board. Often, they have to decide if it is economical to use the HVAC system between two stations. With this addition to the digital twin, this pain could be resolved, and indirectly relieves pains of the primary beneficiary "owner".

5.7 Third Iteration—Propulsion Model

Based on the learnings from the previous two iteration steps and considering the needs of service engineer (and additionally the crew and the engineering department) to better understand the behavior of the ship's behaviour, a further addition to the digital twin was made, which is able to simulate the propulsion system of one of the ships of the SGV, which is an additional digital twin of an equipment according to Sect. 4.. It is a pure system dynamics model that should help, on the one hand, the engineering department and, on the other hand, the crew (Fig. 5). The engineering

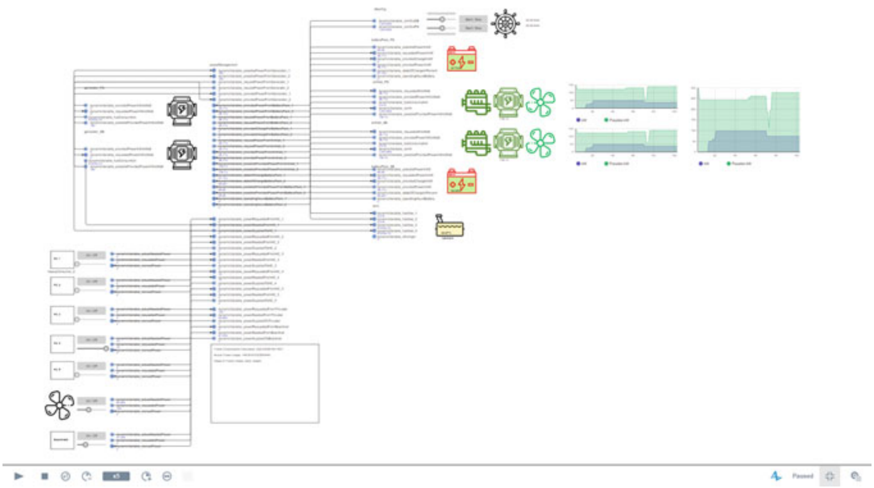

Fig. 5 Propulsion model system dynamics

team can simulate the ship's propulsion and energy system in different conditions and different operating models. The crew gets a support model to decide in advance with which speeds they should drive the ship on the next trip to be as efficient as possible.

5.8 Fourth Iteration—Combination of Operations and Propulsion

The fourth iteration integrated the propulsion model into the operations model from iteration one. This inclusion benefits mainly two actors in the ecosystem. Starting from the Dispatch Manager with helping him to plan more ecological and economical routes for his ships. Another beneficiary is the owner as he will be able to develop new routes and business models that were not feasible before due to the lack of information.

6 Limitations and Future Research

This paper describes the theoretical concept of applying Digital Twins for decision support services in business operations. It is based on the decision chain consisting of the Digital Twin of the equipment and the Digital Twin of processes described in (Meierhofer and West 2020) and applied here in the case study of the shipyard business, in which value is provided to specific actors by decision support services. The concept of the Digital Twin of the equipment and of processes could be successfully applied in this case study. However, this research did not yet systematically elaborate which type of business questions lend themselves for which specific concept of Digital Twin models.

Future research will provide a conceptual methodology for describing how service value creation for business operations is impacted by decision processes and how this concept can be taken to the next level by data-driven services. It will base this approach on the concept of the Digital Twin as a technical resource for informing these decision processes in complex and unpredictable environments.

This will enable to close the significant gap in the understanding, conceptualization, and design of value creation for business operations through data-driven service ecosystems, which is of strategic importance for research, business and society, as well as education.

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Business-Centred, Data-Centred, or User-Centred? A Perspective on the Role of Designerly Approaches to User Centricity in Big Data Innovation

Thomas Abrell

Abstract Digital innovation is of growing importance for manufacturing companies, potentially disrupting entire industries. Particularly the use of big data offers new grounds for innovation in product-service-systems. However, digital innovation poses challenges to incumbent companies on how innovations are created. With an abundance of technological possibilities, potential business challenges, and novel use cases, companies struggle to find the right approach to digital innovation. This conceptual paper builds on a study of big data innovation that proposes to either start with a data or business perspective in the ideation phase (Vanauer et al. 2015) and reflects these approaches with a user innovation perspective, suggesting that the changing role of users and customers in digital innovation may allow for a third, user-centred approach. While a data-centred approach starts with key resources, a business-centred approach starts with organisational goals that need to be fulfilled (Vanauer et al. 2015). Although both approaches may be suitable to lead to innovation, a user-centred approach may help to build big data innovation based on current and future user needs. While some studies criticized that a focus on users may lead to incremental innovation, this may be due to how users are involved. This study explores how designerly approaches such as service design and design thinking may be utilized for innovation of product-service-systems in the context of big data innovation. Based on these concepts, I formulate four propositions for future empirical and theoretical consideration.

Keywords User innovation · Big data · Designerly approaches

1 Introduction

Digital innovation is changing the manufacturing industry profoundly. On the one hand, digital innovation offers manufacturing companies new business opportunities beyond their current offerings (Nambisan 2013; Nylén and Holmström 2015). On

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the other hand, new market entrants are changing the competitive landscape, challenging incumbent players. Existing business models are endangered to be rendered outdated by digital innovation. Therefore, manufacturing companies are seeking ways to utilize digital innovation to create novel products and services. Digital innovation accelerates their endeavors to move from purely product-based companies to offering product-service-systems, as the products become increasingly smart and connected (Porter and Heppelmann 2014), enabling smart product-service-systems (Chowdhury et al. 2018; Zheng et al. 2018). However, as the characteristics of digital innovation differ from product and service innovation, companies need to adopt new ways to manage innovation processes (Henfridsson et al. 2014; Nylén and Holmström 2015). Particularly the concept of big data, which addresses the growing volume, velocity, and variety of data which offers new grounds for innovation (McAfee et al. 2012), is challenging for manufacturing companies.

In an attempt to shed light on creating digital innovation using big data, Vanauer et al. (2015) introduce two starting points and ways of working to create new ideas and develop them in the ideation stage. They contrast an approach to start with data or with a business perspective (in this paper referred to data-centred and business-centred). In this study, I argue that there may be a third approach to innovation: user-centred, as users may guide digital innovation efforts (Abrell et al. 2016). User knowledge, however, may not be readily applicable for innovation use, and user involvement is criticized as being incremental and thus of limited use when it comes to innovation beyond the incremental scope (Ulwick 2002). Companies need to rely on both incremental improvements of their products and services as well as radical innovation. However, the different characteristics of radical innovation requires a different approach (de Brentani 2001). In particular, while identifying and responding to user needs was found to be a significant success factor for both incremental and radical innovation, the latter demands to focus on longer-term user requirements as well as utilize new and creative problem-solving approaches (de Brentani 2001). By drawing on the concepts from the design realm, I argue that a designerly approach to user involvement may lead to opportunities beyond the incremental scope.

This study is structured as follows: First, relevant theoretical constructs are introduced. Subsequently, the proposed model by Vanauer et al. (2015) for the ideation phase of big data innovation is used to illustrate designerly approaches to user centricity, followed by a discussion of users in big data innovation, designerly approaches, and product-service-systems, leading towards four propositions. Finally, the study concludes by pointing out implications for theory and practice.

2 Background

2.1 Product-Service-Systems

A product-service-system (PSS) is defined as a “marketable set of products and services capable of jointly fulfilling a user’s need“(Goedkoop et al. 1999, p. 20). Having its origins in sustainability, one of the PSS goals is to reduce consumption through enabling users to use products without owning them (Beuren et al. 2013). Another aim is to increase the profitability and competitive position in the marketplace (Geng et al. 2010). PSS are regarded as a special case of servitization (Baines et al. 2007). Servitization of manufacturing companies addresses that offerings are increasingly bundles of products and services with services (Rada and Vandermerwe 1988) and transforms manufacturing companies to organisations that are providing integrated product and service offerings that deliver value in use (Neely 2008). Digital innovation is contributing to servitization of manufacturing companies through smart, connected products enabling novel use cases (Porter and Heppelmann 2014). The internet of things is researched as driver for manufacturing servitization (Rymaszewska et al. 2017), and Chowdhury et al. (2018) use the term smart PSS for PSS that are particularly enabled by smart, connected products.

Within this environment, either product companies become more service oriented or vice versa. Following a categorisation of Tukker (2004), PSS can be either product oriented, use oriented or result oriented. While these categories may offer guidance, they are not mutually exclusive, as PSS may include more than one. One of the opportunities of digital innovation is to use data generated by products, merge with other relevant data to generate new useful services.

2.2 User Innovation and Designerly Approaches

Building on the first accounts of the innovative potential of users of Von Hippel in the 70’s (Von Hippel 1976), it is widely acknowledged that users contribute to innovation of products (Baldwin et al. 2006), services (Magnusson et al. 2003), and digital innovation (Abrell et al. 2016). Bogers et al. (2010) state that it is imperative for successful innovation to develop an understanding of user needs. In order to innovate, knowledge about user needs as well as technical solution knowledge is required (Bogers et al. 2010; Von Hippel 2006). However, despite accounts of radical user innovation (e.g. Lettl 2007), user contribution to innovation has been criticized to be limited to incremental innovation, as their knowledge about novel technologies is limited (Ulwick 2002). While this may be the case, research has shown that the approach of how to involve users into innovation may be detrimental (Lettl 2007; Magnusson et al. 2003). In service innovation, Magnusson et al. (2003) urge innovation teams to go beyond asking the customers for ideas, and Lettl (2007) urges that in order to reach radical innovation it is necessary to involve the fitting users at the appropriate timing in the development process and in the right way. Users are defined as individuals using the products and services (Abrell et al. 2016).

Bessant and Maher (2009) suggest the use of design methods for developing radical service innovations, which they describe as a toolkit to express unclear opportunities, through engaging users as active co-creators. Various design approaches such as design thinking (Johansson-Sköldberg et al. 2013), service design (Goldstein et al. 2002), user-oriented design (Veryzer and Borja de Mozota 2005), and user-centred design (Abras et al. 2004) have in common their focus on the user. While acknowledging that these approaches are focusing on certain aspects of design, I subsume them for this conceptual study under the term 'designerly approaches' to user centricity. Verganti (2008) however adds another dimension to the role of design when coining the term 'design-driven innovation', suggesting that design is used for radical innovation of meaning beyond user centricity by the help of interpreters with a profound knowledge of sociocultural models. Important to note is that designerly approaches are going well beyond a pure set of methods. Hassi and Laakso (2011) describe design thinking as a set of practices, thinking styles, and a certain mentality. There are practitioner accounts of using design thinking for innovation, suggesting that designerly approaches may be one way to involve users in the appropriate manner to derive new offerings radically departing from the past (Brown 2008). These designerly approaches have been researched in a number of contexts, however, not in the context of big data, although Maglio and Lim (2016) call for research on service design in this context.

2.3 Digital Innovation and Big Data

Digital innovation is defined as "carrying out new combinations of digital and physical components to produce novel products" (Yoo et al. 2010). While this definition is product-centred, other researchers mention product and service innovation combined in their studies (e.g. Nylén and Holmström 2015). In product-service-systems, the combination of products and services needs to be taken jointly into account (Barrett et al. 2015).

Big data has unique properties that open up opportunities for digital innovation. The vast volume of data, the pace of data creation enabling real-time information (velocity), and the variety of different data sources are among these unique properties (McAfee et al. 2012). The volume allows companies to analyse various datasets to build a more holistic customer understanding (Lam et al. 2017). The variety of big data allows companies to augment their customer data for example with GPS coordinates, tweets, and the like (Lam et al. 2017). Lam et al. (2017) further mention big data completeness, data veracity, and big data value. They describe big data completeness as offering the required depth and breadth of data for the tasks to be done (Lam et al. 2017). Veracity refers to the unpredictability and validity of uncertain data, while value addresses the usefulness of big data for decision making (Vanauer et al. 2015).

Vanauer et al. (2015) approach the topic of introduction of big data by following a stepped approach, with ideation, idea assessment, and implementation, proposing methods for each step to help companies accomplish big data utilization. They follow workgroup ideation processes with two phases: ideation/creativity and implementation phase, with transition and action subphases. They further clarify that the introduction of big data is an innovative process (Vanauer et al. 2015). While implementing innovations is a challenge as such, manufacturing companies struggle to find direction for their digital innovation endeavors. Therefore, this study is focused on the early ideation phase of big data innovation.

2.4 Linking the Concepts: Illustrative Application of Designerly Approaches to User Centricity to the Ideation Phase of Big Data Innovation

Vanauer et al. (2015) use IT value, the question how "IT brings value to firms in the form of competitive advantage" to argue for a business-centred and data-centred approach for the ideation phase. They state that either IT helps to fulfill business requirements, or building on Porter and Millar (1985) that IT creates new business opportunities and that information provides a competitive advantage. Porter and Millar (1985) further argue that products are often combined with information, and this information enables offerings tailored to customers.

Von Hippel (1988) is pointing out two types of competitive advantage: efficiency versus value advantage. While an efficiency advantage allows firms to provide services at a lower cost, the value advantage is gained through a superior value proposition for a customer. When a firm can offer superior products and services to its customers, exceeding the provision cost, then value is created, and if competitors are unable to replicate these, then a competitive advantage may be created. Thus, the customer and user perspective is important for creating competitive advantages. Therefore, a third approach to the ideation phase is proposed: designerly approaches to user centricity. This study follows the structure introduced by Vanauer et al. (2015) to illustrate a user-centred approach to big data innovation.

They describe two steps in the ideation phase, transition and action. The ideation transition sub-phase aims at the identification of opportunities and potential problems leading to a mission definition (Vanauer et al. 2015). The ideation action sub-phase is happening after the transition sub-phase and aims at creative solution development to answer to the opportunities and challenges identified (Vanauer et al. 2015).

In Table 1, a designerly approach to user centricity is described as an illustrative example besides the business- and data-centred approach. In the user-centred approach, the ideation phase goal is to express new service opportunities as service blueprints and service prototypes, in order to combine insights of both users and experts towards a new service opportunity. By making an opportunity tangible, stakeholders are enabled to provide their own contextual knowledge to the new service

Table 1 Business-, Data-, and User-centred approach to big data innovation in the ideation phase

Approach	Business-centred	Data-centred	User-centred
Vanauer et al. (2015)			
Ideation phase goal	Improving current operations by use of big data, expressed as use case ideas	Creating sellable services using big data, expressed as coherent business models	Creating desirable, viable, and feasible services using big data, expressed as service blueprints and service prototypes
Sub-phase objectives	Transition: Identification of enterprise objectives and challenges for improvements Action: Development of use cases	Transition: Identification of key resources Action: Derivation of value propositions based on key resources	Transition: Identification of explicit and tacit user knowledge Action: Combination of product, service, and market knowledge
Primary innovators	Transition (objectives): Senior management, strategists Transition (challenges): First-/mid-level mgmt. Action: First- and mid-level mgmt., operations personnel, data scienitists	Transition: First- and mid-level management, enterprise architects (if enterprise architecture model exists) Action: Senior management, strategists, sales, data scientists/analysts	Transition: User researcher, innovation teams Action: Sales, data scientists/analysts, innovation teams
Main inputs	Strategic goals of organization, current operational challenges (i.e. issues known to affect performance)	Knowledge on organization and potentially available data (i.e. may not yet to be captured), market expertise regarding sales opportunities	User knowledge Knowledge on organization and potentially available data, market expertise
Method support	Transition: Enterprise architecture models of strategy and challenges, goal analysis techniques Action: Enterprise architecture model, creativity tech	Transition: Business model canvas, enterprise architecture model with modelled data objects Action: Business model canvas, creativity techniques	Transition: Ethnographic approaches, scenario building Action: Business model canvas, service blueprinting, service prototyping
Phase result	Use case measurably improving identified objectives by e.g. resolving challenges	Potentially sellable value proposition (service) with customer segments, etc. (cf. business model canvas)	Service blueprints defining a service from user and company point of view and service prototype

opportunity, allowing to iteratively improving the service opportunity. During the ideation phase, explicit and tacit user need related knowledge is collected and interpreted, and combined with internal solution knowledge of the smart, connected products. This is done by interdisciplinary innovation teams, using for example ethnographic approaches, scenario building, rapid prototyping, business modeling, service blueprinting. By constantly and iteratively making ideas and opportunities tangible using these methods, designerly approaches to user centricity facilitate the process of creating new service opportunities using the currently and in future available technical means to respond to current and future user needs.

3 Discussion

In order to innovate, companies have to take need- and solution-oriented knowledge into account (Von Hippel 2006). However, with a wide range of solutions available through digital innovation, companies struggle in identifying meaningful directions for innovation. Previous studies suggest that users may give direction for digital innovation efforts (Abrell et al. 2016). By turning to users, companies can answer questions about potential benefits for users, and relevance of potential service ideas. This may give guidance to identify new service opportunities that respond to current and future user needs and to prioritize development efforts in an environment with ever-increasing amounts of data and analytic possibilities and scarce development resources. It is important to note that besides arguing to start with the user, it is important to constantly and iteratively develop innovation with the users.

Proposition 1: User knowledge may guide big data innovation.

Users are also criticized to only help with incremental innovation which may be due to how they are involved. Designerly approaches are asking questions inspired by observed user problems such as how might we help a user in her situation with a service, followed by detailed service blueprints, low-fi service prototypes such as paper mockups or role playing, followed by click dummy prototypes, followed by semi-functional prototypes, often simulating functionalities that can be made possible by big data through a human to test whether a certain functionality helps the user. The strength of making intangible services tangible through the means of visualisation and enacting helps to rapidly iterate before making larger scale investment efforts into developing functionalities. Therefore, designerly approaches help to identify tacit user needs and translate them into new business opportunities. Representations of user problems, context information, as well as tangible future use case ideas enable a detailed understanding of the use of data. Through personas, user journeys, jobs-to-be-done, and service blueprints the functionality required for future services can be derived. Data supports through enabling personal, situation- and context-specific services (the right content at the right time), by combining knowledge about the user situation, previously used services, information from smart, connected products, and predictive algorithms.

Inherent in designerly approaches is a deep understanding of users, which can lead to a search within the available data to enable services to solve user problems. On the other hand, the turn to users can be also triggered by setting out to understand a certain phenomenon observed in the data where causal chains may not be obvious. Designerly approaches to user centricity can provide answers to why users behave in a certain way that can be seen in the data by exploring the user realm beyond what is visible from data. Therefore, it aids the understanding of the user problem and how a potential solution can provide value to the users.

Proposition 2: Designerly approaches help to identify tacit user needs and translate them into tangible new service opportunities.

However, design teams should not work in an isolated fashion to create innovation, but in interdisciplinary teams including various disciplines, often from the field of technology and business. By involving the specialists from different disciplines, designerly approaches aim to integrate these perspectives into the concepts to rapidly iterate towards desirable, viable, and feasible solutions. Therefore, designerly approaches to user centricity can be seen as an integrative approach taking into account the business- and data-centric perspective, and therefore combining need and solution-related knowledge.

Proposition 3: Utilizing designerly approaches to enfold user centricity in practice is an integrative approach taking into account the user, business, and data perspective.

As shown above, taking the user perspective as a starting point for big data innovation ensures that the innovation in question solves a user problem. By using designerly approaches in an integrative manner, the solution knowledge of a particular company and beyond the company boundaries can be integrated. Designerly approaches to user innovation as an integrative approach is suitable to infuse the user perspective in innovation of both products and services. However, big data innovation opens up manifold possibilities for previously product-oriented companies, paired with often-scarce resources for innovation implementation. By turning to current and future users, understanding their needs and problems, the opportunity space for data-driven services becomes tangible for companies and therefore helps them in the transition from a product- to a use- and result-oriented offering.

Proposition 4: A user-centric approach using designerly approaches to big data innovation helps product-oriented companies in their transition to result-oriented companies.

4 Conclusion

Starting out with the question whether there is a third approach besides a business- or data-centred approach in the ideation phase of big data innovation, this study proposes to utilize designerly approaches to user centricity to reach innovation beyond the incremental scope. The user-centred approach is illustrated using the structure of Vanauer et al. (2015). Four propositions are stated for further theoretical and empirical considerations. Practitioners may consider these propositions in their endeavor to build new user-centred product-service-systems. By starting out from the user perspective, using designerly approaches to involve users, integrating the business and data point of view into the process, they may design new kinds of services and leverage digital business opportunities. Scholars are encouraged to take the propositions as starting point for further studies and to further build on linking digital innovation, design innovation, user innovation, and product-service-systems to shed light on the role of users in digital innovation of product-service-systems.

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