The Digital Transformation of Automotive Businesses

THREE ARTEFACTS TO SUPPORT

DIGITAL SERVICE PROVISION AND INNOVATION

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Abstract:

Digitalisation and increasing competitive pressure drive original equipment manufacturers (OEMs) to switch their focus towards the provision of digital services and open-up towards increased collaboration and customer integration. This shift implies a significant transformational change from product to product-service providers, where OEMs realign themselves within strategic, business and procedural dimensions.

Thus, OEMs must manage digital transformation (DT) processes in order to stay competitive and remain adaptable to changing customer demands. However, OEMs aspiring to become participants or leaders in their domain, struggle to initiate activities as there is a lack of applicable instruments that can guide and support them during this process. Compared to the practical importance of DT, empirical studies are not comprehensive.

This study proposes three artefacts, validated within case companies that intend to support automotive OEMs in digital service provisioning. Artefact one, a layered conceptual model for a digital automotive ecosystem, was developed by means of 26 expert interviews. It can serve as a useful instrument for decision makers to strategically plan and outline digital ecosystems. Artefact two is a conceptual reference framework for automotive service systems. The artefact was developed based on an extensive literature review, and the mapping of the business model canvas to the service system domain. The artefact intends to assist OEMs in the efficient conception of digital services under consideration of relevant stakeholders and the necessary infrastructures. Finally, artefact three proposes a methodology by which to transform software readiness assessment processes to fit into the agile software development approach with consideration of the existing operational infrastructure.

Overall, the findings contribute to the empirical body of knowledge about the digital transformation of manufacturing industries. The results suggest value creation for digital automotive services occurs in networks among interdependent stakeholders in which customers play an integral role during the services' life-cycle. The findings further indicate the artefacts as being useful instruments, however, success is dependent on the integration and collaboration of all contributing departments.

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List of Abbreviations

BM	Business Model
BMC	Business Model Canvas
CDC	Continuous Delivery Checks
CRF	Conceptual Reference Framework
DAE	Digital Automotive Ecosystem
DE	Digital Ecosystem
DI	Digital Innovation
DP	Digital Platform
DT	Digital Transformation
GDL	Goods-Dominant Logic
ICT	Information and Communications Technology
IoT	Internet of Things
IS	Information Systems
IT	Information Technology
IVIS	In-vehicle Information Systems
MS	Microservice
MVM	Minimum Viable Model
MVP	Minimum Viable Product
OEM	Original Equipment Manufacturer
PSS	Product-Service System
RQ	Research Question
RR	Release Readiness
SDL	Service-Dominant Logic
SE	Service Engineering
SM	Software Maturity
SR	Software Readiness
SRA	Software Readiness Assessment
SRT	Software Readiness Template
SS	Service System
TRL	Technology Readiness Level
UML	Unified Modelling Language
VIS	Vehicle Information Systems

1 Introduction

This chapter motivates the topic and relevance of the thesis, stating the problem and describing the resulting research questions. Furthermore, the applied research framework is elaborated upon, comprising the objective, the developed research questions and the methodology. Finally, the chapter concludes with the scientific and practical contributions of this cumulative dissertation.

1.1 Motivation and Problem Statement

Industries proceed through life cycles as they mature. Novel technologies and alternating competitive environments pressure incumbents to react to changes by updating and enhancing their business operations. Companies that fail to do so are at risk of being forced out of the market and replaced by competitors that are "quicker or more efficient in bringing significant innovations to market" (Klepper, 1997, p. 164). Digitalisation has proven difficult for many organisations as prevalent business areas seem to be developing at breakneck speeds (Piccinini, Hanelt, Gregory, & Kolbe, 2015). Digitalisation changes the way in which value is created, potentially disrupting an organisation's prevalent business models (BMs) (Ramaswamy & Ozcan, 2018). As start-ups and information technology (IT) companies occupy digital markets and compete for customer data, the competitive pressure on incumbent firms increases (Riasanow, Galic, & Böhm, 2017). The dynamics of many industries have already been fundamentally altered, such as in finance, commerce and telecommunications, with the manufacturing industry expected to follow as physical products increase in connectivity (Cozzolino & Rothaermel, 2018).

The dissemination of IT implies a large increase in digital services for manufactured goods (Vendrell-Herrero, Bustinza, Parry, & Georgantzis, 2016). Manufacturing firms have digitally servitized their portfolio, shifting from selling products to product-service solutions driven by financial, strategic and marketing aspects (Baines, Lightfoot, Benedettini, & Kay, 2009). This paradigm shift from goods-dominant logic (GDL) to service-dominant-logic (SDL) is reinforced by the penetration and diffusion of IT throughout manufacturing industries (Lusch & Vargo, 2014). Digitalised, physical products generate a large amount of data about their own state or the environment, of which they can exchange with each other or to third parties. Novel insights on how these products are used and the way they are consumed becomes accessible when the generated and processed data is utilised and enriched, promoting the development of innovative services (Pillmann, Wietfeld, Zarcula, Raugust, & Alonso, 2017). Therefore, original equipment manufacturers (OEMs) no longer compete exclusively with physical goods, but also on the digital service level.

However, creating digital services alone is not a guarantee for economic success as altering an organisation's business activities also entails a transformational path (Gaiardelli, Martinez, & Cavalieri, 2015). To stay competitive, incumbents must manage digital transformation (DT) processes and implement digital technologies into their value creation and supporting operation activities (Gimpel & Röglinger, 2015). They must open up to collaboration and partnerships as the provision of digital services leads to an environment of interconnected stakeholders (Weill & Woerner, 2015). Accordingly, manufacturers need to consider how to involve various stakeholders into their value creation processes (Ramaswamy & Ozcan, 2018).

One of the most prominent manufacturing industries affected by DT, is the automotive industry. Its primary product, the vehicle, is no longer regarded as an isolated tangible good, but as an object that integrates different stakeholders, devices, functions, and data into coherent systems of value co-creation (Svahn, Mathiassen, Lindgren, & Kane, 2017). Technological advancements have resulted in vehicles being increasingly equipped with sensors and smart electronics, converting them into mobile Internet-of-Things (IoT) devices (Coughlin, 2016). Modern vehicles can generate up to 25 GB of data per hour (Statista Inc., 2017). These data streams and new technologies offer the potential to create innovative services whose ultimate objective is to provide safer and more convenient mobility solutions as well as to make more efficient use of logistical resources, especially in urban areas (Olia, Abdelgawad, Abdulhai, & Razavi, 2016). If proper analytics are set up and the generated data is utilised with the right intentions, customer data insights can indicate to OEMs how their products are used, feeding their digital service development processes. OEMs push these developments not only because of their intrinsic motivation to generate new income sources, but also because of changing customer demands (Firnkorn & Müller, 2012) and the external pressures created by the market entry of new competitors, such as UBER and DHL's StreetScooter (Chanias & Hess, 2016). Market operators drive the development of digitally enabled innovations (Hildebrandt, Hanelt, Firk, & Kolbe, 2015) that offer great potentials such as reducing environmental, health, urban and social problems, as shown in Figure 1 (World Economic Forum, 2016).

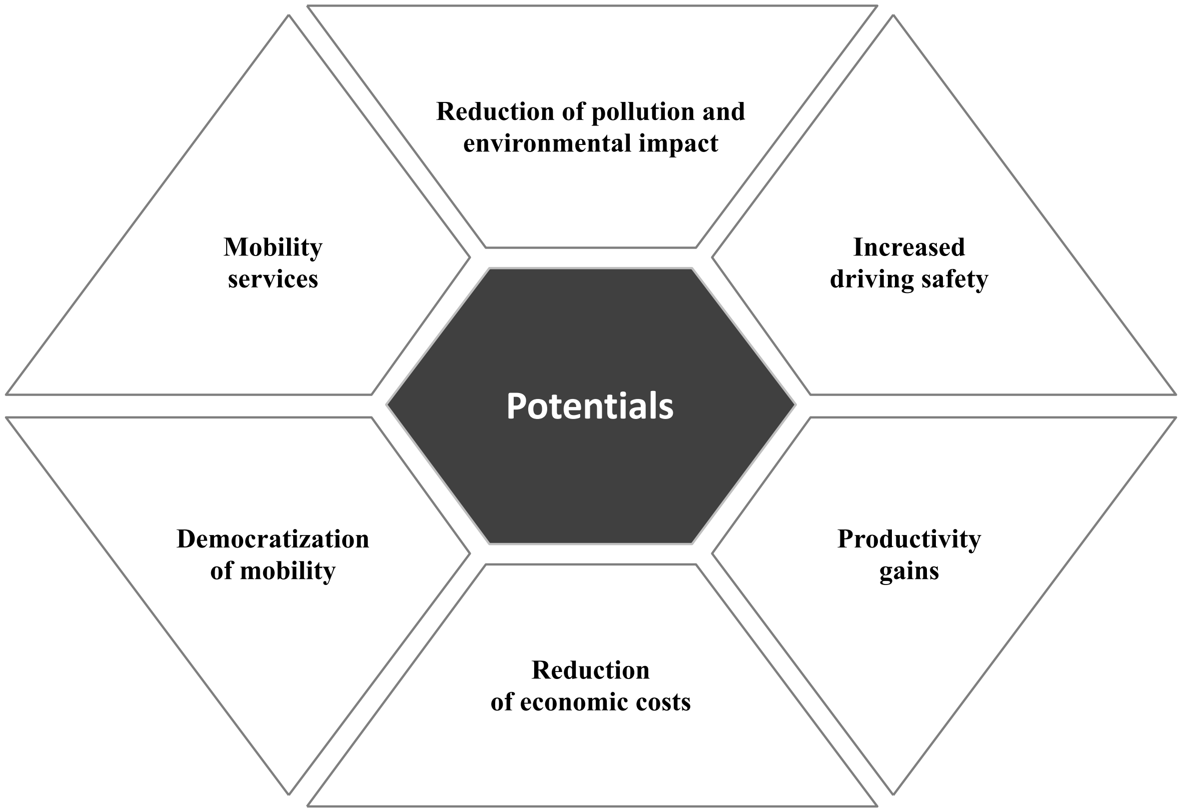

Figure 1: Potentials of digitalised vehicles and services

Gradually, vehicles have become product-service offerings that provide usage-based value (Schäfer, Jud, & Mikusz, 2015) with additional ancillary values (Heinrichs, Hoffmann, & Reuter, 2012). OEMs have placed a greater focus on the design and provision of digitally enabled services for which vehicles are the carriers, such as shared vehicle usage (Kessler & Buck, 2017), connected services (Kaiser, Stocker, & Viscusi, 2017), and autonomous and platform services (Yang, Ozbay, & Ban, 2017). Prominent examples are *Car2Go* by Daimler (Daimler AG, 2018), the alliance on navigational services with regard to the *here* project of BMW, Audi and Daimler (HERE Global B.V. 2015), the energy solution initiatives of BYD (Shead, 2018), and the recently introduced *RIO* platform (MAN Truck & Bus AG, 2017) that allows arbitrary systems, such as telematics or tracking and tracing systems, to connect and execute their functions.

In this context, mutual interactions gain in importance as customers, partners and other stakeholders converge towards one another (Paulus-Rohmer, Schatton, & Bauernhansl, 2016), as seen with Apple and their achievements in integrating digital services and partnerships to leverage themselves in a commoditised hardware market. DT drives the shift from bilateral, interdependent relations within value chains towards a platform approach that can handle different types of relations and third-party content integration. Organizations are in the process of, or have already developed, digital platforms (DPs) (Schweiger, Nagel, Böhm, & Krcmar, 2016) around which they ultimately intend to establish digital ecosystems (DEs) (Bilgeri, Wortmann, & Fleisch, 2017). Network leadership is seen to be "a key to driving innovation and points to the critical importance of" (Dodourova & Bevis, 2014, p. 268) managing intellectual property and an infrastructure of supportive stakeholders, such as intermediaries and suppliers.

DT affects an organisation's strategy (Henriette, Feki, & Boughzala, 2016) and leads to a strategic realignment that significantly modifies and expands an OEM's skill set that has been built around a product-centric point of view, focusing on the quality and feature advancement of manufactured goods (Firnkorn & Müller, 2012). Now, OEMs need to build up IT capabilities (Wallin, 2013), digital service competencies (Pagoropoulos, Maier, & McAloone, 2017) and incorporate new ways of collaboration in their value creation processes (Matthies et al., 2016). In addition, the extension of product-focused business activities with digital service are changing many manufacturers' value propositions, creating the demand for an increased customer-centred perspective (Vendrell-Herrero et al., 2016). Therein, customers are not mere consumers of products and services, but play a pivotal participatory role in the digital value creation process (Kowalkowski, Gebauer, Kamp, & Parry, 2017; Lusch & Vargo, 2014; Ramaswamy & Chopra, 2014). As Henriette et al. (2016, p. 3) put it: "The digital transformation places users at the heart of corporate strategy."

To strategically realign a company and drive digital service development forward, operational processes must respectively be adapted and implemented so that digital services can be developed quickly in the necessary quality within the apt methodology. As digital products and services become more customised and fragmented into smaller features (Olsson, Alahyari, & Bosch, 2012), the development methodologies software projects utilise change too. Flexibility, incremental releases and development speed, i.e. the reduction of a product's time to market, are primary project requirements and are a necessary precondition to stay competitive (Al Alam, Pfahl, & Ruhe, 2016). Therefore, manufacturers increasingly introduce agile development methods that promise greater productivity, product and service quality, and shorter development cycles in return (Dingsøyr & Lassenius, 2016).

Complementing traditional BMs with services has been a long-standing trend in the automotive industry (Verstrepen, Deschoolmeester, & Berg, 1999) and OEMs have intended to do the same with digital ones (Hoffmann & Leimeister, 2011). However, initial efforts in the early 2000s failed, and most OEMs remain mainly product-centred organisations (Mahut et al., 2015). Their predominant BM is largely unaltered, and service innovation proceeds to take place among industry newcomers, as are the cases of Lyft and Tesla. Now, the automotive industry is in the process of digitally transforming itself to keep up with digital technologies and with new entrants who are not held back by traditional linear processes. Increasingly, OEMs are demanded to operate and innovate like IT companies and transform the vehicle into a DE hub that “merges cyber-physical content and social networking, as well as agile processes for development” (Tian, Chin, & Karg, 2016, p. 6). DT “requires a rethinking and restructuring [of] the whole business logics of an organisation” (Piccinini et al., 2015, p. 14) as the transformation impacts organisations on a strategic level including their BMs and ecosystems.

So far, research on DT has mainly set the priorities on detecting obstacles and necessary fields of action for the successful implementation and management of the relevant processes (Baines et al., 2009; Beuren, Gomes Ferreira, & Cauchick, 2013; Chanias & Hess, 2016). But few empirical studies on how to transform manufacturing organisations exist (Gimpel & Röglinger, 2015) and applicable industry-specific methods and instruments to guide the realization of these transformational areas are missing (Wallin, 2013). Research on DT “needs further conceptual refinement, especially with regard to its nature, scope, and implications for decision-making in organisations” (Bounfour, 2016, p. 23). Notably, DT affects and challenges manufacturers on multiple dimensions (Piccinini et al., 2015): From strategic decision-making (Bilgeri et al., 2017), to the conception of digital services (Zott & Amit, 2017) and their procedural implementations (Gimpel & Röglinger, 2015) (see Figure 2).

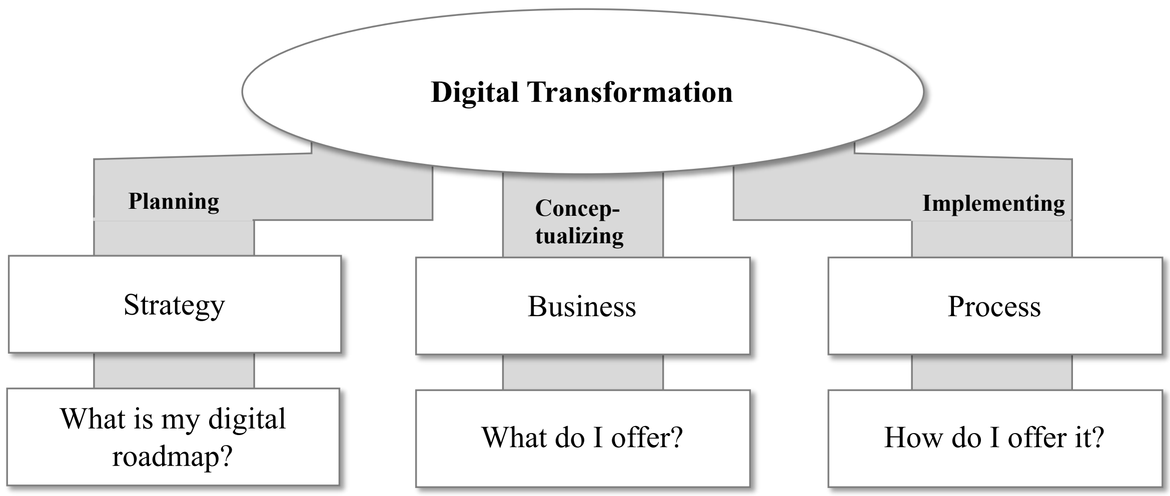

Figure 2: DT dimensions in accordance with Piccinini et al. (2015)

Hence, manufacturers undergoing DT processes need to address the questions: *”What is my digital roadmap?”*, *“What do I offer?”* and *“How do I offer it?”*. By answering these questions, an organisation can effectively incorporate strategic objectives into their revenue models and business activities (Kaiser et al., 2017). But, despite the prominence of DT on organisations’ agendas, the industry is still looking for applicable solutions to guide this process from its strategic design to its procedural implementation (Winkelhake, 2017). There is a concrete need for transformational instruments that are applicable and empower an organisation to conduct (Matt, Hess, & Benlian, 2015) and structure these environments (Winkelhake, 2017).

1.2 Objective and Research Questions

This research shall contribute to the clarification of DT implications and provide a better understanding of the changes required to utilise digital technology in an efficient way. The addressees are automotive OEMs that are in the process of digitally transforming themselves so that they can enhance their BM portfolio with digital services. Consequently, the objective of this dissertation is the investigation of the DT of automotive manufacturers to product-service providers with regards to its strategic, business and procedural dimensions. To contribute to the research for each of these dimensions and to help automotive organisations with applicable artefacts, the following research questions (RQ) were formulated:

- **RQ1:** *"How can a digital automotive ecosystem be represented and what are its essential elements and underlying topology?"*
  RQ1 refers to the strategic dimension and investigates an OEM's strategic orientation as well as an applicable topological structure of an automotive digital ecosystem taking into account infrastructural elements, stakeholders and their interdependent relations.
- **RQ2:** *"How can original equipment manufacturers be supported in the conceptualization of automotive service systems taking into account relevant stakeholders?"*
  RQ2 refers to the business dimension, exploring automotive services and their applications within service systems (SS). The results aim to support OEMs in their effort to develop digital service-based BMs and guide them during the conception of digital services by categorizing and systemizing SSs in the automotive industry.
- **RQ3:** *"How can an organisation transform its software readiness assessment procedure to enable agile digital product development within its current operational infrastructure?"*
  RQ3 refers to the procedural dimension and examines the implications of DT initiatives on an organisation's backend processes when expanding digital service development activities under consideration of the existing operational infrastructure.

1.3 Research Methodology

The dissertation addresses a relevant, practice-oriented and practice-motivated research problem. For this reason, the design-oriented framework for Information Systems (IS) following Österle et al. (2011) was applied as it aims at solving relevant issues and generating outcomes that provide utility in the form of applicable artefacts and practical courses of action, as is the stated fundamental premise of design-oriented IS research (Hevner, March, Park, & Ram, 2004). Therein, the phases analysis, design, evaluation and diffusion were repeatedly traversed, as seen in Figure 3. In addition to fulfilling the design objective by creating applicable artefacts, an explicative objective is simultaneously pursued to improve an OEM's decision-making. The applied research methods in each phase per RQ are displayed in Table 1.

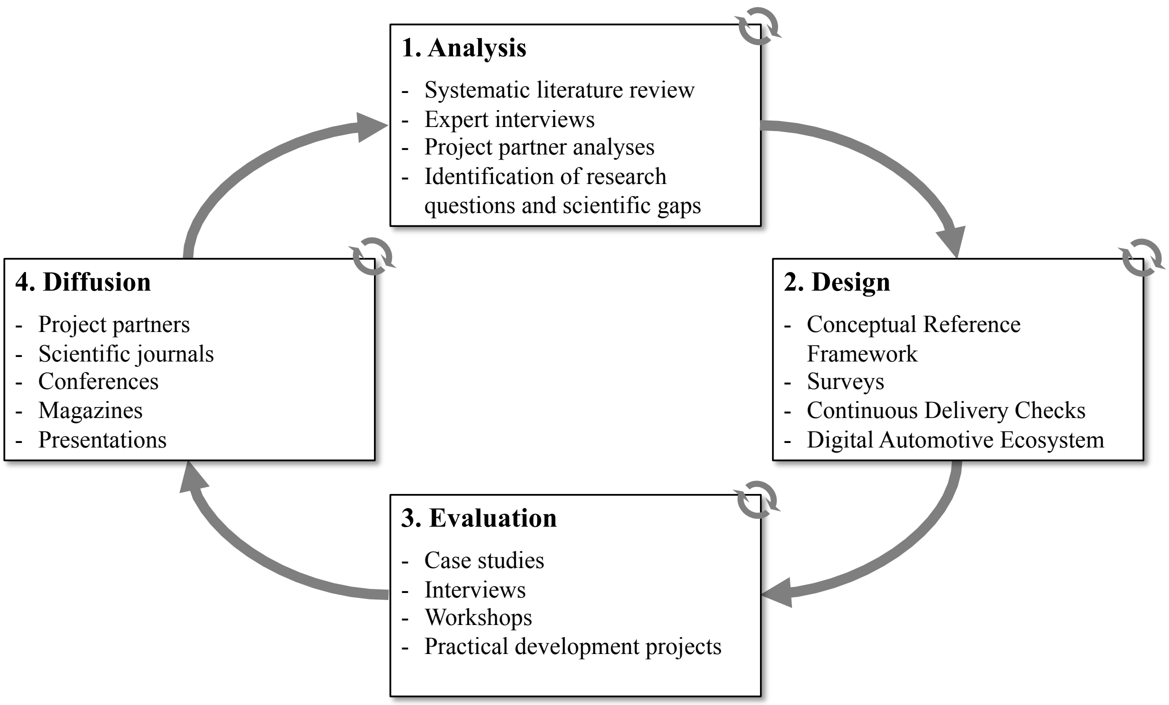

Figure 3: The design-oriented IS research framework by Österle et al. (2011)

1. Analysis

Within the analysis phase information is gathered and examined, the problem statement is described, and the research objectives are formulated. When defining the problem to be investigated, ensuring its relevance is particularly important (Österle et al., 2011). By involving case partners in the forms of an automotive OEM and a DT advisory firm, real operational problems were captured and used to inform this research. Within the analysis phase, a research plan is set up, describing and organizing the utilised research methods. Therein, practically motivated problems and scientifically substantiated research gaps were analysed.

2. Design

During the design phase, an artefact for the identified problem is developed and derived from generally recognised research methods. According to Hevner et al. (2004), design is a process and comprises a sequence of activities which create an innovative artefact. Two of the three main artefacts were developed in empirical research environments while studying an OEM, creating novel solutions within this context. In turn, this reinforces the demand to develop specific implementations that can serve as a catalyst for the examination of theories and other knowledge (Österle et al., 2011).

3. Evaluation

Throughout the research process, artefacts and applied methods were examined in multiple evaluation iterations. The evaluations were conducted practically by means of organisational projects and workshops, interviews with industry and scientific experts, and by peer-reviewed publications. In doing so, the evaluations provided feedback and enhanced the comprehension of the problem , thus improving “the quality of the product and the design process” (Hevner et al., 2004, p. 78).

4. Diffusion

Finally, the developed results were widely communicated to technology-oriented and management-oriented audiences, providing both practitioners and researchers the capability to utilise them and expand their knowledge on DT (Hevner et al., 2004). Scientific rigour was ensured by choosing peer-reviewed, high-class conferences and journals (Gregor & Hevner, 2013). Additionally, diffusion was promoted by the application of the results within case companies, and by publications at academic conferences and scientific journals. Since the research topic is of high practical relevancy, user-oriented outlets such as Wirtschaftsinformatik & Management (WuM, 2017) and Automobiltechnische Zeitschrift (ATZ, 2017) were served as well.

Table 1: Overview of the applied research methods per phase and RQ

Approach or Method	RQ 1	RQ 2	RQ 3
Analysis			
Searching and analysing literature (vom Brocke et al., 2009)	x		x
Systematically reviewing literature (Fettke, 2006)		x	
Interviewing and conducting workshops (Crowe et al., 2011; Mayring, 2014)	x		x
Analysing documents of research partners (Bowen, 2009)	x		x
Design			
Applied an Action Design Research Framework (Sein et al., 2011)			
Conceptually modelling a use case model in UML (Misbhauddin & Alshayeb, 2015; Olivé, 2007)	x		
Conceptually modelled a DE architecture (Misbhauddin & Alshayeb, 2015)	x		
Software-supported content coding using ATLAS.ti (Version 8) (ATLAS.ti Scientific Software Development GmbH, 2017; Mayring, 2014)	x		
Formation of elements by categorisation (Given, 2008)	x		
Applying a conceptual modelling approach for reference frameworks (Rößl, 1990)			
Developing a phenomenon-based research outlined by Krogh, Rossi-Lamastra, and Haefliger (2012)		x	
Formation of elements by categorization (Given, 2008)		x	
Mapping the business model canvas to the SS domain (Deelman et al., 2005)		x	
Conceptually modelling a class model in UML (Gomaa, 2005)		x	
Applying the phenomenon-based research approach by Krogh et al. (2012) within a case study research (Schramm, 1971; Yin, 2014)			
Conceptual modelling a project template and an activity diagram in UML 2 (Hoppenbrouwers et al., 2005)			x
Practice-oriented prototyping of a microservice project template (Beynon-Davies, Tudhope, & Mackay, 1999)			x

Table 2: Continued overview of the applied research methods per phase and RQ

Approach or Method	RQ 1	RQ 2	RQ 3
Evaluation			
Following guided evaluation processes for reference models (Frank, 2007)		x	x
Applied the Guided Framework for Evaluation in Design Science Research (FEDS) (Venable, Pries-Heje, & Baskerville, 2016)			
Followed a 'Human Risk & Effectiveness' strategy (Venable, Pries-Heje, & Baskerville, 2016)	x	x	x
Implementing the artefact within organisational case projects (Yin, 2014)			x
Intervening the artefact MVPs within organisational context (Sein et al. 2011) and conducting semi-structured interviews (Myers & Newman, 2007)	x		
Conducting guideline-supported interviews (Mayring, 2014)		x	x
Conducting workshops by means of a real problem case (Crowe et al. 2011)	x	x	
Qualitatively analysing data (Mayring, 2014)	x	x	x
Analåysing cross-case results (Khan & VanWynsberghe, 2008)			x
Diffusion			
Conference			x
Journal	x	x	x

1.4 Contributions

This thesis contributes to the research in empirical transformation studies of how to transform manufacturing organisations on the strategic, service conception and process levels. Further, this research contributes with specific concepts and applicable artefacts to guide automotive OEMs during DT to integrated solutions providers. The results of this thesis are presented in four peer-reviewed publications consisting of a conference proceeding and three journal articles. The publications contain three main artefacts:

1. Expert interviews and the Digital Automotive Ecosystem (DAE) as a layered conceptual model for digital ecosystem design and strategic decision support (Grieger, Glöckner, Ludwig, & Shen, 2018)

2. Literature review on Automotive Service Systems and the Conceptual Reference Framework (CRF) as a structuring framework for digital automotive service development (Grieger & Ludwig, 2017)
3. The Continuous Delivery Checks (CDC) as a methodology by which to integrate software readiness assessments into an agile development approach (Grieger, Ludwig, & Shen, 2018; Ludwig, Shen, & Grieger, 2018)

Each artefact answers one of the above posed RQs and is presented in the respective paper. The results of study 3, the Continuous Delivery Checks artefact (Grieger et al., 2018), were generalised into the transformation of software readiness assessment processes independent of industry specification, then further revised and submitted as paper 4 to the Communications of the Communications of the ACM (CACM) journal. An overview of the artefacts and publication venues is presented in Table 3.

Table 3: Publications overview by research question and artefact type

Research Question	Title	Artefact Type	Publication Venue
RQ1	Designing a Layered Conceptual Model of a Digital Ecosystem for the Automotive Industry	Layered Conceptual Model	Information Systems Journal (ISJ)
RQ2	On the Move Towards Customer-Centric Business Models in the Automotive Industry	Conceptual Reference Framework	Electronic Market (EM) Journal
RQ3	Adding Agility to Software Readiness Assessment Procedures	Design Methodology	European Conference on Information Systems (ECIS)
	Continuous Software Readiness Assessments for Agile Product Development		Communications of the ACM (CACM) Journal

According to the five different theory types in IS research following Gregor (2006) (seen in Table 4), this thesis also contributes to the Analysis, Explanation, and Design and action theory types.

Table 4: Theory types in IS research and thesis contributions (Gregor, 2006)

Theory Types in IS Research	Thesis Contribution
I Analysis	DAE (Artefact 1)
II Explanation	CRF (Artefact 2)
III Prediction	
IV Explanation and prediction	
V Design and action	CDC (Artefact 3)

The DAE adds knowledge in the analysis and description of a digital automotive ecosystem, displaying relations and interdependencies, by providing a layered, conceptual model. The CRF provides explanations on how digital services can be conceptualised within a network of multiple stakeholders. Finally, the CDC provides a concrete methodology upon which specific directives for the configuration of an agile software readiness assessment are given.

1.5 Outline

The thesis is structured in six chapters as follows: Chapter 1 motivates the research need in DT for incumbent automotive OEMs, presenting the objectives and research questions. Chapter 2 creates an understanding of the concepts and theoretical foundations in DT needs and substantiates the research gaps as described in the introduction. Chapter 3 provides and discusses a conceptual model of a digital automotive ecosystem. Following, Chapter 4 describes a literature review on automotive SSs and introduces the conceptual reference framework for digital service conception. Chapter 5 presents the Continuous Delivery Checks, a methodology by which software readiness processes are aligned to agile project development. Finally, Chapter 6 depicts the scientific and managerial contributions before concluding with the results of this thesis and recommendations for future research.

2 Background

2.1 From Interdependent Value Creation to Digital Ecosystems

2.1.1 Digitalisation Drives Collaboration

Digitisation refers to the technical aspect of converting “analog signals into a digital form, and ultimately into binary digits” (Tilson, Lyytinen, & Sørensen, 2010, p. 749). As digitisation fundamentally alters the way of handling information, its storage and transmission, this mere technical phenomenon entails diverse changes, possibilities and even competitive threats. These changes at a socio-economic level are subsumed under the term “digitalisation” which is hard to specify insofar as to what it actually means as there are many ways of interpretation (Khan, 2016). It can be defined as “applying digitizing techniques to broader social and institutional contexts that render digital technologies infrastructural” (Tilson et al., 2010, p. 749). Concerning economic contexts, digitalisation describes the transition to new BMs driven by the use of digital technologies that provide novel income and value-producing opportunities (Gartner Inc., 2017). Ultimately, digitalisation results in digital artefacts, such as new digital products or product increments (Kaiser et al., 2017).

In the automotive industry, digitalisation is understood as an important driver that enables the development of new services and their respective BMs even across organisational contexts. Especially in the fields of connected and quantified vehicles, a number of new competitors have entered the market since digitalisation has given rise to the phenomenon of “digital entrepreneurship” (Kaiser et al. 2017, p. 1), meaning more unbounded and less predefined entrepreneurial processes and outcomes. In this respect, fixed boundaries dissolve, enabling completely new value arrangements and possibly resulting in an ecosystem. Ultimately, digitalisation offers new possibilities for an increased collaboration among internal and external stakeholders (Legner et al., 2017).

2.1.2 Pursuing an Ecosystem Strategy

Value Networks

Across these collaborative relations, values are created by multiple stakeholders that mutually interact with each other in a network. To model, visualise, analyse, and optimise the business relationships and interdependencies among these stakeholders, the concept of value systems is applied. Within an organisation’s value system, linkages of physical activities are visualised between its value chains, its suppliers, distribution channels and customers (Porter, 1985). To the contrary, the value chain concept is a rather linear approach by which competitive advantage can be created by optimizing the connections and relationships of a value system (Riasanow et al., 2017). Consequently, digitalisation drives the shift from bilateral value relations to multilateral ones, elevating value systems to value networks (Biem, 2008; Peppard & Rylander, 2006). Value networks are an advancement of the value system concept that models business relations with an increased amount of connections and dependencies that more appropriately reflect the context of a globalised and digitalised world.

The concept of a value network opens up the perspective of a framework being composed of quite autonomous units, nevertheless cooperating on the basis of mutual agreements (Peppard & Rylander, 2006). Each actor concentrates on its core competencies with their connections and common value creation. Today, singular roles can no longer be clearly defined nor industries "classified as suppliers, customers and competitors" (Riasanow et al., 2017, p. 3193). The concept of value networks facilitates the visualisation of mutual exchanges, complex cooperation relationships and alliances. Moreover, it displays the value streams between all actors in the network. In the generic value network of the automotive industry, Riasanow et al. (2017) shows the complexity of these value streams and introduces new market roles such as *disruptive technology providers*. The authors argue that "the automotive industry transformed to a multi-sided value network, and thus moves away from the traditional one-sided supplier-buyer business model" (p. 3197).

Digital Platforms

Within the digital domain, value networks can be beneficially used to conceptualise digital platforms (DPs) and their cooperative relationships. DPs have experienced emerging interest within IS research due to their transformational power in leading to changes in communication and client-provider-interaction (Spagnoletti, Resca, & Lee, 2015), developments in inter-organisational relations (Eaton, Elaluf-Calderwood, Sørensen, & Yoo, 2015), and adaptations from monolithic system architectures to modular DPs (Tiwana, Konsynski, & Bush, 2010). Reuver et al. (2017) establishes two perspectives on DPs, a technical and a sociotechnical. According to the technical view, platforms are understood as extensible codebases, serving as a basis for ecosystems in which third-party modules are added to this codebase (Boudreau, 2012; Tiwana et al., 2010). Following the sociotechnical view, a DP is seen as an assemblage of technical elements (software or hardware) and related organisational procedures (Tilson et al., 2012). Many researchers have also examined the question of governance regarding DPs raising the question of balancing different, sometimes diverging, interests (Darking et al., 2008). Wareham et al. (2014) apply the concept of dialogical relationships, whereas Tilson et al. (2010) study paradoxical relationships of change and control.

All in all, “digital platforms can be seen as a less complex subtype of digital infrastructure with specific control arrangements (Hanseth & Lyytinen, 2010)” (Reuver et al., 2017, p. 4). Thus, they represent an expandable software system, which provides core features that are shared by the components and interfaces which interact with it (Tiwana et al., 2010).

Platform approaches influence businesses, networks and even collaboration and competition dynamics, thus, having the potential to transform entire economies (Gawer & Cusumano, 2002; Parker, van Alstyne, & Choudary, 2017; Reuver et al., 2017). DPs are just as complex as the objects they handle resulting from the foundation of sub-systems, platforms and infrastructures (Evans & Basole, 2016; Reuver et al., 2017), such as hardware, operating systems, apps and browsers (Pon, Seppälä, & Kenney, 2014), and their distributed characteristics (Henfridsson, Mathiassen, & Svahn, 2014). In the context of the automotive industry, OEMs must develop scalable platforms and heavily invest in IT technologies to be able to simultaneously provide “high security, uptime, performance, fault tolerance, redundancy, and safety” (Tian, Chin, & Karg, 2016, p. 6). Often organisations establish platforms first and strategically develop them into an ecosystem consisting of several entities (Tan et al., 2015).

Ecosystems

Following, the term “ecosystem” and its differentiation from other concepts that similarly focus on interdependent activities or organisations is clarified, as sometimes, terms like “ecosystem”, “platform” and “market” are used as synonyms within scientific literature (Tan et al., 2015, p. 250).

The biological metaphor of an “ecosystem” was introduced by Moore (1996, p. 26) into business literature to explain the evolutionary development of processes, rivalries, competition, and ways of interaction within a community. Thus, a picture was drawn of an interdependent, self-organizing network with single actors being entangled amongst each other as mutually interdependent entities. Other researchers, such as Iansiti and Levien (2004, p. 8) follow this network-view, and specify that an ecosystem is “characterized by a large number of loosely interconnected participants who depend on each other for their mutual effectiveness and survival”. The perspective of putting actors and their interdependent relationships into the centre of analysis has been coined as “ecosystem-as-affiliation” by Adner (2017, p. 41).

To differentiate this view from other concepts handling similar phenomena of interdependence, such as networks, platforms, and multisided markets, Adner (2017) introduces the concept of an “ecosystem-as-structure”, putting the value proposition at the centre. Rather than focusing on actors, Adner (2017) focuses on the actors’ activities to fulfill the value proposition. Following a structuralist approach, he defines an ecosystem as “the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize” (p. 40).

Furthermore, Adner (2017) demonstrates that the two concepts build up a line of argumentation along opposite directions: Ecosystem-as-affiliation starts with actors, follows their links to other actors and finally identifies potential value propositions, whereas the ecosystem-as-structure perspective inversely starts from the value proposition, identifies “the activities required for its materialization, and ends with actors that need to be aligned” (p. 44). Following the approach of the ecosystem forming around a focal actor as the ecosystem leader (ecosystem-as-affiliation), an ecosystem is constituted of the following elements, as can be seen in Figure 4:

- *Actors,* being entities that are connected to a central actor
- *Positions*, which can be derived from links to other actors and
- *Links,* that tie the actors together (Adner, 2017).

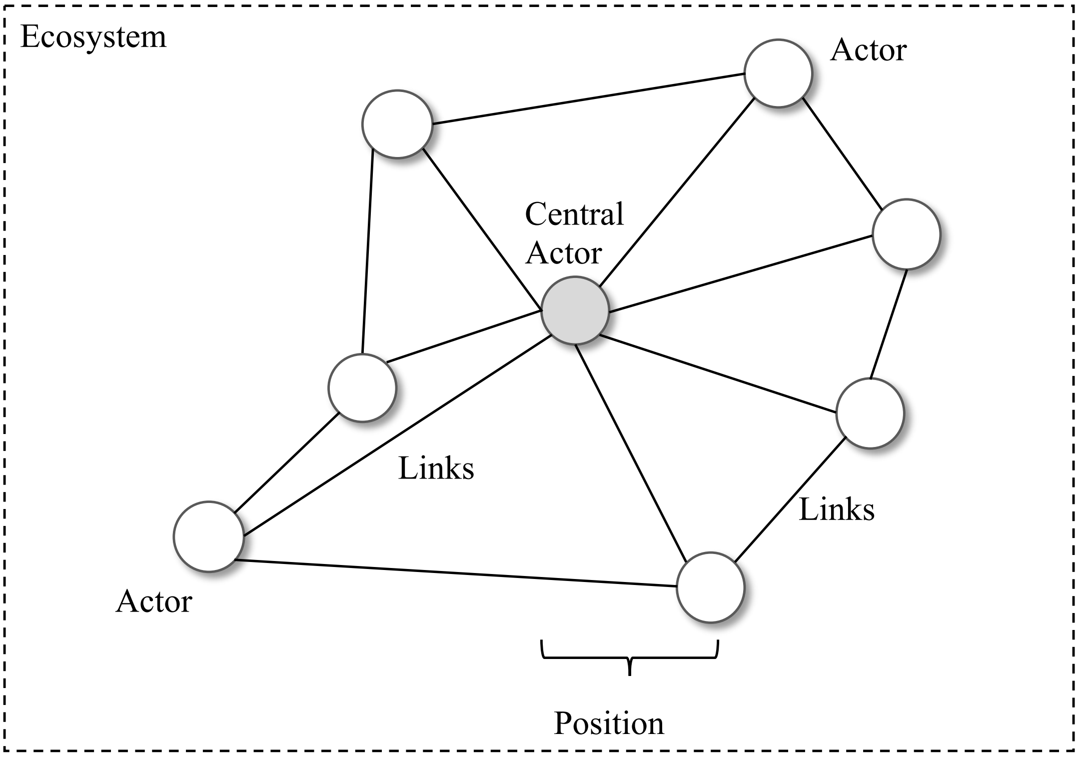

Figure 4: Ecosystem elements following Adner (2017)

For instance, an ecosystem leader can empower contributories by providing beneficial tools and services which attracts more stakeholders entering the ecosystem or underlying platform, thus, leveraging the system's overall attractiveness and benefits (Tan et al., 2015). Many OEMs have already set up business ecosystems to increase profitability and impact (Altman & Tushman, 2017), reducing their operating costs as well as providing higher service quality to customers (Tan et al., 2015). Accordingly, they are in the process of enhancing their value propositions in the digital sphere, setting up their own digital ecosystems (DEs).

Digital Ecosystems

Studies indicate that companies that predominantly generate revenues via DEs, know end customers better than average typically accounting a 32% higher growth in revenue and a 27% higher margin of profit than their competitors (Weill & Woerner, 2015).

A DE can "be defined as an open, loosely coupled, domain clustered, demand-driven, self-organising agent environment, where each agent of each species is proactive and responsive regarding its own benefit/profit [...] but is also responsible to its system" (Boley & Chang 2007, p. 399). Differing from biological and social ecosystems, DEs remove geographic limitations and offer instruments for collaboration across systems as they are not hindered by physical barriers. Their elasticity allows overlapping with other ecosystems as a single system, capturing the benefits of collaborating with other entities (Boley & Chang, 2007).

DEs are thus an environment of interconnected stakeholders that mutually rely on each other (Peltoniemi & Vuori, 2008) and work synergistically to offer customer value (Tan et al., 2015). Various organisations are converging towards one another as mutual interactions gain in importance (Paulus-Rohmer et al., 2016), as illustrated in the case with Apple, which successfully integrated digital services and tethered partners to maintain a powerful position in an otherwise commoditised hardware market. Reuver et al. (2017) further structures DEs by distinguishing them from a technological and organisational point of view, emphasizing the importance of further investigation into the conceptual representation of the "structure and dynamics of digital ecosystems" (p. 6).

Assumingly, the number of mobile platforms and ecosystems will grow (Sørensen, Reuver, & Basole, 2015) and DE arrangements will become more complex (Bilgeri et al., 2017). DEs and platforms are closely interconnected, with some researchers even use the terms synonymously (Reuver et al., 2017). Both platforms and ecosystems are based on interrelations of individually acting stakeholders that could be cooperating and competing on different fields at the same time (Gawer & Cusumano, 2002; Thomas, Autio, & Gann, 2014). Following Uludağ, Hefele, & Matthes (2016), platforms are regarded to be contributing entities for the development of DEs within this study. Concludingly, DE can be distinguished from extant strategic approaches as can been seen in Table 5.

Table 5: Definition of a DE and extant concepts of strategic interdependence

Concept	**Characteristic**	**Example**
Supply Chain and Value Chain	▪ "Make vs. buy decisions; bargaining; partner reliability" to manage and secure supply (Adner, 2017, p. 52) ▪ A linear path with clear and accepted roles, and positions of suppliers and buyers	Toyota
Value Network:	▪ A framework comprised of autonomous units, cooperating on the basis of mutual agreements (Peppard & Rylander, 2006). ▪ Focus on a broad set of parties: firm, rivals, customers, suppliers, complementors (Adner, 2017)	Tesla
Digital Platform	▪ Focus on technology (access, incentives, control) and the provision of interfaces for different actors (Adner, 2017) ▪ Contributing entities for the development of DEs	RIO MAN
Digital Ecosystem	▪ Ecosystem-as-affiliation with focus on actors and a network view vs. ecosystem-as-structure with focus on activities and a common value proposition (Adner, 2017) ▪ Loosely coupled and self-organizing environment (Boley & Chang 2007) with mutual interdependence of stakeholders (Peltoniemi & Vuori, 2008)	UBER

Ecosystem Strategy

Ecosystem structures are not always visible in mature industries when changes result in few to no adaptations leaving the ecosystem structure, actors, their positions and the established relationships unaffected (Adner, 2017; Nelson & Winter, 1982). Many companies have an antiquated picture of what taking part in, or even steering, a linear value chain looks like, never mind the idea of being a single element within a multidimensional ecosystem (Weill & Woerner, 2015). However, when innovation, such as digitalisation, affects both the established configurations and the underlying structure, a crucial moment arises when "the ecosystem becomes apparent and where consideration of ecosystem dynamics becomes critical for crafting and understanding strategy" (Adner, 2017, p. 44). In this regard, an

ecosystem perspective can help organisations in situations where activities, positions, actors and relationships need to be rearranged, new links established and co-innovations made.
Adner (2017) illustrates his point with an example of an innovation in the tire industry where Michelin introduced the PAX run-flat tire that allows vehicles to continue driving for 125 miles after puncturing. As workshops had to accept a new generation of tire repair equipment, they "shifted from being latent members of the ecosystem to being actors whose participation would be a matter of their own choice" (Adner, 2017, p. 46). If this acceptance had not happened, or if consumers would not have demanded the new tires, the whole system would not have worked in the expected way.
Hence, in situations like these, with changes occurring in at least one of the three structural elements of actors, positions and links, the analytical concept of an ecosystem is of a high explanatory utility. Therefore, taking an ecosystem perspective can be especially useful in digital environments as digitalisation and "the phenomenon of digital transformation is rapidly and fundamentally changing existing businesses and organisations alike" (Khan, 2016, p. 1; Collin, 2015).

Table 6: Advantage of an ecosystem strategy

Having an ecosystem strategy helps to manage situations where activities, positions, actors and relationships need to be rearranged, new links established and co-innovations made (Adner, 2017)

According to Adner (2017, p. 47) an "ecosystem strategy is defined by the way in which a focal firm approaches the alignment of partners and secures its role in a competitive ecosystem." In doing so, an organisation focuses on the number of actors being linked to a focal actor or platform and on questions of power (Brandenburger & Nalebuff, 1996; Jacobides, Knudsen, & Augier, 2006). Having an ecosystem strategy helps to manage these aspects and possible shifts in structure, including the elements that should be aligned, the ways to design the alignment, and methods for managing rivalries within and across ecosystems (Adner, 2017). Closely linked to this is the question of the ecosystem leader and followers: As each actor pursues its own objectives, ecosystem strategies can be in line or collide with the strategies of other actors. Therefore, the focal firm must try to align partners as they are intended in the ecosystem with their ecosystem strategy. Co-innovation and adoption risks can potentially threaten the success of this alignment as well as expectation gaps about the leader-follower role. Ecosystem leaders can be seen as members of the ecosystem who have achieved their visions and are able to set certain conditions. Ecosystem followers orient themselves to these and align their actions respectively. “If the heart of traditional strategy is the search for competitive advantage, the heart of ecosystem strategy is the search for alignment” (Adner, 2017, p. 49).

All in all, organisations pursue an ecosystem strategy to reduce operating costs and higher service quality (Tan et al. 2015), and for increased revenue growth and profit margin potential than that of their competitors as indicated by empirical investigations (Weill & Woerner, 2015). Additionally, organisations that pursue these strategies become more open (Boudreau, 2012), engage in interdependent relationships outside of their organisational boundaries and pursue coopetition BMs (Altman & Tushmann, 2017; Brandenburger & Nalebuff, 1996).

2.1.3 Research Gaps and Strategy Formulation Obstacles

The development of a DE challenges manufacturers in multiple aspects as adopting digital technologies for an integrated service delivery ultimately alters the organisation’s value creational activities and strategic IT objectives (Bilgeri et al., 2017). A major obstacle faced by automotive incumbents is competition within DEs as new and non-industry rivals are entering the market. If OEMs follow a DE strategy, they must digitally transform themselves concerning multiple IT dimensions (Piccini et al., 2015). According to Bilgeri et al. (2017), large manufacturers that are in the process of transforming from sellers of solely physical products to digitally integrated solutions lack the knowledge that meet the needs of digitalisation, i.e. “where and how to allocate and align digital capabilities within their organisational structures” (p. 2). New organisational structures are necessary as current ones are critical barriers against the ability to implement and develop digital strategies and offerings (Lindgren, Eriksson, & Lyytinen, 2015).

Compared to their importance in practice, research on the topological structure of DEs is not comprehensive and practical insights are scant as there is still a lack of clarity on specifications, scoping and design within practitioner and academic discourse (Sørensen et al., 2015). Studies demand the investigation of stakeholder networks, their composition, and their structural interactions (Reuver, et al., 2017). Although new communication and coordination possibilities have caused great scientific interest with regards to issues of strategy and interdependence leading to several new concepts, such as that of DEs, there is still a missing connection to the structure of value creation (Adner, 2017). Further, research on the boundaries of an ecosystem, what positions to include, and how far to trace the respective influences and basics, is still a gap to be investigated (Adner, 2017). In this respect, the questions on coordination, sequencing, and the role of institutions or regulators in influencing processes of alignment and creating the context need to be addressed as well (Adner, 2017; Hannah & Eisenhardt, 2016; Jacobides, MacDuffie, & Tae, 2015). So far, few studies have investigated what constitutes DEs and how to compose essential elements (Paulus-Rohmer et al., 2016). Though some studies address all design dimensions and do propose procedural models or frameworks to implement or analyse DEs, they fall short in explaining its architecture and structural composition. Further, no studies could be identified that provide conceptual models for OEMs to scope and topologically outline DEs themselves. An overview of the identified managerial obstacles and research gaps needing to be addressed is given in Figure 5.

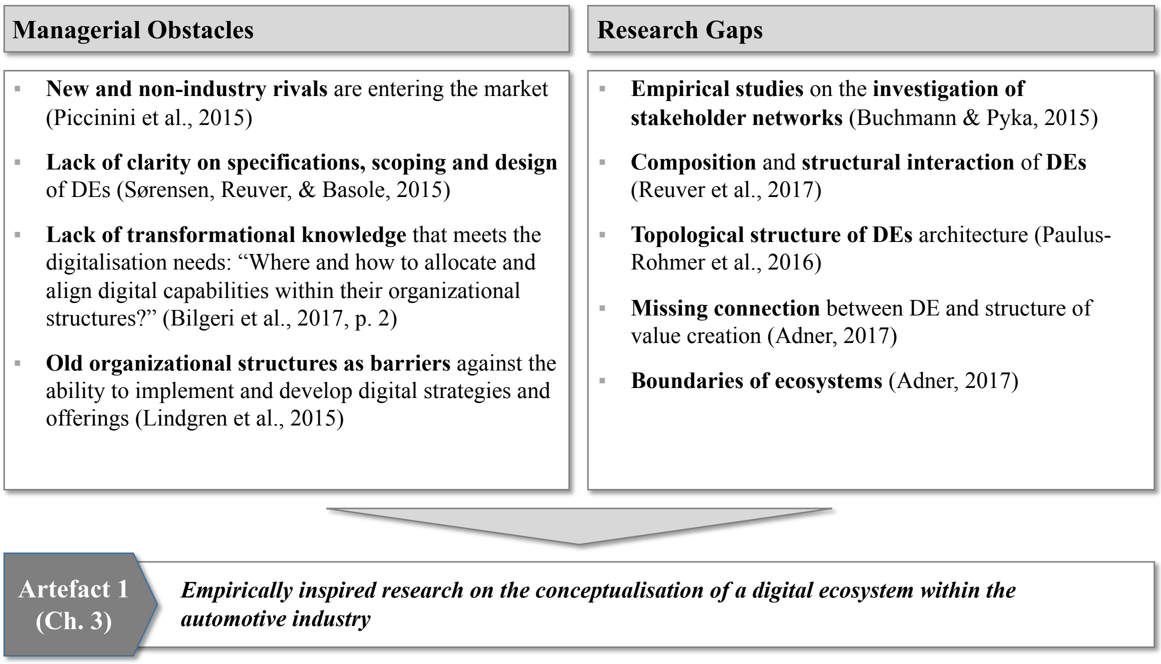

Figure 5: Overview of research gaps and strategic obstacles

The research gap to investigate the conceptualization of a DE in an empirical context is explored in study 1 (Chapter 3).

2.2 From Products to Product-Service Solutions

2.2.1 Digital Service Fulfilment Requires Co-Creational Networks

Digitalisation is seen to be a profound and lasting evolution that reinforces IT importance in the automotive sector (Frey, Charissis, & Nahm, 2016) and ultimately propels the shift towards digital services (Kaiser et al., 2017). The enhancement of a manufacturer's portfolio with the bundling of goods and services is a longstanding trend, not least among automotive OEMs, referred to as "servitization" (Baines et al., 2009; Vandermerwe & Rada, 1988; Verstrepen, Deschoolmeester, & Berg, 1999). Boundaries between the service and the manufacturing sector are blurring as one or several services are added to a product (Beuren et al., 2013; Mahut et al., 2015). As goods become increasingly commoditised and thus suffer lower profit margins, services can be instruments for both the differentiation in the pursuit of building competitive advantages (Porter, 1985) and for the generation of different sources of income (Suarez, Cusumano, & Kahl, 2013). Rolls Royce is an example of a successful implementation of a servitization strategy as they had shifted their aircraft engine manufacturing division from selling products to selling performance using an IoT approach and establishing a strong network of maintenance infrastructures all over the world (Mahut et al., 2015)

Service-Dominant Logic

Traditionally, manufacturing firms put tangible goods in the centre of activity focusing on goods-oriented BMs (Ibusuki & Kaminski, 2007; Orsato & Wells, 2007). As firms servitized their products, these service activities were operated similarly to the prevalent goods-orientated engineering mindset (Ng, Parry, Smith, Maull, & Briscoe, 2012). This mindset necessitates that the producers' responsibility ends with the ownership transfer of the product to the costumer (Ng et al., 2012), with the way in which the product is used being of little importance. Contrary to the prevalent goods-centred view in manufacturing firms, Lusch and Vargo (2014) introduced a course of thought where the customer is the centrepiece, called service-centred dominant logic (SDL) (Lusch & Vargo, 2014; Kuzgun & Asugman, 2015). The SDL suggests that servitization is one of the key trends in an increasingly digitalised and interconnected world (Lusch & Vargo, 2014). In SDL, services are broadly defined as the exchange of resources to the benefit of the recipient and are seen as "the fundamental basis of exchange" (Vargo & Lusch, 2008, p. 7), i.e., a value proposition for customers, be it for the individuals (e.g. automobile drivers) or organisations (e.g. logistic service providers) (Lusch & Vargo, 2014). The value of the goods lies in the carriage of these services (Spohrer, Maglio, Bailey, & Gruhl, 2007). In this sense, vehicles are seen to be goods for the provision of mobility services. Changing customer expectations on mobility and technology drive this development, influencing and even forcing reactions and adaptations by OEMs. So, in combination with different societal trends, it is the availability and applicability of digital technologies which propels the shift from a GDL to an SDL.

Product-Service Systems

The above-mentioned example of Rolls Royce demonstrates manufacturers not giving up on product development, but rather enhancing their current value propositions with additional services, building the respective BM around them. In this way, manufacturers offer integrated, marketable solutions of both goods and services that meet consumer demands, scientifically referred to as product-service systems (PSS) (Beuren et al., 2013; Reim, Lenka, Frishammar, & Parid, 2017). Boehm and Thomas (2013, p. 252) define a PSS as "an integrated bundle of products and services which aims at creating customer utility and generating value."

The concept of PSS describes a transformational process from manufacturing firms to product-service solution providers (Gaiardelli et al., 2015). Davies et al. (2006) argue that integrated solutions offer greater customer value than individual products or services. Specifying this process, Sakao and Shimomura (2007) developed a model for service delivery including the elements service provider and service channel.

Table 7: PSS characteristics

PSS are "an integrated bundle of products and services which aims at creating customer utility and generating value" (Boehm & Thomas, 2013, p. 252)

The benefits of this integrated service offering can be increased efficiency, improved resource allocation and more customer touchpoints, resulting in both positive economic and environmental effects (Mont, 2002; Reim et al., 2017). PSSs in the automotive industry have shown beneficial calculable cost reductions for consumers, for instance, in maintenance measures as manufacturers can offer service agreements (Mahut et al., 2015).

Research on PSS has focused on the typification of PSS between product-oriented, use-oriented and result-oriented (Tukker & Tischner, 2006), its classification (Oliva & Kallenberg, 2003), dimensions of product extensions (Uchihira et al., 2008) and the role of services within the PSS (Mathieu, 2001). Currently, most manufacturers are still product-centred, however, there is an increasing number of mobility services providers like UBER and Lyft that are providing result-oriented services, leading to a clear "dichotomy" between these two groups of stakeholders (Mahut et al., 2015).

Berman (2012) demonstrates that companies can successfully integrate hardware and software if they both build up digital technology capabilities that enable customer involvement in the value creation process and the ability to reshape their value proposition. Davies et al. (2006) list examples of manufacturing corporations that have successfully integrated hardware and software, offering solutions and, thus, differentiating themselves via high-value propositions. Hence, digital offerings lead to a transformation of a "punctual selling exchange into a relationship-based contract, giving customer utility and to creating value" (Mahut et al., 2015, p. 843).

Integrating the PSS concept within an organisation requires the adaptation of its operating model, infrastructural conditions, and internal procedures. To guarantee PSS offerings over the entire lifecycle, manufacturers have to establish an infrastructure supporting the service delivery defined as a "network" by Mont (2002). Among the barriers identified in the adoption of a PSS by Kuo et al. (2010), the main ones are a general lack of awareness regarding PSS, insufficient support by laws and regulations, and high efforts to guarantee the maintenance of SS (Mahut et al., 2015).

Cavalieri and Pezzotta (2012) acknowledge the necessity of different skills and expertise for service engineering and product design. Most companies are challenged by the efforts needed to offer PSS solutions because of their internal inability to successfully design and implement PSS BMs (Barquet et al. 2015). Additionally, research still needs to contribute to the knowledge with regard to infrastructures, methodologies supporting transitional processes, facilitation for the development of a product-service offering as well as tools that monitor and improve PSS (Mahut et al., 2015; Reim et al., 2017; Vezzoli, Kohtala, & Srinivasan, 2017; Wallin, 2013).

Automotive Services

In the automotive industry, digital service development is driven from external pressure on incumbents by the entry of new competitors (Chanias & Hess, 2016), and rising environmental regulations (Firnkorn & Müller, 2012) in addition to the OEM's intrinsic motivation to generate new income sources. According to Juehling et al. (2010), automotive services comprise all services that provide benefit for customers over the vehicle's life cycle and can be generally distinguished between technical and non-technical services. In addition, Mahut et al. (2015, p. 846) classifies these services as "pre-sales", "sales" and "after sales", ultimately remaining product-related. Many researchers investigate technical services, more specifically, some form of assisted driving system (see Bengler et al., 2014; Guériau et al., 2016; Mahut et al., 2015). Their primary aim is to increase the carriers' safety, e.g. via early brake support, collision mitigation, ABS, ESP, etc. These technical services are triggered through sensory input with computations taking place within the vehicle. Technology around driving assistance systems brings about more automatic and cooperative driving (Bengler et al., 2014), upgrading the control of the vehicle from manual operation to semi-autonomous or autonomous driving.

Connected, digitalised vehicles can be understood as mobile IoT-devices, consisting of distinct value-creating dimensions, as seen in Figure 6 (Fleisch, Weinberger, & Wortmann, 2014). The dimensions do not have to causally build on top of each other but are all necessary in order to fulfil the digital service provision.

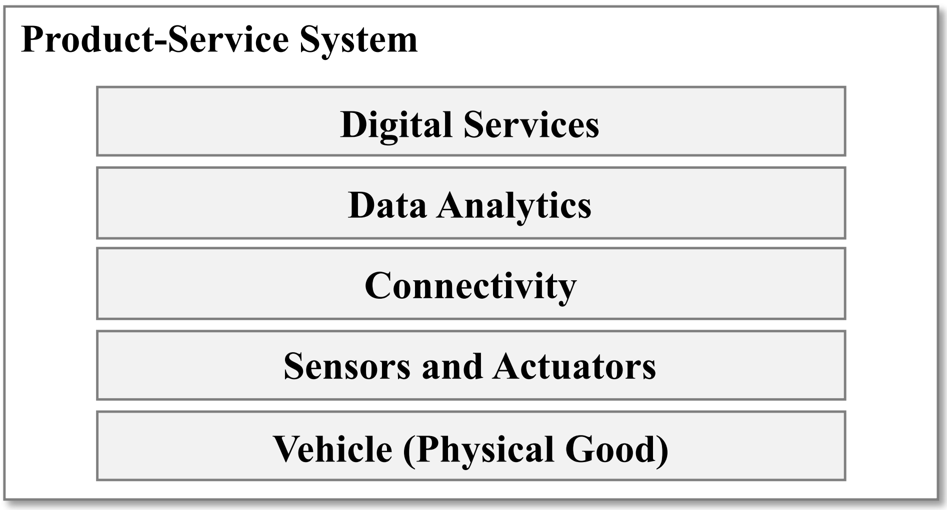

Figure 6: Value-creating dimensions of PSS after Fleisch et al. (2014)

To create integrated service solutions, OEMs must attain an understanding "of its participants, processes and activities that they perform, the product/services that are produced, the customers, and so on", which can then be beneficially conceptualised as a SS (Alter 2017, p. 1828).

Service Systems

SSs exist on a variety of levels (Hefley, Murphy, Demirkan, Spohrer, & Krishna, 2011). They can be a single person, organisations, corporations or the entire world (Maglio & Spohrer, 2013). Spohrer et al. (2007) describe a SS as the dynamic combination of resources that possibly generate value with other SSs through shared information. A SS in this manner is characterised by a co-creation of value (Maglio & Spohrer, 2013) and can thus be considered a basic abstraction of SDL. This shared information contains language (e.g. binary digits), laws (e.g. contracts) and measures (e.g. prices). Alter (2017, p. 1828) describes SSs as “work systems that produce product/services and that may or may not involve coproduction by customers and value co-creation.” Normann (2001) argues that each SS acts as both a provider and as a client of services within connected value networks. Therefore, an automotive SS can be broadly defined as a network of people, technology, and organisations that create and deliver mobility-related services. For instance, the provision of a navigational service can be conceptualised within a SS. A driver who is willing to send his position data when using navigational services, such as Google Maps, generates additional value. Thus, involving customers in collaboration with the service provider co-creates value (Lusch & Vargo, 2014; Normann, 2001; Ng et al., 2012).

Customer-Centric Co-Creation

Value in an SS is created during a co-creation process by technology, people, and shared information (Maglio & Spohrer, 2013). This implies services are generated in ecosystems, or actor-to-actor networks, representing the central theme of SDL. In these ecosystems, value is no longer created by one actor, but increasingly created through co-creation, making the understanding of the underlying value network crucial (Riasanow et al., 2017, p. 3192). Being purely customer-oriented, customers are collaborators in value creational or client-provider-networks (Spohrer et al., 2007; Siegmann, 2014), thus, the customer is seen as one of the stakeholders (Mahut et al., 2015) and as a “co-creator of value” (Hanelt et al., 2015, p. 1324). Such as in the example of a driver who is willing to share their location when using navigational services, this data can be of value to other stakeholders. In turn, customer involvement together with firms co-create value-in-use within a SS (Lusch & Vargo, 2014; Ng et al., 2012; Normann, 2001).

The understanding of value creation is derived from the perspective one applies to the concept. Mele and Polese (2011) elaborate upon the distinguishing characteristics between supplier-centric, customer-centric and stakeholder-centric value perspectives (see Table 8). They describe the supplier-centric perspective as being a representation of GDL with an exchange occurring between a provider of a valued service and a customer. They elucidate on how service is delivered through a transaction with a customer who uses the service but does not contribute to the value creation process. Furthermore, the authors differentiate the customer-centric perspective as being closely aligned with SDL, where the value is created when the product or service is used, shifting the emphasis to the customer. In this context, they characterise the customer as being actively involved in the value-creation process, acting as a so called "prosumer". Rather than just an exchange of value, value becomes inherent in the service's usage (Lusch & Vargo, 2014; Mele & Polese, 2011).

Table 8: Value creation perspectives after Mele and Polese (2011)

Logic Representation	**Perspective**	**Value Substance**	**Process**
Goods-dominant logic	Supplier-centric	Value-in-exchange	Value creation of product or service provider
Service-dominant logic	Customer-centric	Value-in-exchange / Value-in-use	Value co-creation
Co-creational network	Stakeholder-centric	Value-in-exchange / Value-in-use / Value-in-experience	Value co-creation among SS actors

In a stakeholder-centric perspective value is co-created in networks among SS actors (Mele & Polese, 2011). According to Ballantyne and Varey (2006), the service offered to the customer is a fulfilment of multiple co-creations within a network of interdependent stakeholders (Ballantyne & Varey, 2006; Mele & Polese, 2011). Resources, be they tangible or intangible, are exchanged and shared among the network participants to achieve certain objectives. This perspective suggests that the customer is one of the many beneficiaries as all stakeholders co-create value in the SS and expect it in return (Mele & Polese, 2011). As Maglio and Spohrer (2013) point out, the formative procedure occurs in complex global networks rather than isolated local processes, leading to a paradigm shift from an individual "service system managing particular stakeholders" (p. 41) towards a collaboration as partners from multiple SSs in a co-creational network.

The definition of SS and automotive SS in particular are inextricably linked to networks. Value-adding activities within these networks are collaborations between many stakeholders, whose communication and coordination are efficiently facilitated by digital technologies. Starting with this co-creational perspective, OEMs also intend to initiate and incorporate more customer-centric service development approaches into their operational activities (Capon & Senn, 2017). Concepting services in this way, enables OEMs to maintain customer contact beyond the point of sale (Hoffmann & Leimeister, 2011). However, it remains to be analysed how customers and other stakeholders can be integrated into value creation processes underlying a shared service offering, especially in the context of the automotive industry (Bucherer, Eisert, & Gassmann, 2012; Chesbrough 2010; Spieth et al. 2014).

2.2.2 Enhancing Business Models with Digital Services

Business Models

Service provision and innovation will only occur if an organisation is able to monetise them, established through an organisation's BM (Chesbrough, 2010). Research on BMs arose with the proliferation of the electronic market in the 1990s and its novel approach of doing business (Bucherer et al. 2012; Gibson & Jetter, 2014; Morris et al., 2006). Adequate frameworks and methodologies that could explain these unconventional ways of developing digital businesses were missing (Morris et al., 2006) and the BM concept was able to provide a way to combine these distinct perspectives (Bucherer et al., 2012). Since its creation, researchers have not been able to agree on one generally accepted definition of a BM (Chesbrough, 2010; Morris et al., 2006), but for the practical application of this contribution, Osterwalder and Pigneur's (2011) definition is followed which describes a BM as the way in which companies capture, deliver and create value. Digital BMs in this context are comprised of concepts where digital technologies fundamentally transform a company's business operations as well as the way income is generated (Veit et al., 2014). They offer new ways to conceptualise customer integration in the value creation process. Subject to the perspective, several components make up BMs including financial, customer relationships, value proposition and operational aspects (Bucherer et al., 2012; Morris et al., 2006; Osterwalder & Pigneur, 2011).

As the research on BMs matured, the understanding regarding definitions (Morris et al., 2006; Timmers, 1998, p. 4), classifications (Burkhart, Krumeich, Werth, & Loos, 2011; Timmers, 1998) evaluations, dimensions and frameworks (Al-Debei & Avison, 2010; Osterwalder, 2004) grew. A variety of concepts and frameworks were introduced to capture and initiate BMs, differing in extent and depth. Among them are Timmers' (1998) three step-approach, Morris et al.'s (2006) six-core component, Osterwalder and Pigneur's (2011) nine-component BM canvas and Gassmann et al.'s (2014) St. Gallener Business Navigator methodology.

Business Model Innovation

BM innovation, on the other hand, is a relatively recent object of research and adds an element of novelty that can reconfigure and define a company's core business logically and structurally, or create an entire new market, e.g. Facebook or Cirque du Soleil (Bucherer et al., 2012; Freiling, 2015; Spieth et al., 2014). Chesbrough (2010) reasons that BM innovation "requires significant trial and error, and quite a bit of adaptation ex post" (p. 356). Though authors promote this entrepreneurial way (Günzel-Jensen & Holm, 2015; Sosna, Trevinyo-Rodríguez, & Velamuri, 2010), the application of suitable frameworks and methods could minimise development costs and accelerate time-to-market (Günzel-Jensen & Holm, 2015; Reim et al., 2017). What is suitable and applicable depends on the respective business case and market, but research indicates that more theoretical constructs and empirical cases are needed (Bucherer et al., 2012; Foss & Saebi, 2017; Spieth et al., 2014).

Digital Automotive Business Models

Digitalisation, and consequently DT, causes several types of BM changes. OEMs strategically shift "from delivering only a product (the vehicle), towards delivering also a service (mobility)" (Hanelt et al., 2015, p. 1321). In this context, the importance placed by a customer on the vehicle as a status symbol decreases and shared mobility services are welcomed as an alternative. Consequently, the relation between the OEM and its customers has changed as the predominant ownership revenue model of one car belonging to one customer has been enhanced by pay-per-use BMs, "leading to an n:n type of relationship" (Hanelt et al., 2015, p. 1321). The portfolio of digital automotive services is expected to increase: new strategic alliances are being built up, and start-ups, e.g. in the sector of connected vehicles, are considered a promising possibility for investments (Kaiser et al., 2017).

Table 9: Business model enhancement

The provision of digital automotive service requires OEMs to enhance and innovate upon their current BM portfolio within a connected vehicle environment (Chanias & Hess, 2016)

With the decision to become a digital automotive service provider, an OEM's strategy changes. As in the physical world, OEMs need to focus on finding potential network partners (Riasanow et a., 2017), while also concentrating on building open ecosystems and multi-sided BMs (Mele & Polese, 2011; Tian et al., 2016). When automotive manufacturers offer product-related digital services themselves, they have "enter[ed] the digital world" (Hanelt et al., 2015, p. 1322).

Generally, Kaiser et al. (2017, p. 6) identified three approaches regarding digital automotive service offerings: "Brand dependent assistance services [...], Brand-independent apps and services [...], and strategic alliances of vehicle manufacturers with ICT firms." To provision these service offerings, OEM's have to enhance and innovate upon their current BM portfolio within a digitalised vehicle environment (Chanias & Hess, 2016). A first attempt by the German automotive industry in the early 2000s to provide services to gain competitive advantages over other manufacturers failed (Hoffmann & Leimeister, 2011), as the services did not fulfil customers' expectations among other things (Werder, 2005). Those experiences and additional research indicate (Chanias & Hess, 2016) that OEMs have difficulties concepting digital services that customers desire and want (Piccinini et al., 2015).

2.2.3 Research Gaps and Service Conception Obstacles

While the SDL has been fundamental for the understanding of the service provision, the role of the customer and its market consequences (Kuzgun & Asugman, 2015; Lusch & Vargo, 2014), the concepts still "lack the strategic, functional and tactical directions for organisations to apply" them (Gaiardelli et al., 2015, p. 1165). Most organisational and BM research studies focus on the adding of particular services rather than the transformational process (Gaiardelli et al., 2015; Kuzgun & Asugman, 2015). Furthermore, organisations find it hard to cope with the transformation towards a greater service provision, as the transition eventually causes higher costs and does not bring the expected results (Cavalieri & Pezzotta, 2012).

Research presumes that one of the biggest obstacles in the process of service transformation is a change in mindset from merely exchanging a produced good towards offering an integrated solution and thus delivering value-in-use (Baines et al., 2007; Kowalkowski et al., 2017). To do so, the creation of value has to be seen out of a customer-oriented perspective, representing a great challenge for manufacturing firms as their business logic tends to focus on product-based thinking (Capon & Senn, 2017).

No framework or method makes the claim of being an all-encompassing approach. Beuren et al. (2013) note that experience and knowledge regarding PSS BMs is small and not sufficiently exchanged between business and academia. As Veit et al. (2014) points out, so far BM concepts have only taken generic aspects into account, without considering industry specifics (Veit et al., 2014) and research in the field of innovating BMs provides many opportunities as it is of present relevance (Spieth et al., 2014). Companies have a demand for assistance in the transformation of BMs (Foss & Saebi, 2017) and further research support is necessary in giving implementation guidance (Massa, Tucci, & Afuah, 2017). In addition, there are few insights regarding digital automotive SSs, their composition and relevant stakeholders.

There is a necessity for further research regarding the pro-active integration of customers in BM methodologies (Veit et al., 2014) taking into account domain specific characteristics (Capon & Senn, 2017). It is of crucial importance to gain a fundamental understanding of the stakeholders and objects involved in value creation processes of automotive SSs (Hoffmann & Leimeister, 2011). Methodologies that support and manage these transitional processes still need to be researched (Beuren et al., 2013; Reim et al., 2017; Wallin, 2013).

An overview of the identified managerial obstacles and research gaps needing to be addressed is given in Figure 7.

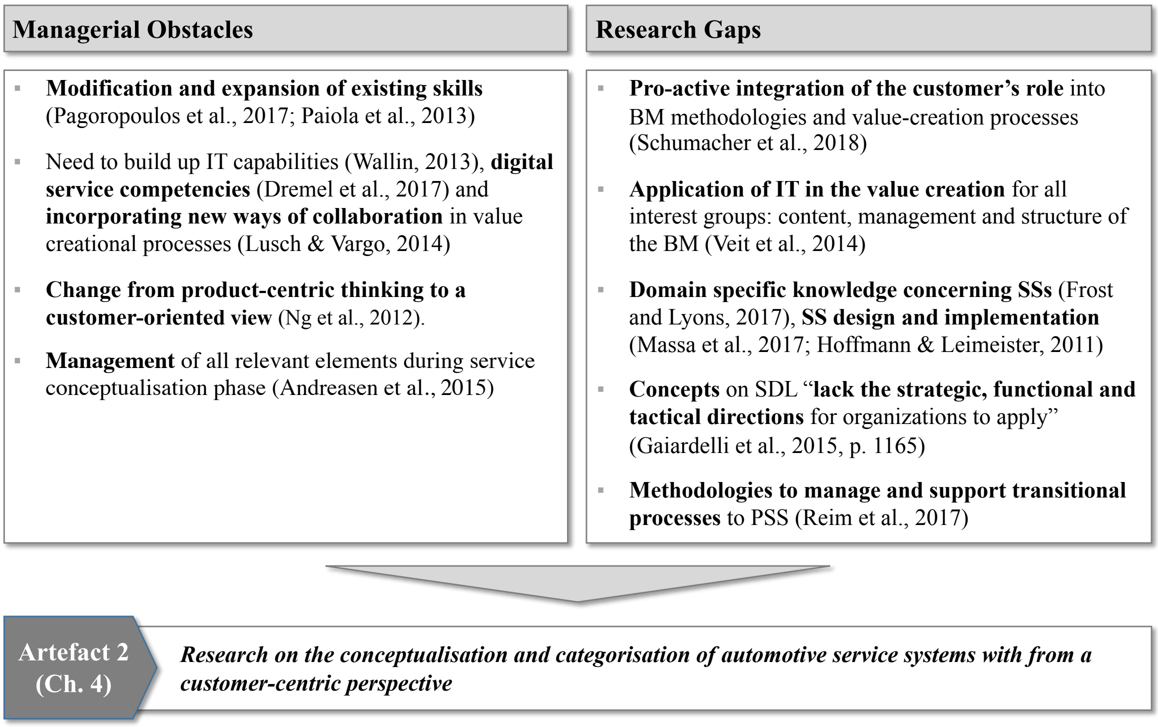

Figure 7: Overview research gaps and service conception obstacles

The research gap to investigate digital automotive service conception from a customer-centric perspective is explored in study 2 (Chapter 4).

2.3 From Linear Development to Continuous Innovation

2.3.1 Digital Innovation Demands Digital Transformation

Digitalisation leads to an increasing fusion of physical and virtual value creational aspects (Hanelt et al., 2015). Increased flexibility and shorter reaction times to meet customer demands are needed, and manufacturers must build up an extended portfolio of respective capabilities (Berman, 2012). A major challenge for automotive companies is the necessity to "operate and innovate like IT companies" and "make the car a central part of an ecosystem that merges cyber-physical content and social networking, as well as agile processes for development" (Tian et al., 2016, p. 6). Therefore, DT has great implications for OEMs (Hildebrandt et al., 2015) as it changes the way in which value is created and captured (Collin et al., 2015), demanding the adaptation of both their customer value proposition as well as their business operations (Vendrell-Herrero et al., 2016).

Having defined a digital strategy and conceptualised digital services, manufacturers need to align these initiatives, respectively adapting and implementing new processes that enable fast and flexible digital product development, and ultimately, enable digital innovation (DI).

Digital Innovation

DI is the process of combining or enriching physical products and digital services to create new products (Yoo et al., 2010; Lee & Berente, 2012). In this context, innovation is related to the importance of the underlying architectures of IT artefacts which support or limit the possibility of developing new IT artefacts as well as affecting the processes that help manage innovation within companies. Even though DI is related to design processes, the concept can be said to carry a broader perspective beyond as it is often "organized and effected within the IT services function" (Kohli & Melville, 2018, p. 3). Besides innovation processes being shaped by the organisation, innovation in turn might shape the organisation itself and provide the possibility to design new BMs (Fichman et al., 2014).

There have been numerous investigations on innovation processes in IS research (Kohli & Melville, 2018) and, in particular, DI. Research in DI has examined the creation of new BMs (Fichman et al., 2014), the specific nature of digital technology with its impact on society (Yoo et al., 2010), infrastructural connections (Henfridsson & Bygstad, 2013), the combination of physical and digital components (Hylving & Schultze, 2013), changes in product development capabilities (Henfridsson et al., 2014), and innovation ecosystems (Piccinini et al., 2015).

An important driver of DI is an organisation's competitive environment (Kohli & Melville, 2018) and implementing respective actions involves several organisational changes. Change must be understood as "a complex, nonlinear process within organisation fields with feedback loops and unanticipated outcomes" of people and technology (Kohli & Melville, 2018, p. 10). When examining these phenomena, one must look beyond the organisation and include cultural and national contexts as identical technologies can have significantly disparate effects in different environments and organisations (Kohli & Melville, 2018).

Digital Transformation

For manufacturers to be able to digitally innovate they must organisationally implement digital technologies with the objective of generating novel value-creating activities (Bounfour, 2016), referred to as DT (Gimpel & Röglinger, 2015). DT thus reflects the effects of digitalisation and its technological adoption along an organisation's value chain (Collin et al., 2015; Khan, 2016; Westerman, Bonnet, & McAfee, 2014). Although a universally accepted definition of DT does not exist (Ferreira, Moreira, & Seruca, 2017), it generally refers to the usage and adaptation of digital technologies to enable value creating activities within and around an organisation (Bounfour, 2016; Gimpel & Röglinger, 2015). By drawing on applied management literature, Hanelt et al. (2015) define DT as the application of new digital technologies aiming at significant business improvements within organisations.

In many studies, DT has been investigated alongside other topics with regards to various dimensions (Bounfour, 2016), business strategic aspects (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013; Hess, Matt, Benlian, & Wiesböck, 2016), driving factors (Chanias & Hess, 2016; Gimpel & Röglinger, 2015) and implementation processes (Dremel, Herterich, Wulf, Waizmann, & Brenner, 2017)).

To be successful in the process of DT, companies must address two complementary goals at the same time: redesigning customer value propositions and simultaneously transforming their operations using new, digital technologies (Berman, 2012). After surveying over 50 companies among different sectors and customer foci, Gimpel and Röglinger (2015) defined more specifically the fields of action for executing a company's DT: the customer, the accrued data, the transformation of the value proposition, the organisation, a firm's operation activities, and its transformation management. In addition, appropriate governance and collaboration mechanisms throughout the organisation need to be set-up. These studies demonstrate that DT is a complex venture that "affects many or all segments within a company" (Hess et al., 2016, p. 2).

Generally, manufacturing companies recognize the need for DT and, in turn, many have formed units in respect thereof (Chanias & Hess, 2016). Bermann (2012) proposes paths to

DT and stages to reshape the customer value proposition. Similarly, Dremel et al. (2017) describe how to establish big data analytic methods for an automotive OEM within its DT venture on a strategic level, applying a three-stage model. Case studies on DT, such as Hess et al. (2016), focus on the strategic transformation implications, but do not give guidance on how to practically conduct specific tasks. Specific to the automotive industry, DT has been researched by several authors, as Table 10 shows (Riasanow et al., 2017):

Table 10: Overview of automotive DT studies following Riasanow et al. (2017)

Authors	**Digital transformation in the automotive industry**
Hanelt et al. (2015)	▪ Examination of the impact of digital trends on automotive BMs ▪ Identification of four types of BM changes: extension, revision, termination, and creation
Hildebrandt et al. (2015)	▪ Investigation of digital technology-related mergers and acquisitions (M&As) as an external knowledge integration (Henfridsson & Lind, 2014) and the changing, as well as emergence, of DEs
Piccinini et al. (2015)	▪ Investigation of DT challenges by conducting a Delphi study with industry experts of the automotive industry
Chanias and Hess (2016)	▪ Case study of the formation of strategies due do DT applying the activity-based process model ▪ Identification of the starting point of DT: a variety of bottom up processes is more important than a single strategic planning process at the management level
Remane et al. (2016)	▪ Identification of 27 different BM types clustering in: creator, distributor, landlord, and broker

Piccinini et al. (2015) identified the eight DT aspects OEMs ought to consider during their DT process, as shown in Figure 8.

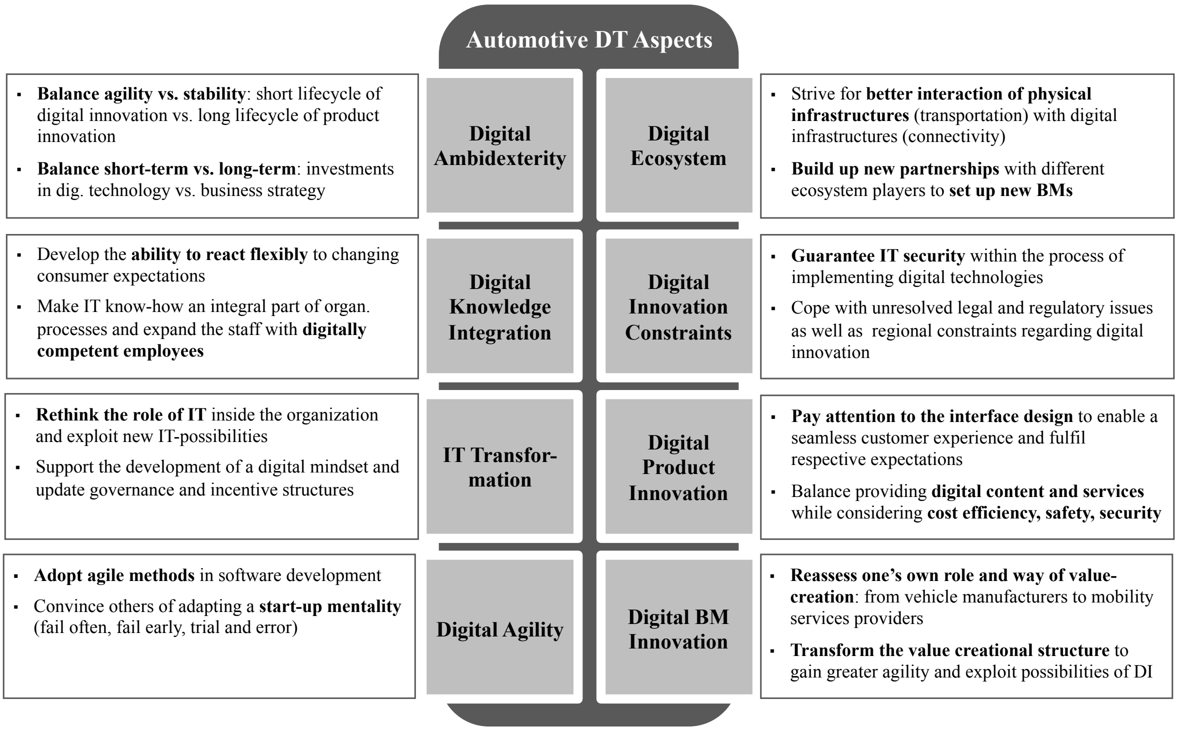

Figure 8: DT aspects for OEMs to consider following Piccinini et al. (2015)

An important DT aspect identified by Piccinini et al. (2015) is to set up a digitally agile organisation, i.e., the implementation of agile methods into the software development method.

Agile Software Development

As digital products and services have become more individualised and fragmented into smaller features (Olsson et al., 2012), the demands software development projects need to meet have changed too. Flexibility, incremental releases and development speed, i.e. the reduction of a product's time to market, are primary project requirements and are a necessary precondition to stay competitive (Al Alam et al., 2016). To meet flexible and fast product delivery, more and more large companies adopt agile development methodologies (Henriques & Tanner, 2017) replacing the predominant traditional ones, such as the waterfall procedure, as they are not suited for fast requirement changes (Kotaiah & Khalil, 2017). To specify agility, most researchers rely on the definition of the Agile Manifesto that is based on a practitioner's experience (Hummel, 2014) and is comprised of four values and twelve principles. The values are to favour "individuals and interactions over processes and tools", to produce "working software over comprehensive documentation", to enable "customer collaboration over contract negotiation" and to respond "to change over following a plan" (Beck et al., 2001, p. 1).

Agile development methodologies follow the primary principles of collaborative and lean development, customer and stakeholder integration, and flexible response to change (Selleri Silva et al., 2015). In adopting agile methods, organisations expect to raise productivity, product and service quality, and accelerate their software development cycles (Dingsøyr & Lassenius, 2016). Since the conception of the agile manifesto in 2001 (Beck et al., 2001), many researchers have investigated a number of agile software development methodologies, such as eXtreme programming, Crystal, SCRUM and Feature Driven Development. Generally, the agile development process iteratively goes through the multiple phases, i.e. requirements definition, design, implementation, testing, review and completion (Kotaiah & Khalil, 2017), by promoting small release cycles that continuously integrate both customers into the development process (Hummel, 2014) and new code as soon as it is ready (Abrahamsson, 2002). Software is developed lean and fast, following a minimal viable product (MVP) approach, thus allowing growth incrementally over time.

Research so far has mainly centred on success factors for agile development projects (Ambler, 2014), maturity models, adoption frameworks (Fontana, Meyer, Reinehr, & Malucelli, 2015), organisational issues (Iivari & Iivari, 2011), and people (McHugh, Conboy, & Lang, 2012; Henriques & Tanner, 2017). Agile development methodologies emphasise continuous product delivery, enabled by continuously integrating code during development (Dingsøyr & Lassenius, 2016). The objective of continuous delivery is to constantly keep software in a releasable state. Therefore, organisations must in some way automatize software building, deployment, testing and release processes (Humble & Farley, 2011). In addition, continuous delivery makes the adoption of cross-functional teams within an organisation necessary. Teams are vertically structured and follow a DevOps approach, taking an end-to-end responsibility for the product with software development and operations being combined (Dingsøyr et al., 2014). To instantly know if software is in a releasable state, respective assessment processes have to be set-up accordingly.

2.3.2 Assessing Digital Products

Before a software product is released to the market or integrated into goods, assessing its readiness is critical to ensure correct operations. Operational readiness refers to a concept that attempts to quantify the "probability that, at any point in time, the system is ready to be placed into operation on demand when used under stated conditions" (Kececioglu, 2003, p.24). In the 1970s, the National Aeronautics and Space Administration (NASA) were the first to develop a figure of merit to systematically and effectively assess and document the maturity of novel technologies by introducing nine Technology Readiness Levels (TRL)

(Papafotiou, Demetriades, & Agelidis, 2016). These TRLs are applicable towards both hardware and software environments, ranging from the initial observation of basic principles to final product operations (Mankins, 2009). NASA (2015) defines a software at the final readiness level if it is debugged, fully integrated with all operational software systems, has complete documentation, and has proven to operate successfully in the operational environment.

Subsequently, procedures to predict operational readiness have been investigated and developed by researchers and practitioners in the form of software maturity (SM) (Mankins, 2009), release readiness (RR) (Al Alam et al., 2017) and software readiness (SR) (Asthana & Olivieri, 2009). All these research streams examine the assessment of software by certain criteria in order to support the decision between releasing software in a timely manner (Quah, 2009). The division among them is blurry as the definitions for RR (Al Alam et al., 2016), SM (Schaefer, 2009) and SR (Olivieri, 2012) are not well-defined, and the terms “maturity” and “readiness” are often used synonymously (Gove & Uzdzinski, 2013).

Typically, SRA are conducted at several points during a software’s life cycle and, depending on the organisation, can be either a small task or an extensive, highly formal process that involves external peer reviewers. However, assessing technologies poses various organisational and methodological challenges, from choosing the right metrics to ensuring and achieving the right technology level across multiple systems (Mankins, 2009). All technologies that are implemented and applied are eventually evaluated to at maturity, however, as Mankins (2009, p. 1221) points out, “in almost all cases, the end of last ‘bug fixing’ aspects of true ‘system development’ do not occur until an actual system is first deployed” and the product is operational.

The purpose of SRA methods is to identify a discrepancy which will be resolved by subsequent improvement actions (Mettler, 2011; Pfeffer & Sutton, 1999). Common approaches to assess SR are checklists, industry standards and academically developed methodologies (Asthana & Olivieri, 2009). Since Gibson and Nolan (1974) first introduced a four stage maturity model, (Gibson & Nolan, 1974) many more assessment models have been developed over the years: the capability maturity model (CMM) (Paulk, Curtis, Chrissis, & Weber, 1993), the ISO/IEC 15504 norm or SPICE (software process improvement and capability determination), BOOTSTRAP (Kuvaja & Bicego, 1994), Model-driven Development (MDD) Maturity Model (Hutchison et al., 2006), and the IT Capability Model Framework (IT-CMF) (Curley & Kenneally, 2012) to name a few. Deciding the readiness of software makes it necessary to continuously perform standardised methods of measurement (Al Alam et al., 2017). Often these decisions, derived from successful projects or experience-based in a sense of "good practice" (Mettler 2011, p. 82), are subject to a "key informant bias". Therefore, applying software maturity assessment models alone is not a guarantee that an organisation will be successful.

Despite the undertaken standardisation efforts, assessing SR remains a highly individual task for any organisation, requiring future research on the subject as indicated in the current state of the art analysis by Proença and Borbinha (2016). Further investigation on how methods can be used and applied to existing maturity assessment methods, that is, the existing operations infrastructure of an organisation, is needed. The models are highly complex and specialised, which is why majority of the information gathering tasks are still carried out manually (Proença & Borbinha, 2016). Research on assessing SR is ongoing and as Mettler (2011) points out, many models do not contain sufficient information on how to effectively carry out assessment processes. As software development methodologies shift towards agile, SRA procedures have to transition as well.

2.3.3 Research Gaps and Implementation Obstacles

So far, a clear "misalignment between demands in the marketplace and organisational capabilities" of companies has been witnessed (Kohli & Melville, 2018, p. 1). Though innovations in digital technologies presses organisations towards adapting their BM, surveys illustrate that many organisations are not yet ready to answer these trends (Kane, Palmer, Phillips, Kiron, & Buckley, 2015).

As DI shows unique characteristics, managing the process of DI is significantly different from managing traditional IT (Piccinini et al., 2015). Piccinini et al. (2015) demonstrate how automotive organisations and their work processes are challenged by changes on the BM and ecosystem levels: "Structures, mindsets and methods known from the IT industries must be implemented in organisations that have developed fixed rules, assumptions and procedures for over a century now. What becomes apparent are the spillovers from the digital to the physical world" (p. 14), for example: using agile methodologies or thinking in platforms and ecosystems.

Though many researchers, such as Henfridsson et al. (2014), Hylving and Schultze (2013), and Seeger and Bick (2013), have already examined the automotive industry, research gaps still exist, especially regarding managerial challenges related to DT (Piccinini et al., 2015). The challenges automotive manufacturers face "represent a major deviation from their traditional business and the capabilities necessary to conduct it (Henfridsson et al. 2009)" (Piccinini et al., 2015, p. 5). Further research is needed on the DT "of primarily physical industries, whose products cannot be completely digitized" (Hanelt et al., 2015, p.1313), such as the automotive industry. Concerning the current DT processes in the automotive industry, Riasanow et al. (2017, p. 3194) notes the necessity of a “detailed actor-to-actor analysis”, criticising that current studies focus exclusively on organisations’ BMs.

Generally, manufacturers recognize the need for DT and many automotive OEMs formed DT units in respect thereof, as a survey of Chanias and Hess (2016) indicates. Despite this, OEMs are especially challenged by the efforts to execute the shift from product-centric to customer-centric structures as several studies point out (Baines et al., 2009; Beuren et al., 2013; Chanias & Hess, 2016; Reim et al., 2017).

To achieve setting up innovative operations and agile development processes, OEMs have to align and integrate their IT infrastructure to the requirements of its DT processes (Gimpel & Röglinger, 2015). In this regard, digital products need to be assessed quickly and continuously to support effective decision-making (Nierstrasz & Lungu, 2012), necessitating transitioned operational procedures (Vendrell-Herrero et al., 2016). Further, intelligent processes that enable product development speed, which is the reduction of its time to market, are a prerequisite to stay competitive. Processing IT projects in accordance to these requirements poses difficulties to OEMs as their current structures impede the efficient operational handling of them (Riasanow et al., 2017).

Scientific research has so far mainly focused on detecting DT challenges and necessary fields of action for a successful implementation and management of the according processes. But, as Wallin (2013) and Reim et al. (2017) indicate, tools and methodologies that guide an organisation on how to address these specific fields are scarce. Further, empirical studies on how to transform software assessment processes within an operational organisation do not exist, as applicable processes cannot be developed on a blank canvas and must fit in the existing business environment. Nierstrasz and Lungu (2012) call out for a separate agile software assessment discipline, examining tools and techniques to provide software developers with methods for integrating analysis tools into their daily work. These new tools will be characterised by customizability for flexible analyses, the ability to capture and exploit the organisational context, as well as the continuous advancement of a software and its context.

An overview of the identified managerial obstacles and research gaps needing to be addressed is provided in Figure 9.

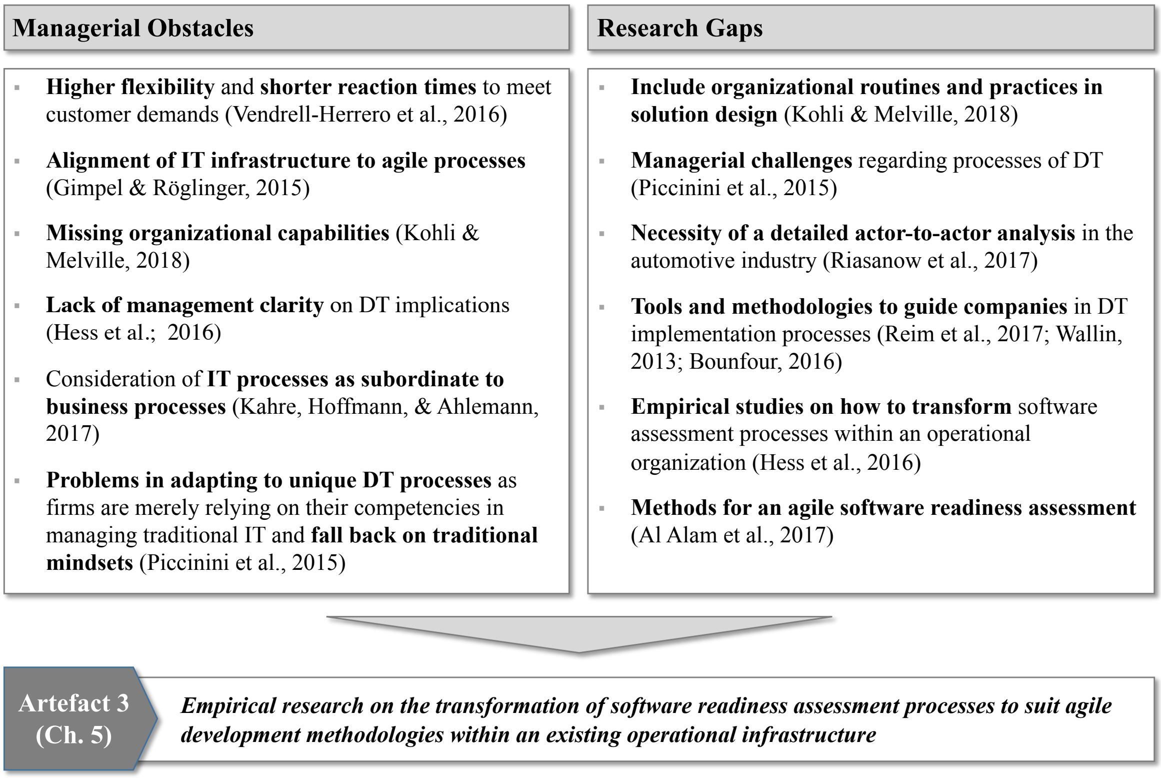

Figure 9: Overview of research gaps and implementation obstacles

The research gap of empirically investigating the transformation of backend processes to suit agile development methodologies within an existing operational infrastructure is explored in studies 3 and 4 (Chapter 5).

Manufacturers struggle to adapt their internal operations to the requirements DT demands of them, especially to provide an integrated IT infrastructure that enables collaborative, fast and flexible product development (Gimpel & Röglinger, 2015). Hence, the lack of applicable studies suggests the need for both empirical and methodological investigations on DT.

3 Artefact 1: Digital Automotive Ecosystems

Grieger, M., Glöckner, M., Ludwig, A., & J Shen, J. (2018). Designing a Layered Conceptual Model of a Digital Ecosystem for the Automotive Industry. In *Information Systems Journal.*

3.1 Meta Data

Table 11: Meta data of the publication Digital Automotive Ecosystems

Title	**Designing a Layered Conceptual Model of a Digital Ecosystem for the Automotive Industry**
URL	https://onlinelibrary.wiley.com/journal/13652575
Type	Journal article
Publication in	Information Systems Journal (ISJ)
Status	Under review
Editor	Robert Davison
Series Title	-
Publisher	Wiley-Blackwell
Place of Publication	Hoboken, New Jersey, United States
Ranking	CORE: A+[1] VHB: A[2] h-index: 37[3]

1 http://portal.core.edu.au/jnlranks/?search=information+systems+journal&by=title&source=ERA2010%0D%0A&sort=arank&page=1

2 https://vhbonline.org/nc/en/service/jourqual/vhb-jourqual-3/complete-list-of-the-journals/

3 https://scholar.google.com/citations?hl=en&view_op=search_venues&vq=information+systems+journal&btnG=

3.2 Summary

This study proposes and validates a layered conceptual model of a DE for the automotive industry by categorizing the necessary elements and stakeholders involved. A structure of a digital automotive ecosystem (DAE) is presented that was practically motivated as part of an empirical investigation of an OEM that already had intentions of setting up a solution. The DAE is a conceptual model consisting of hierarchical, interconnected layers within a dynamic network structure.
This research aims to look at the strategic objective of DT paths and investigates RQ1: *How can a digital automotive ecosystem be represented and what are its essential elements and underlying topology?*

The necessity to provide a conceptual model of a DAE arose through an empirical study with a German OEM that introduced MS architectures during a DT effort to enable fast digital product development. Platforms are the intermediary step for these organisations to build, manage and maintain DEs, as is the case with the OEM partner. The organisation struggled to initiate activities as the structure and modelling of DEs is unclear.
In this study, an action design research framework was applied, partnering with the OEM's advisory organisation for setting up a DE (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011). For the model's development, 26 semi-structured interviews were conducted (Myers & Newman, 2007) and qualitatively analysed (Mayring, 2014) to derive structural elements. The interviewees were purposefully sampled and are experts in their field from 14 different organisations (Palinkas et al., 2015). 471 pages of transcripted data was collected, iteratively coded and categorised (Saldaña, 2016) supported by software following a constructivist grounded theory approach (Charmaz, 2014) until meaningful elements could be derived (Given, 2008). By conceptually modeling a use case scenario in UML (Olivé, 2007) and developing a conceptual architecture, a minimum viable model (MVM) of the DAE was created and iteratively advanced over multiple evaluation cycles and through a practical workshop (Venable et al., 2016).

The DAE provides an ecosystem like structure with architectural layers that distinguish between backend and customer-facing, frontend structures as demonstrated in Figure 10. All layers are interconnected and the interfaces, mainly API services, are managed by the respective managing unit.

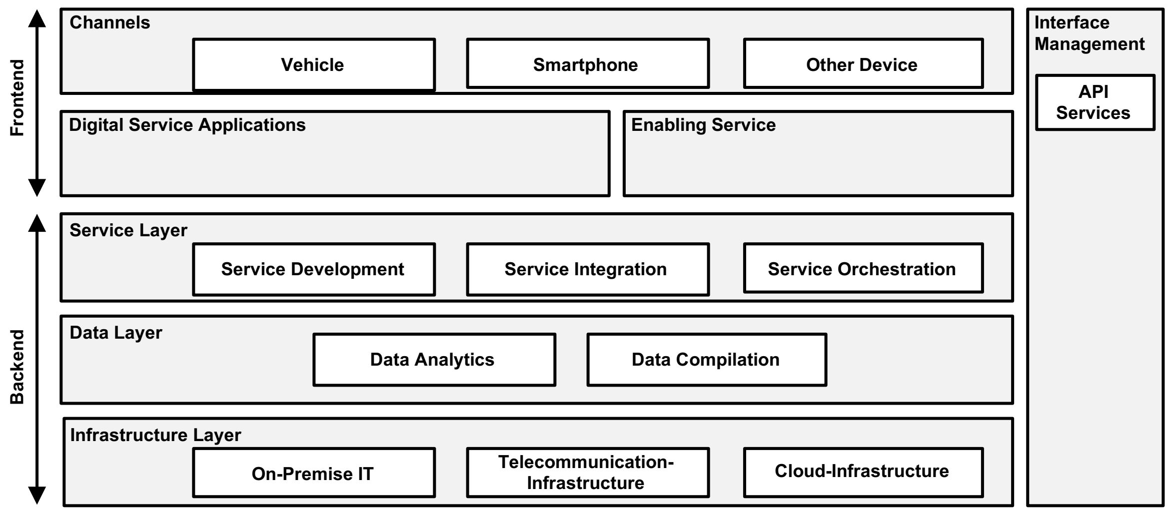

Figure 10: Conceptual architecture of the DE elements

The layered conceptual model (Figure 11) provides a more complete understanding of the DE concept upon which management can scope and define commercial fields of action. The results demonstrate that a multitude of platforms make up each ecosystem layer and can be comprised of a variety of these expressions. The structure shows that vehicles are channels for accessing the customer's DE, as are mobile devices. Though a necessary part, vehicles are not the centre of the automotive ecosystem, the customers who engage in a multitude of ecosystems throughout their daily journeys, are.

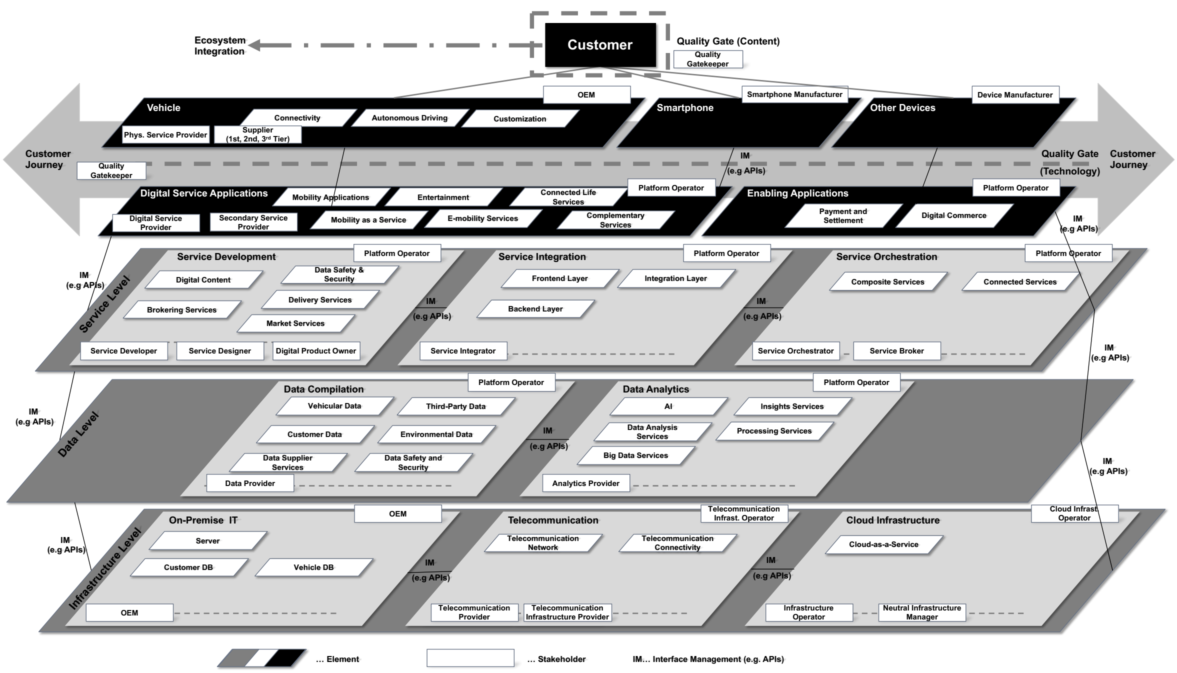

Figure 11: The Digital Automotive Ecosystem model

The DAE strengthens the notion of DEs being environments of collaboration and partner integration (Adner, 2017; Gomes, Facin, Salerno, & Ikenami, 2016). Further, the model draws attention to the crucial role of quality gatekeepers both on a content and technical level.

The artefact is perceived to be rather useful on a strategic dimension rather than operational. It provides a communication instrument for decision makers organizing and structuring this complex domain. The workshop's findings suggest that the DAE is useful for manufacturing organisations in a broader scheme as well. Further, the DAE was found to be a beneficial instrument in shaping and defining service journeys from the customer's specific demand to the configuration of necessary backend operations.

Appendix A, B, C provide the interview guideline, the denomination and distribution of elements and concepts, as well as the denomination and distribution of stakeholders in the DAE.

3.3 Designing a Layered Conceptual Model of a Digital Ecosystem

Designing a Layered Conceptual Model of a Digital Ecosystem for the Automotive Industry

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Abstract

Digitization leads to collaborative networks and the formation of digital ecosystems (DEs). Manufacturers are in the process of enhancing their value propositions in the digital sphere and setting up DEs themselves. Many organizations aspiring to become participants or leaders of DEs struggle to initiate activities as the structure and modelling of DEs is unclear. Compared to their practical importance, research on the topology of DEs is not comprehensive and practical insights that support the scoping and design of these environments is few. In this article we propose and validate a layered conceptual model of a DE for the automotive industry. Following an action design research approach, an artefact is developed by conducting and qualitatively analysing 26 expert interviews from different organizations, followed by conceptually modelling the structure and its visual representation within the context of an original equipment manufacturer's digital transformation program (OEM). This research leads to novel insights on how DEs are structured and efficiently displays elements, stakeholders and their interdependent relations. Our findings suggest a conceptual model leads to more clarity about DEs and supports decision makers on a strategic level, but does not provide operational implementation guidance.

Keywords: Digital ecosystem, Digital transformation, Digital services, Automotive industry, Conceptual model, Action design research

1 Introduction

Digitization enables manufacturing industries to transform their products towards digital service offerings. Digital services are seen to be complementary ways that not only deliver value but also create and maintain competitive advantages (Schatton, & Bauernhansl, 2016). Providing these services leads to a “more-connected future of digital ecosystems” (DE) (Weill & Woerner, 2015, p. 27), which is an environment of interconnected stakeholders that mutually rely on each other (Peltoniemi & Vuori, 2008) and work synergistically to offer customer value (Tan, Pan, Lu, & Huang, 2015). Various organizations are converging towards one another since mutual interactions gain importance (Paulus-Rohmer et al., 2016), as a case of Apple illustrates, which successfully integrated digital services and tethered partners to maintain a powerful position in an otherwise commoditized hardware market.

In the manufacturing industry, many firms have already set up business ecosystems and aim to extend this strategy to digital fields of action in the course of their digital transformation (Hess, Matt, Benlian, & Wiesböck, 2016). Respectively, they are in the process of or have developed digital platforms (DPs) (Schweiger, Nagel, Böhm, & Krcmar, 2016) around which they intend to establish DEs (Bilgeri, Wortmann, & Fleisch, 2017).

However, building a digital ecosystem challenges manufacturers in multiple aspects as adopting digital technologies for an integrated service delivery ultimately alters the organization’s value creational activities and strategic information technology (IT) objectives (Bilgeri et al., 2017). The complexity of these arrangements is increasing, and integrated empirical studies demand the investigation of stakeholder networks (Tilson, Lyytinen, & Sørensen, 2010), their composition, and their structural interaction (Reuver, Sørensen, & Basole, 2017). Compared to their importance in practice, research on the topological structure of DEs is not comprehensive and practical insights are scant as there is still a lack of clarity on specifications, scoping and design within practitioner and academic discourse (Sørensen, Reuver, & Basole, 2015).

The goal of this research is to develop a conceptual model of a digital ecosystem formulating the concepts, technical elements and stakeholders applicable to the automotive industry. A conceptual model helps to gain a better understanding of DEs, their forming entities and relational connections (Olivé, 2007). Industries such as trading and services have already experienced digitization developments, and now manufacturing industries are facing the same challenge, with the automotive industry being a prominent representative of this change. The artifact shall assist original equipment manufacturers (OEMs) with scoping and designing DEs by providing a topological visualization. Based on the preliminary studies we therefore investigate the following research questions:

RQ: How can a digital automotive ecosystem be designed and what are its essential elements and underlying topology?

We investigate the research questions following an action design research approach, interviewing 26 experts from different types of businesses about the digital transformation of automotive OEMs to digital solution providers and qualitatively analysing them. The automotive industry is well-suited for applying this study as OEMs undergo digital transformation processes and have already established IT departments and legacy systems. Many of them are in the process of building DEs and are heavily expanding their IT business activities.

The remainder of this paper is structured as follows. Section 2 provides background information on digital transformation and DEs, substantiating the motivated research gap. Section 3 presents the action design research approach and respectively gives an overview of the applied methods for each step in the research process. Section 4 outlines the artifact's development process, provides the qualitative analyses of the interviews and the evaluated approach. In section 5 we discuss the scientific and managerial implications of the investigation and conclude the article in section 6.

2 Background

2.1 Digital Transformation towards Digital Ecosystems

Digital transformation generally refers to the usage and adaptation of digital technologies to enable value creating activities within and around an organization (Gimpel & Röglinger, 2015; Bounfour, 2016). In order for companies to succeed in their digital transformations, they have to reshape customer value propositions and transform their operations (Berman, 2012). Reshaping a company's value proposition can be approached through various paths, such as the stages presented by Berman (2012): (1) Enhance, i.e. enriching physical products or services with information and digital content. (2) Extend, i.e. applying the former enrichments in developing new revenue streams. And, (3) redefine, i.e. replacing physical value with a digital one, or by generating value and revenue based on fully integrated digital/physical products and/or services. After surveying over 50 companies among different sectors and customer foci, Gimpel and Röglinger (2015) specifically defined the fields of action for executing a company's digital transformation: the customer, the accrued data, the transformation of the value proposition, the organization, a firm's operational activities, and its transformation management. The scope and complexity of these fields demand a sophisticated solution in order to handle and redefine value propositions towards fully integrated physical-service offerings. Even though research on digital transformation is ongoing, so far only a few organizations have managed to provide integrated offerings consisting of physical products and digital services (Bilgeri et al., 2017).

The automotive industry is one of the most apparent manufacturing industries where digital transformation is changing the predominant way of value creation through physical objects. The emergence of new digital technologies and innovative services threaten incumbent market participants (Gao & Zhang, 2016) by offering DPs such as UBER, Android Car and ZipCar with the potential to evolve into DEs (Riasanow, Galic, & Böhm, 2017). Due to rising market competition OEMs must align their strategic business activities to these altered competitive conditions in which more customer-centric solutions are provided and predominant value networks are defined (Matt, Hess, & Benlian, 2015; Gao & Zhang, 2016; Riasanow et al., 2017). This evolution challenges OEMs that intend to digitally operate and innovate like IT companies and create integrated products merging digital content, networking and agile development processes (Tian et al., 2016, p. 6). OEMs have difficulties integrating physical and digital infrastructures that align with the objectives of identifying novel cross-industry structures and building up complementary partnerships that ultimately result in the creation of new business models and digital value (Piccinini, Hanelt, Gregory, & Kolbe, 2015). A promising strategy is the establishment of digital services based on an ecosystem approach (Reuver et al., 2017; Altman & Tushmann, 2017).

Shifting towards DEs creates new options of doing business and provides higher revenue growth and profit margin potential than that of their competitors as indicated by empirical investigations (Weill & Woerner, 2015). At the same time, operating costs can be reduced with better customer experiences being made available (Tan et al., 2015, p. 263). Additionally, organizations that pursue these strategies become more open (Boudreau, 2010), engage in interdependent relationships outside of their organizational boundaries (Thompson, 1967; Kleinbaum & Tushmann, 2007) and pursue co-opetition business models (Brandenburger & Nalebuff, 1996; Altman & Tushmann, 2017).

OEMs are pursuing the establishment of vehicles as the carriers of digital services and the focal point of the ecosystem (Dremel, Herterich, Wulf, Waizmann, & Brenner, 2017). Strategically, OEMs and ICT competitors are particularly interested in exploiting the vehicle's data and becoming data providers, initiating a "battle on setting up a successful car data-service-ecosystem," as Kaiser et al. remark (2017, p. 348). So far, OEMs have failed to establish DEs themselves. Initiatives have been fragmented and do not allow for brand-independent data life cycles (Kaiser et al., 2017). Additionally, few ideas exist on how to profitably utilize anonymized car data for digital services (Kaiser et al., 2017).

2.2 The Concept of Digital Ecosystems and Platforms

The concept of DEs is adapted from research on business ecosystems (Saleh & Abel, 2016) being described as a network of stakeholders, such as suppliers, distributors, outsourcing firms, technology providers, and many other organizations (Iansiti & Levien, 2004, p. 68), affecting and being affected by their own value propositions. These synergetic networks are characterized by dynamic structures of interconnected organizations that mutually depend on each other (Peltoniemi & Vuori, 2008). Boley and Chang (2007) define a DE "as an open, loosely coupled, domain clustered, demand-driven, self-organizing agent environment, where each agent of each species is proactive and responsive regarding its own benefit […] but is also responsible to its system" (p. 399). In this regard, a DE is a self-organizing, open community without permanent, centrally exercised control for a single behavior (Boley & Chang, 2007) and can be distinguished through both technological and organizational points of view (Reuver et al., 2017). Differing from biological and social ecosystems, DEs remove geographic limitations and offer instruments for collaboration across systems as they are not hindered by physical barriers. Their elasticity allows overlapping with other ecosystems as a single system, capturing the benefits of collaborating with other entities (Boley & Chang, 2007).

In order to participate in or create a DE, organizations often establish platforms first and strategically develop them into an ecosystem consisting of several entities (Tan et al., 2015, p. 263). DPs have experienced an emerging interest in information systems research due to their transformational power leading to changes in communication and client-provider-interaction (Spagnoletti, Resca, & Lee, 2015), developments in inter-organizational relations (Ghazawneh & Henfridsson, 2013; Eaton, Elaluf-Calderwood, Sørensen, & Yoo, 2015) and adaptations from monolithic system architectures to modular DPs (Tiwana, Konsynski, & Bush, 2010).

A DP is an expandable software system, which provides core features that are shared by the components and interfaces which interact with it (Tiwana et al., 2010, p. 675). Platform approaches influence businesses, networks and even collaboration and competition dynamics, thus, having the potential to transform entire economies (Gawer & Cusumano, 2002; Parker, van Alstyne, & Choudary, 2017; Reuver et al., 2017). DPs are just as complex as the objects they handle resulting from the foundation of sub-systems, platforms and infrastructures (Evans & Basole, 2016; Reuver et al., 2017), such as hardware, operating systems, apps and browsers (Pon, Seppälä, & Kenney, 2014), and their distributed characteristics (Henfridsson, Mathiassen, & Svahn, 2014). It is likely that the number of mobile platforms and ecosystems will grow (Sørensen et al., 2015), and DE arrangements will become more complex (Bilgeri et al., 2017).

DEs and platforms are closely interconnected and some researchers even use the terms synonymously (Reuver et al., 2017). Both platforms and ecosystems are based on interrelations of individually acting stakeholders that could be cooperating and competing on different fields at the same time (Gawer & Cusumano, 2002; Thomas, Autio, & Gann, 2014). Following Uludağ, Hefele, & Matthes (2016), we regard platforms to be contributing entities for the development of DEs. Within an ecosystem, different platforms can compete against each other such as when service providers use multiple platforms for their service offerings, e.g. iOS and Android (Reuver et al., 2017).

2.3 Current Research on Digital Ecosystems

In literature, DEs have been researched with regard to various dimensions. Saleh, Abel, & Misseri (2015) investigate the similarities between DEs and collaborative systems and propose an ontology model that merges them conceptually. Therein the authors distinguish between agents, species and the environment of interaction, but do not discuss necessary technical elements. Investigating the dynamics between platform providers and application developers within mobile ecosystems, Oh, Koh, & Raghunathan (2015) identify revenue-sharing models to be a crucial success factors for leveraging a platform's attractiveness. Uludağ et al. (2016) investigate governance principles for the establishment of mobility platforms and their surrounding ecosystems by developing a framework for their systematic description and analysis. They propose four strategies for successfully establishing DPs that include network effects usage, retaining strategic platform decision rights, finding quality control balance and providing comprehensive developer support. In addition, Uludağ et al. (2016) provide several terminological definitions that can be applied to the further understanding of platform concepts and ecosystems.

Briscoe, Sadedin, and Wilde (2011) implement a DE by analogizing nature in the area of distributed computing in order to better handle software and the complexities surrounding its maintenance and development. Though mimicking biological ecosystems for the design of DEs was experimentally confirmed as a successful strategy, the approach exposed deviations, i.e. information-centric dynamically reconfigurable network topology and species abundance, deemed as features unique to DEs.

Trying to improve the understanding of social networks, user behaviors and system interactions within complex DEs, Tang, Wu, Karhu, Hämäläinen, & Ji (2010) developed an ecosystem architecture for a ubiquitous living lab innovation platform consisting of multiple layers and various roles. The authors provide us with clarifications on what constitutes DEs and give an exemplary design manifestation.

Paulus-Rohmer et al. (2016) investigate the transformational path of manufacturers to ecosystem participants and propose a roadmap of four-phases for consistent strategic positioning: (1) analyze the current positioning, (2) target the intended positioning, (3) realize the strategy and (4) implement changes. Similarly, Hadzic and Chang (2010) propose a general five-step methodology for designing DEs using electronic medical records. Their process involves defining roles and collaborations of digital actors, making them intelligent, implementing security requirements, and iteratively improving the overall design by providing additional services for digital actors. The authors conclude the artifact as being an initial practical step towards the design of DEs and emphasize the incorporation of further works as a greater understanding is attained.

Tan et al. (2015) empirically investigated the development and deployment of DEs and its effects by means of an online marketplace following a multi-sided platform approach focusing on IT capabilities. The authors develop a three-step capability process model and provide insights into the respective strategic orientation, but do not comment on how to shape an ecosystem or develop its structure. Within the manufacturing industry Hu, Huang, Zeng, & Zhang (2016) conducted a case study of a custom-suit company that is in the process of building a DE, highlighting the importance of institutional entrepreneurship. The case illustrates the building of a DE as being characteristic of a co-evolutionary process during which organizations simultaneously follow competitive and cooperative business strategies. Interviewing 16 experts across the Internet of Things (IoT) ecosystem, Bilgeri et al. (2017) identify six organization-critical issues regarding digital transformation implications for companies, mainly involving culture and structure. By means of a longitudinal case study, Lindgren, Eriksson, & Lyytinen (2015) investigate the organizational dynamics that occur when evolving from a public administrative organization towards a digital service provider within a mobile ecosystem and identify a constant conflict between the old identity and the aspiring new one.

DEs have been researched with regard to various dimensions and application domains, see Table 1 below. So far, few studies have investigated what constitutes DEs and how to compose essential elements (Paulus-Rohmer et al., 2016). Though, some studies address all design dimensions and do propose procedural models or frameworks to implement or analyze DEs, they fall short in explaining its architecture and structural composition. Further, no studies could be identified that provide conceptual models for OEMs to scope and topologically plan DEs themselves.

Table 1: Concluding overview of research on DE structures

		Topological design domains				
Authors	**Application domain**	**Structure**	**Constructs**	**Stakeholders**	**Relation**	**Structural Conceptual Model**
Boley & Chang, (2007)	no specific domain	○	●	○	○	No
Tang et al., (2010)	Sensor-based systems, Web 2.0 and mobile applications	●	●	●	●	No
Hadzic & Chang, (2010)	Healthcare Industry	●	●	○	●	Yes - Digital Ecosystem Design Methodology
Briscoe et al., (2011)	Distributed computing	●	●	○	●	Yes - UML model incl. agents, populations and habitat
Bilgeri et al., (2015)	General Internet-of-Things	○	○	○	●	No
Saleh et al., (2015)	Online marketplace	○	●	●	●	No
Tan et al. (2015)	Online marketplace	●	●	●	●	No
Lindgren et al., (2015)	Public transportation sector	○	○	●	●	No
Hu et al., 2016	Manufacturing industry	○	○	●	○	No
Uludağ et al. (2016)	Companies that operate within a mobility related-	●	●	●	●	No
Paulus-Rohmer et al. (2016)	Manufacturing industry	●	●	●	●	No

● adressed ○ not adressed

2.4 Reflection and Learning on the Design of Digital Ecosystem

After consolidating the literature, we identified a basic set of expressions with regard to its structure, elements, stakeholders and relations for both querying the experts and for the development of the conceptual model (see Figure 1). The investigation also revealed various literature deficiencies. Despite the variety of research initiatives, there is still a lot of ambiguity concerning the relations between DPs and ecosystems in academic and practical debate. Compared to the industry importance of DEs, ongoing research is limited and practical insights sourced from within case organizations is scant (Sørensen et al., 2015). Though some studies address methodologies or organizational frameworks, the development process of DEs "remains elusive to many firms" (Hu et al., 2016, p. 498). Supporting practitioner-oriented and empirical investigations on DE structures for manufacturing industries are rare despite the claimed demands (Tilson et al., 2010; Bilgeri et al., 2017). A recent systematic literature review on DPs and ecosystems suggests bolstering the visualizations of the structure and dynamics of DEs, and establishes the importance of determining "how to effectively describe the underlying structure and topology" of them (Reuver et al., 2017, p. 8).

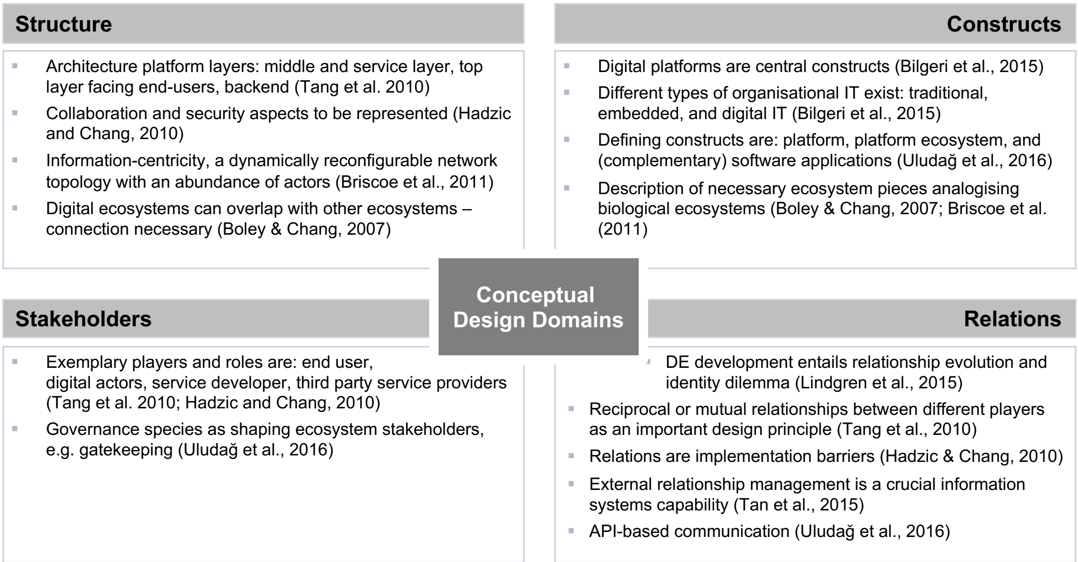

Figure 1: Empirically derived ecosystem elements and dimensions

3 Research Methodology

Information systems research is intended to improve the management and usage of IT through the design and development of innovative artifacts (Hevner, March, Park, & Ram, 2004). Models, as part of the design science research output, are propositions or statements which express relationships among elements (March & Smith, 1995) that in turn represent concepts of a specific domain (Vaishanvi, Kuechler, Petter, & Stacie, 2017). Within this research, we develop a conceptual model for a DE out of an OEM’s perspective. Since we want to satisfy both a scientific knowledge contribution and to give practical guidance, we follow the “Action Design Research” approach proposed by Sein, Henfridsson, Purao, Rossi, & Lindgren (2011).

ADR focuses on the development, interference and evaluation of artifacts that reflect the theoretical enabling and research intention, as well as the ongoing practical influence of users in a specific context. The approach intends to overcome the shortcomings of many existing design science methods that separate and sequence the design, development, and evaluation phases, typically criticized as being too theory focused and too distant from actual application cases and users (Sein et al., 2011). As can be observed from Figure 2, in applying the ADR, we began by (1) formulating the problem, (2) / (3) collecting and analyzing data for an initial artifact, then iteratively evaluating the elements, its architectural structure, and relations. Subsequently, we (4) formalized our findings in a discussion about its general validity. In the problem formulation phase, we practically perceived the problem and identified the theoretical need for a structural conceptual DE model out of an OEM’s perspective that addresses fundamental elements, representing relevant stakeholders and displaying hierarchical relations. Therefore, we systematically investigated the problem that has been motivated and substantiated with literature (see section 2). In addition, we sourced preparatory work on DEs and derived design principles to consider when modeling the artifact.

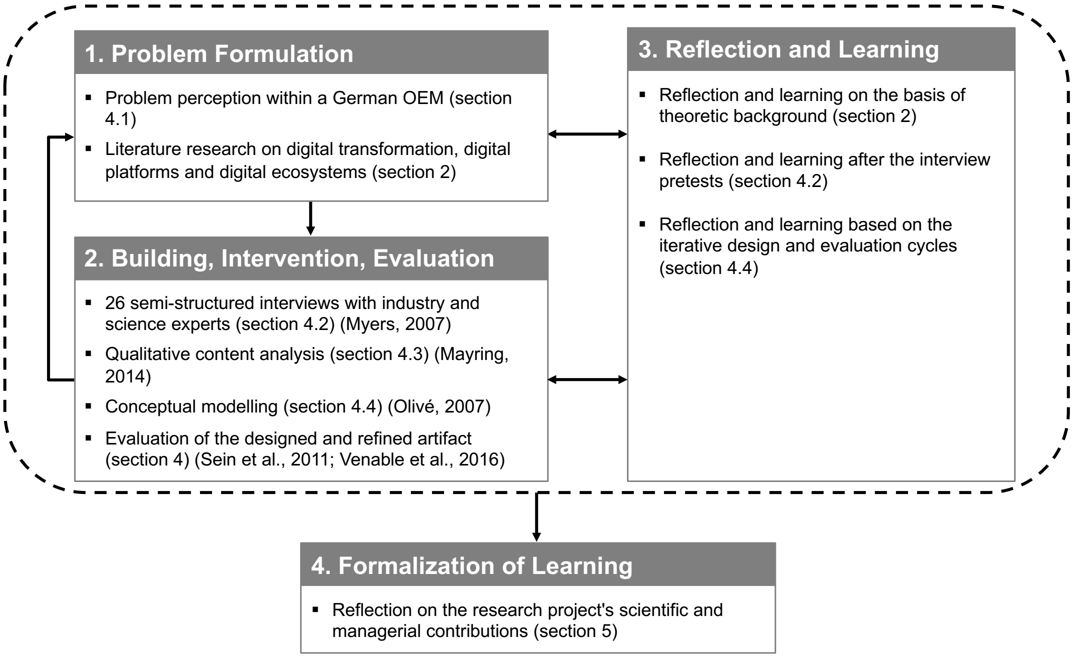

Figure 2: Action Design Research framework adapted from Sein et al. (2011)

Next, we built, organizationally involved and evaluated the design of the artifact based on the theoretical premises adopted from the problem formulation phase. Thus, the artifact was iteratively shaped and reflected upon to increase the overall quality taking into consideration the inclusion of stakeholders from different organizations. In doing so, building and evaluating the artifact becomes an ongoing process with multiple iterations involving researchers, practitioners and users. The interplay of the preliminary research design and the continuous shaping by the interviewee's feedback are essential ADR characteristics (Sein et al., 2011). The initial evaluation of the artifact is formative, being refined by both anticipated and unanticipated consequences, while the evaluation of later versions is summative in terms of assessing the value and utility of the results. In addition, we conducted a workshop applying the artifact in a real problem scenario with potential end users. Throughout the building, intervention and evaluation phases we reciprocally adapted and formed the artifact and concurrently evaluating it within an organizational context.

At the same time, we analyzed and reflected on the intervention results for each step and built a rather abstract and conceptual understanding of the solution. Reflecting and learning is an ongoing process conducted in parallel to the first two stages to ensure a continuous advancement and knowledge contribution (Iivari, 2003; Garud, Jain, & Tuertscher, 2008). Finally, we abstracted the results of the structural DE investigation and discussed the transferability of the results from the automotive industry to the manufacturing industry and possibly beyond. We therefore propose DE design principles for manufacturing industries and discuss future research opportunities.

4 Conceptualizing a Digital Automotive Ecosystem

4.1 Problem Formulation within the Automotive Domain

The notion of conceptually modelling a digital automotive ecosystem arose while conducting an empirical study with a German OEM that introduced microservice architectures during a digital transformation effort in order to enable fast digital product development. The OEM is a public limited company with an annual turnover of over 50 billion Euros and over 100,000 employees. The OEM's current revenue is majorly generated through vehicle production and distribution that ranges from compact to luxury vehicles. In addition, the OEM offers garage services, leasing businesses, and other ancillary services that are connected to its physical ecosystem. Digital products are offered under the OEM's brand via established third-party platforms and through its own online store. The current portfolio of digital products is small and is not yet integrated to enable seamless customer journeys across the organization's multiple channels. The OEM possesses few insights about its customers' digital life and how it is connected to its products. organizationally, the company set up internal IT departments that execute administrative IT tasks and assumes ownership of digital product development. Succeeding previous digitization programs, the OEM intended to launch an initiative to introduce a DE with the objective to enhance the customer experience and gain more insights about user journeys in order to be able to develop and deliver more valuable digital services. The OEM plans to develop the necessary internal skills and capacity to assume ownership of the DE, manage its operation and respectively enhance it. However, the OEM did not know how to scope and design a DE given its legacy IT and organizational structure. It was unclear in which areas it is best to strategically invest IT resources and which long-term partnerships or acquisitions should be pursued. As a basis for decision making and conceptually planning this endeavor, a structural target picture of a DE, its elements and relations was missing. The organization's steering committee asked for strategic external advice to plan the DE with consideration to the organization's structure and legacy IT, displaying necessary elements and deriving a target model. In a posterior phase, the DE shall be implemented and globally rolled out.

During this study we partnered with an advisory firm to strategically plan and implement a DE that takes the previous issues into consideration in collaboration with, and on behalf of the OEM. As a result, we could intervene our outcomes during jour fixe with the steering committee and digital architects and could continuously evaluate the artifact with advisory agents. Using this as a starting point, we reviewed existing literature about DEs and digital transformations in the manufacturing industry and identified the research gap that is introductory motivated (section 1) and further substantiated (section 2).

4.2. Data Collection and Setting

The conceptual model is constituted of elements, stakeholders and structural arrangements. In order to collect data for deriving necessary elements we conducted 27 semi-structured expert informant interviews of 14 organizations over a period of 10 months, from November 2016 to August 2017 (see Figure 3). We interviewed personnel from various organizations to include both a comprehensive set of perspectives and to take into account that ecosystems are constituted of various interconnected stakeholders (Peltoniemi & Vuori, 2008). Following a purposeful sampling strategy, we chose and approached representatives that could provide rich information about OEMs digital transformation processes (Palinkas et al., 2015).

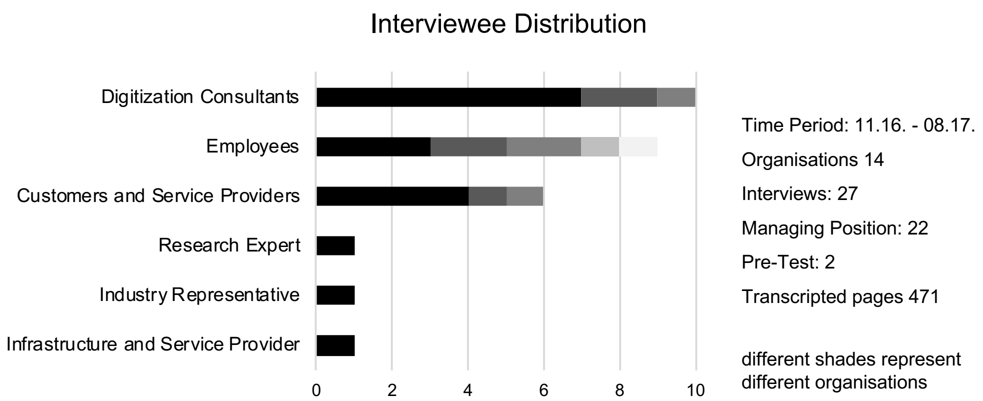

Figure 3: Interviewee distribution by sector

Thereby, we wanted to satisfy both an in-depth knowledge dimension, while also including a broad spectrum of possible DE stakeholders. In order to gain expert access, we used the existing network within the partner company and proactively reached out to individuals or organizations that fit the interviewing criteria and objective. 22 of the interviewees hold managing or top-level management positions (see Table 2). Around 70% of interviewees were automotive digitization consultants and OEM employees and the third largest group represents OEM business customers, mainly from logistics and mobility service providers. In order to gather a holistic perspective, both a leading future mobility research institution as well as the automotive industry representative organization were included in the survey. Consequently, we gathered data from an external, an internal, the customers' and the academics' points of view.

Table 2: Overview of Interviewees

Code	Position	Business Context	Interview Duration	Transcripted Pages	Code Amount
Pt	Team leader Customer Solutions	Logistics Service Provider	45:48	21	-
Pt	Application Manager	Logistics Service Provider	1:08:38	21	-
I1	Partner	IT Consultancy (Automotive)	46:32	18	35
	Managing Consultant	IT Consultancy (Automotive)			
I2	Partner	IT Consultancy (Automotive)	56:27	22	42
I3	Team leader Package	Logistics Service Provider	51:50	15	23
I4	Expert Connected and Auto. Driving	Industry Represative	1:06:34	17	36
I5	Senior Consultant	IT Consultancy (Automotive)	31:26	12	18
I6	Managing Consultant	IT Consultancy (Automotive)	56:01	18	43
I7	Head of Future Innovation	OEM	54:18	17	28
I8	Managing Consultant	OEM	50:12	18	27
I9	Head of Innovation	Logistics Service Provider	43:21	16	30
I10	Future Innovation	OEM	1:05:53	23	33
I11	Product Manager	Logistics Service Provider	56:29	21	19
I12	Business Model Researcher VW	OEM	56:35	16	31
I13	Managing Director for a Mobility Innovation Centre	Research and Knowledge Centre	27:26	12	38
I14	Global Head of Sales Training	Logistics Service Provider	1:06:02	20	21
I15	Team leader in-car technology, connected car	OEM	28:00	13	36
I16	Product Manager Connected Mobility	IT Service Provider	51:06	14	24
I17	Project Manager Digitization	OEM	...	7	24
I18	Managing Partner	IT Consultancy (Automotive)	1:02:28	21	29
I19	Senior Consultant	IT Consultancy (Automotive)	59:14	20	31
I20	Senior Consultant	IT Consultancy (Automotive)	58:39	20	24
I21	Chief Marketing Officer	Mobility Service Provider	50:40	15	24
I22	Managing Consultant	IT Consultancy (Automotive)	1:05:16	20	37
I23	Business Innovation Manager	OEM	56:34	21	31
I24	Manager Production	OEM	49:57	15	39
I25	Managing Director	IT Consultancy (Automotive)	1:00:46	18	35
				471	

I1... Interviewee 1 Pt... Pretest

The interviews were carried out either face-to-face or by telephone, with one of the 27 sessions including two interviewees. All interviews were audio recorded except for one, of which the content was captured in written form. Generally, interviews lasted between 45 minutes to an hour with an interview guideline being provided beforehand (see Appendix A). The guideline served as a reference point, containing an outline with open-ended questions. The interviewees could utilize the questions and were free to improvise if they felt the need to do so creating room for topic exploration (Myers & Newman, 2007). During the interviews we paid attention to interpretations and the experts reasoning processes (Spiegel et al., 2016).

Initially, we ran pretests with two OEM customers and service providers, serving as reflection and learning iterations (Given, 2008). As a result of the interviewees' feedback and our experience, we revised the observation schedule and adapted the guideline. We included an introduction to illustrate the objective, restructured the guideline and improved the overall clarity. Further, we decided to focus primarily on selecting experts with deep industry and organizational knowledge rather than broadening the variety of service providers.

4.3 Qualitative Data Analysis

Following the constructivist grounded theory approach by Charmaz (2014), we transcribed the interviews verbatim to reduce information loss, only eliminating utterances. Next, we ordered and summarized the 471 transcript pages as suggested by Mayring (2014). Thereby, we first reduced the information amount by selecting relevant text parts, and abstracting and simplifying the transcripts. We then structured these text parts in accordance to specific sections and ordered them by means of the interview guideline. Afterwards, we qualitatively analyzed the amounting 220 pages with coding and software assistance, namely ATLAS.ti (Version 8) (ATLAS.ti Scientific Software Development GmbH, 2017). We chose this program as it is advantageous for handling large amounts of data, efficiently searching and retrieving information, and it provides the options to code and link data (Mayring, 2014).

During the data analysis we created codes (and sub-codes), categories (and sub-categories) and abstracted them to themes, upon which we ultimately developed the ecosystem elements (Saldaña, 2016). Coding the documents is seen to be an initial step for researchers when attempting to derive valuable information from the collected data with the goal of forming categories that are intermediate stages in a continuous process of structuring meaningful units (Given, 2008).

As there are existing theoretical concepts regarding the composition of DEs and the digital transformation of manufacturing industries, we applied a directed content analysis whereby we defined codes both before and during the data analysis (Hsieh & Shannon, 2005) and repeatedly performed the coding starting with different interviews each time in order to improve reliability (Downe-Wamboldt, 1992).

Following the process proposed by Lichtman (2013) we initially openly coded the text using in-vivo codes*,* which are terms used by the interviewees in line with the suggestion for directed content analysis by Hsieh and Shannon (2005). In a second round, we coded larger text parts and paragraphs, and expanded the coding process using gerunds, including changing and reforming the set of codes (Saldaña, 2016). During the process we wrote memos to systematically capture implications, theoretical ideas, connections and emerging questions (Carmichael & Cunningham, 2017).

Subsequently, we reflected on the codes, removed or merged redundant ones, and discussed their meanings to eliminate unclarity among the researchers. For instance, we merged “vehicles”, “cars” and “car” into the code “vehicle”. Following, we aggregated the codes into categories and sub-categories, thus adding a hierarchy. Once again, we discussed the categories, clarified their meanings and resolved issues of misunderstanding. Adding more analytical depth and nuances to the descriptive codes and initial categories, we reflected on the information content and their contextual meaning (Carmichael & Cunningham, 2017).

After having finished the initial coding, we re-read the interviews to identify structures (cause-and-effect patterns) and dependencies between codes, forming categories. Further, we proceeded with the focused coding of the transcripts (Charmaz, 2014; Saldaña, 2016) aiming to identify conceptually related codes and the most frequently referred to ones. Again, we reflected on the results, discussed their interpretation and resolved any misunderstanding by reaching an agreement on the codes' meaning. Consequently, we merged and streamlined codes, and created new categories and sub-categories. Next, we coded the transcripts axially, where we considered the properties and attributes between them, and refined the categories and sub-categories. Building upon the categories, we formed a set of concepts with regard to DE elements and stakeholders, as can be seen in Appendix B and C (Olivé, 2007). Therefore, we looked for patterns across categories and further conceptualized them (Given, 2008). For instance, we subsume references to artificial intelligence, Big Data, data analysis, insights and processing services within the concept of data analytics, manifesting themselves as technical elements of the data analytics platform. Again, we discussed the results, reduced misunderstanding and resolved terminological ambiguities until a satisfactory understanding was reached.

4.4 Building, Intervention, Evaluation

4.4.1 Building and Intervention

Based on the identified stakeholder concepts and preparatory literature work, we applied a use case model in UML to a service the OEM was conceptually investigating (see Figure 4). A use case model structures the stakeholders' relation from a behavioral point of view and is advantageous in gathering the functional requirements that constitute the ecosystem (Misbhauddin & Alshayeb, 2015).

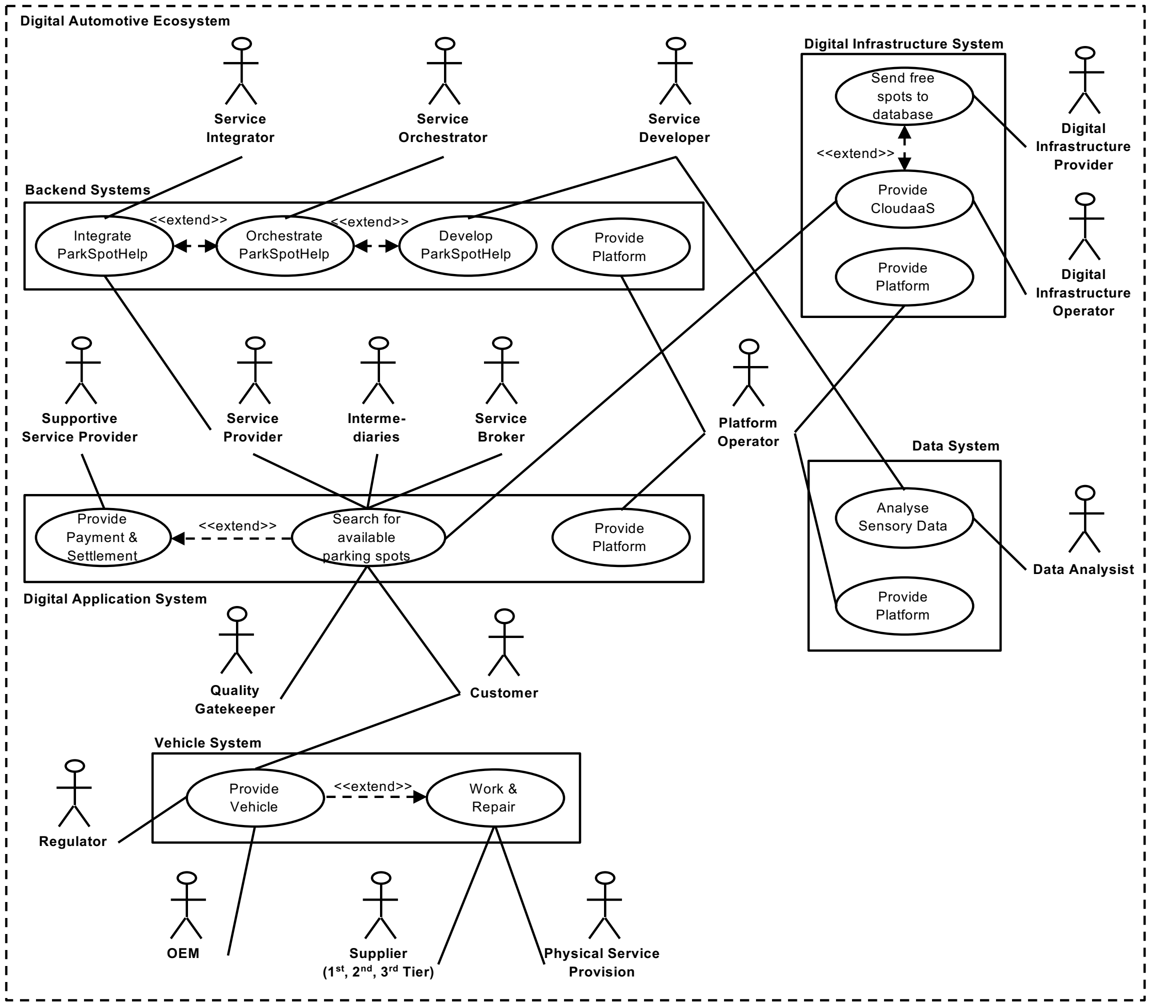

Figure 4: Use case model of the DE stakeholders in UML

As seen in Figure 4, the use case is of a customer demanding an intelligent parking service (ParkSpotHelp) through the customer's in-vehicle information system. Customer services that are provisioned via the in-vehicle information system are surveyed with regard to quality and governance aspects from gatekeepers. In this case, customers can only access curated applications that are relevant and do not negatively affect the driving behavior. On the other side, the digital application system is accessed by various service delivery agents. For the service delivery agent to provide the service to the customer, backend services ranging from development, integration to orchestration, have to be realized. Further, vehicular sensor data has to be processed and enriched, for which digital infrastructures have to be provided and operated. Central agents for a DE are platform providers that enable the services to work by providing essential infrastructure. Subsequently, we proceeded to model the structure of the identified concepts (see Figure 5).

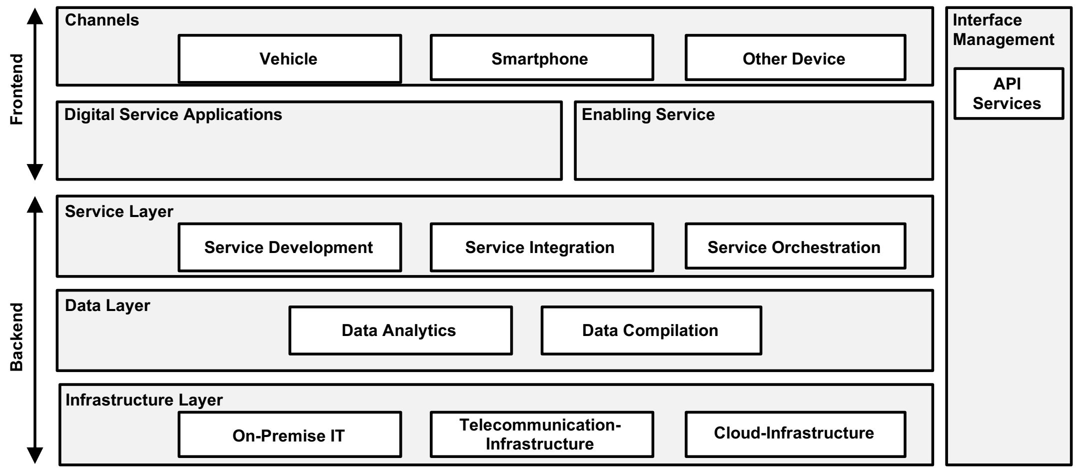

Figure 5: Conceptual architecture of the DE elements

The DE is constituted of multiple layers that are distinguished between customer-facing frontend layers and backend layers with no direct customer touchpoints. The levels are hierarchically arranged from a customer's point of view and the different channels they use to access the digital application portfolio. The service development, its integration as well as its orchestration, take place within the service layer. Synchronously, data from different sources are compiled and analyzed according to the application. In addition, IT infrastructures have to be in place that enable the development process. Typically, OEMs have on-premise IT systems (e.g. own servers, databases and administrative IT systems), but also use cloud computing providers as fallbacks. All elements communicate and are managed through mainly API-based interfaces.

Both the use case model and the conceptual architecture were coordinated within jour fixe with the OEM. The use case model was coordinated with members of the organization's digital program management and coordination teams. The conceptual architecture was presented to the digital architects that intended to include business unit initiatives within the DE program and are involved in the overall concept. The meetings were useful in evaluating the functional requirements and gaining a sense of the organization-specific problems. The persons of contact identified both models to be correct.

However, attendees also remarked them to be abstract and difficult to utilize in their specific organizational context. We observed a discrepancy between our scientific aspiration of the model's generalizability and the business' demand to solve a particular problem. For satisfying the latter, more detailed element specifications and the involvement of legacy systems and corporate structures would have to be considered. Therefore, conceptual elements would need to be turned into organization specific, meaningful entities and specified per addressee. For instance, service development occurs in an open source development environment that is hosted on-premise within the organization's IT headquarters. The service development process is supported by the organization's tool stack that includes a continuous integration and delivery pipeline for automated testing and deployment. Hence, integrating the development environment, tool stack and delivery pipeline solution as elements within the concepts would be desirable. We reflected on the experiences, discussed them and further adapted the model until a satisfactory degree of generalizability was reached that allows the deduction of organization specific elements.

Subsequent, we developed an initial version of a layered conceptual model of a digital automotive ecosystem (DAE) that was continuously evaluated (see section 4.4.2 for a detailed description of the evaluation process), formed and refined (see Figure 6). Within the artifact's design, the previously identified literature, interviews and intervention, and evaluation iterations, were considered and respectively incorporated.

Figure 6: Layered conceptual model of a digital automotive ecosystem

The DAE model is constituted of elements (parallelograms) and stakeholders (rectangles). Elements can be structuring levels or technical hardware (e.g. vehicle) and software expressions (e.g. digital service application platforms) by which digital services are provisioned. Each of the identified technical elements can represent a multitude of expressions, for instance various ‘Data Analytics Platforms’, and is integrated within the system via interfaces, such as APIs. The elements are interconnected as is typical within an ecosystem and most manifest themselves as platforms, such as a ‘Data Compilation’ platform. A data compilation platform is connected to multiple data sources, which can be platforms themselves, such as vehicle data, customer data or third-party-data sources etc. Stakeholders refer to an organization or a natural person and operate or manage the elements, which are expressed as platform operators (positioned at the top-right corner of the parallelogram). Apart from the operator, other stakeholders contribute to the service provisioning and operate on the platform, but do not manage it, such as service developers on a service development platform (positioned at the low end of the parallelograms). The service provisioning is shielded or protected by quality gatekeepers with regard to content and technical dimensions. Contrary to the perceived notion of the vehicle being the central element of the DE, or digital hub, the customer is the initiator of the digital service delivery process and respectively placed. Customers traverse through customer journeys whereas a DAE can be one of various ecosystems of involvement for them and can also be integrated with other ecosystems.

4.4.2 Evaluation

Following Venable, Pries-Heje, & Baskerville’s (2016) Framework for Evaluation in Design Science Research, we chose a naturalistic evaluation exploring the performance of a solution technology in its real environment, typically within an organization. Thereby, we applied a ‘Human Risk & Effectiveness’ strategy as the risk of the designed artifact is of social and user-oriented nature. We chose this strategy since the application and user acceptance of the layered conceptual model are of primary concerns and the major risks are user-oriented, in other words, the interpretation and application of the model (Olivé, 2007). Our fundamental evaluation objective is to test the artifact’s utility. In total we traversed five evaluation episodes and a workshop concerning a real problem through which we continuously adapted and formed the previously developed minimum viable model (MVM) of the DAE (see Figure 7).

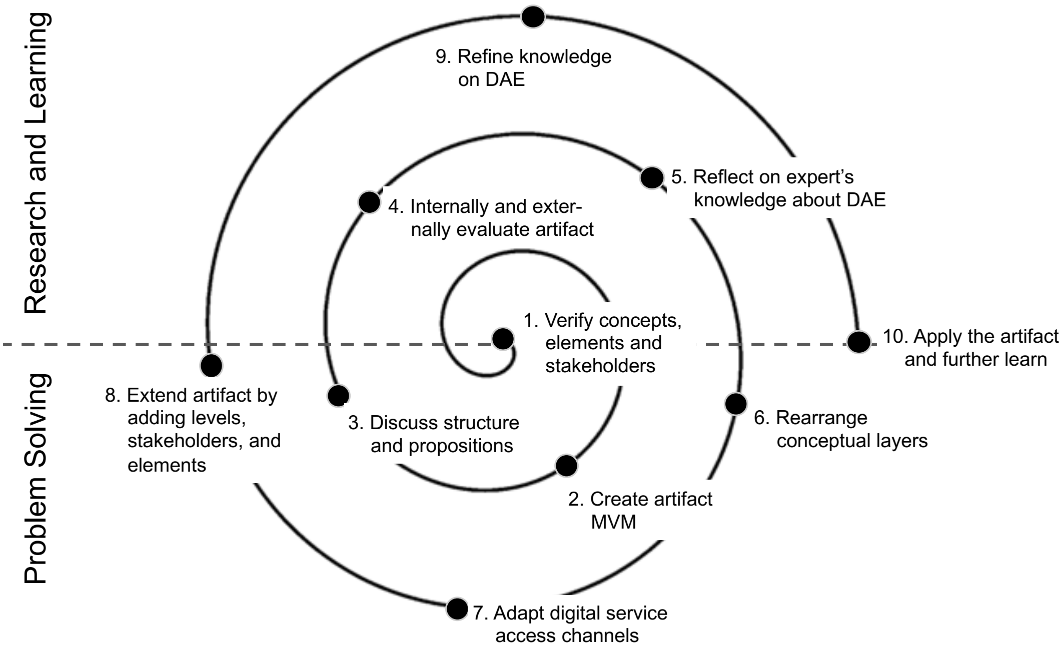

Figure 7: Overview of building and learning iterations

Having verified the concepts, elements and stakeholders within the organization, we proceeded to internally and externally validate the artifact by means of semi-structured interviews. Therefore, we queried five persons from three different organizations representing the internal perspective (of an OEM employee), the external perspective (of OEM advisors) and the scholastic point of view (of researchers). We sent the artifact MVM prior to the interviews and explained the intended evaluation objective. After each evaluation episode we summarized the protocols and then abstracted and formulated them as new statements (Mayring, 2014). Subsequently, we reflected on the interviewees suggestions and respectively adapted the artifact, as can be seen in Table 3.

Table 3: Overview of Evaluation Episodes

	Automotive IT Consultant	Automotive IT Consultant	Automotive BM and Innovation Expert	BM Innovation Researcher	Automotive IT Consultant
Code	I1	I2	I3	I4	I5
Level	Partner	Management	PhD Researcher within an OEM mobility unit	Senior Researcher	Management
Useful-ness	- Concepts seem to be correct - Useful on a strategic level to give an overview - Low applicability for business departments	- Useful to outline the strategic target state in a big picture sense - Customer-centricity is clearly visible	- Elements seem conclusive and it is useful to have a breakdown of the service provisioning tasks into development, orchestration, intergation and orchestration	- The DAE is perceived to be correct; the elements and stakeholders appear to be conclusive - Scientifically valuable as it helps to understand the structure and so far visualisations are not common	- The representation seems to be correct from interviewee's perception - Strategically helpful, but it is hard to imagine a use case scenario where to put it into action - Capabilities would be a useful extension
Adapta-tions:	- Reordered arrangement of layers, e.g. vehicle as an access channel	- Added other digital application access devices	- Added exemplary service to the DAE description	- Inserted levels infrastructure and service for clarification and differentiation	- Inserted data level and put it as a third ecosystem layer
	- Put customer centrally on top	- Inserted customer journey	- Refined quality gates between technical and relevant		- Added on-premise infrastructure platform
		- Added a quality gate around the customer	- Inserted API-based IM as connections between platforms		- Distinguished between data platform and data analytics platform

All interviewees found the DAE or parts of it useful, but the degree of this judgement differed. Generally, the DAE is perceived to be of strategic value (I1, I2, I5) and not operational (I1, I5). While I1 and I2 found the artifact to be a good visual representation for discussing a DE conceptually, I5 had difficulty with imagining a scenario in which to put it into use. The elements and identified stakeholders were perceived to be correct and conclusive (I3). Scientifically, having a topology of a digital ecosystem was regarded to be of value, as few structural representations of elements and stakeholders currently exist (I4). The evaluation cycles proved to be of considerable benefit, as we incorporated propositions from each of the interviewees. We rearranged the conceptual layers, extended the scope of elements, added structuring levels and stakeholders. Further, the interviewees suggested additions and extensions to the DAE that would increase the value of the artifact for users by facilitating organizational decision making with regard to distinct dimensions. These dimensions include but are not limited to the following: First incorporation capabilities that could be mapped to elements of the ecosystem (I5), implementing governing structures and elements that go beyond the representation of the quality gatekeeper role (I3), implementing factors that facilitate the decision of whether to procure services inhouse or outsource (I3) and adding connecting factors of customer journeys to specific service categories (I1). Each of these suggestions were carefully examined, however, it was concluded that they would extend the present research scope and would make generalization beyond an organization specific point of view difficult.

After having refined the artifact, we put it into practical use by conducting a workshop with an internationally operating applied research institute specializing in the dissemination of knowledge to businesses and industries. We discussed a real use case with three researchers from the digital business model unit (subsequently referred to as test persons) at the institute's premises and explored the possibility of using the DAE in order to approach the provided problem. Therefore, we explained the topology and observed how the artifact would be used and by which modality (Nunamaker, Chen, & Purdin, 1990).

The test persons faced the problem to explore how small- and medium-sized manufacturing enterprises (SMEs) can create services from mechanical sensory data of machinery equipment and complex tools to competitively differentiate themselves and expand current product portfolios. Particularly, the test persons confronted the challenge of formulating digital service scenarios and communicating them to the SME addressees, mostly represented by the director or executive board. The test persons did not receive any starting points for outlining and breaking down the technical provisioning process.

We explored the problem by exemplarily discussing a predictive maintenance scenario the SME could develop into a service. In doing so, we noticed the test persons applying the artifact for the creation of service journey for a specific function of machine. Therefore, they used the DAE elements and stakeholders to develop a narrative by which they transferred the initial idea into an outlined delivery plan. The test persons quickly pointed out the SME can only provide the data collection and enrichment and would need to integrate or partner with other DE stakeholders. In doing so, the test persons came up with multiple starting points to convey digital service offerings and the surrounding ecosystem.

Reflecting upon the findings, they pointed out that using the artifact gives a practical starting point in conceptualizing digital services and provides an understanding of the entire service provisioning process. It could thus facilitate communication and provide a ubiquitous understanding of a complex domain.

The workshop illustrated the application potential of a digital ecosystem model outside the automotive industry and for different addresses, in this case, SMEs. Primarily, it was perceived to be useful as an educational instrument during the conceptualization of digital services from a technical point of view, as it outlines which elements have to be in place and managed in order to provide a specific functionality. However, the attendees also remarked the artifact to be of strategic use rather than operational.

5 Formalization and Learning

5.1 Scientific Implications

An empirical investigation of an OEM which intends to set up a digital ecosystem formed the basis for the DAE model. We conceptually developed the model by interviewing 26 experts from 14 different organizations and derived necessary elements and relevant stakeholders. Recapitulating the initial research question, the artifact consists of different layers that are interconnected within a dynamic network structure. Each layer can comprise a multitude of platforms that can be clustered in digital applications, service developments, data analyses and infrastructural platforms. Customers access these platforms and the ecosystem around them through channels, vehicles being one of many possible touchpoints. This study contributes to the understanding of digital ecosystem elements and their topological composition generating multi-disciplinary knowledge as they are established in distinct areas of academic literature (Thomas, Autio, & Gann, 2014; Sørensen, Reuver, & Basole, 2015; Reuver et al., 2017). Thus, they can be investigated and further substantiated from different perspectives, such as the shaping role of governing entities who fulfil curating functions in terms of quality and content (Uludağ, Hefele, & Matthes, 2016).

The conceptual model contributes to the debate differentiating platforms from ecosystems as contributing entities for the latter (Adner, 2017). It adds to the stream of knowledge with a rich and structured understanding of what occurs in a DAE and of which elements, roles, and relations it is constituted of (Reuver et al., 2017). To the authors' knowledge no investigations have been conducted that provide a dynamic conceptual model of a DAE linking architectural layers and digital platforms. If applied in future empirical research, the DAE will provide analytical consistency allowing the differentiated exchange and comparison of research work.

In addition, the findings contribute to the empirical body of knowledge about digital ecosystems (Weill & Woerner, 2015), particularly in the automotive industry (Bilgeri et al., 2017). It provides further insights taken from the case organization as well as other industry representatives about digital platforms and ecosystems (Sørensen et al., 2015).

As suggested by previous studies, the artifact strengthens the notion of digital ecosystems being environments of collaboration and partner integration (Gomes, Facin, Salerno, & Ikenami, 2016; Adner, 2017). Apart from the customer as the initiator of any digital activity, platform operators will play roles of central importance. These findings further suggest developing a DAE is a matter of integrating these platforms into a coherent system that can deliver a specific value proposition. The criteria of linkage and value proposition positioning is managed by governing entities. The DAE displays the relative importance of the relationship between these layers in the contribution to the overall delivery process.

5.2 Managerial Implications

Physical products are perceived to be channels for customers to access DEs within their journeys, indicating a substitutionary function as commoditized devices. This implies a loss of significance for the physical product being the center of gravity for many manufacturing companies. However, physical goods remain important and can be seen as intersections between predominant ecosystems and digital ones.

Although, recent studies have further specified definitions of a DE, a layered conceptual model proposes a more complete understanding of the concept upon which management can scope and define commercial fields of action. OEMs that intend to operate in the digital market have to be clear which platform they intend to manage, which technologies and capabilities need to be sourced and integrated, and for which they have to formulate strategic partnerships.

In addition, the conceptual model provides means by which decision makers can better recognize the relationships among stakeholders and gain an understanding of the importance of being able to integrate their value propositions within customer journeys. Thus, it turns management's focus towards this specific imperative and the need of an integration-based approach in outlining their strategy, potentially expanding their current operational model by improving digital value co-creation.

Additionally, the model draws attention to the crucial role of quality gatekeepers during the entire service delivery process, since through these access points curated content is approved. In this way, OEMs as the producer of the physical platform infrastructure, or vehicle, could fill this strategic position and leverage their brands. Vehicles or physical products will become more commoditized and thus the asset of a brand is going to be a crucial factor in the pursuit of providing curated experiences or governmental value propositions.

The investigation further revealed the conceptual model to be a useful tool in shaping and defining service journeys from the customer's specific demand to the configuration of necessary backend operations. Accordingly, decision makers can classify their existing value proposition within the context of the entire value chain, which is useful in building up respective capabilities early on and integrating necessary partners for the entire provisioning process. Visualizing the necessary elements and involved stakeholders provides a map by which strategies can be translated into action-oriented decisions. This in turn supports organizations which decide to alter their strategic positioning from product to solution providers as identified to be the case in the automotive industry (Nenonen & Storbacka 2010).

6 Conclusion

In this article, we investigated how a conceptual model of a DAE can be designed and structurally represented. The study was performed by means of an empirical study of an OEM that intends to setup a digital ecosystem. For the development of a layered conceptual model of a DE, we interviewed 26 experts from distinct organizations, qualitatively analyzed the data and derived elements as well as defining stakeholders. We conceptually modeled an initial artifact applying an action design-oriented approach and iteratively evaluated and enhanced the artifact through multiple interventions within the case organization, the partnering organization and by interviewing experts. In addition, we applied the artifact by means of a real problem scenario and formulated and discussed general learnings from this research.

The layered conceptual model of a DAE is a domain-specific artifact that provides visual representation of the layers that constitute a digital ecosystem, its relevant stakeholders and the relationships among each other. The artifact supports decision makers in strategically planning and outlining digital ecosystems themselves. Besides the development of the conceptual model, this research contributes to the body of knowledge about digital ecosystems and its demarcation from digital platforms. Further, the findings provide a deepened comprehension about the automotive industry and allow for partial abstractions for digital ecosystems of manufacturing industries. Within the applied framework we were informed by a problem-relevant case and iteratively built a practitioner-oriented solution traversing cycles of practical development, reflection and learning.

However, this research is subject to limitations in a number of respects. First, in order to define the theoretical basis of digital ecosystems, only parts of the entire literature were researched and identified. Second, the DAE model has only been applied by one research group within one OEM, which is in the process of building a digital ecosystem. Involving the artifact in another organization could have possibly resulted in different expressions of the digital ecosystem model and compatibility. Although we attempted to be exhaustive in the contextual description and setting, researchers should handle the transfer of our findings to other organizations and industries with care. Third, the selection and choice of experts as well as the sampling size impact the data collection and thus influence the derivation outcome of the elements that we identified. Finally, the selection of applied research methods within the organizational context worked well, but it cannot be reasoned that we developed the best conceptual model for a DAE.

We strongly recommend applying the artifact within different organizations of the automotive industry and to further test its applicability in other manufacturing industries. In light of the growing importance of digital ecosystems, we highly encourage building on these findings and further clarifying the structure of digital ecosystems within other domains. Additionally, it could be investigated how to align different types of IT, i.e. product development and administrative IT, within the ecosystem structure. Though it was not a focus of this investigation, the value of the ecosystem could be enhanced by identifying capabilities connected to the different platforms and mapping them accordingly. Thus, organizations can gain a richer understanding about digital ecosystems and assess more precisely which resources would be necessary to be able to operate parts of that ecosystem.

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4 Artefact 2: Conceptual Reference Framework

Grieger, M. & Ludwig, A. (2017). On the Move Towards Customer-Centric Business Models in the Automotive Industry – A conceptual reference framework of shared automotive service systems. In *Electronic Markets.*

4.1 Meta Data

Table 12: Meta data of the publication Conceptual Reference Framework

Title	**On the Move Towards Customer-Centric Business Models in the Automotive Industry - A conceptual reference framework of shared automotive service systems**
URL	http://www.electronicmarkets.org/home
Type	Journal Article
Publication in	Electronic Markets - The International Journal on Networked Business State: Accepted with minor revisions
Status	Conditionally accepted with minor revisions
Editor	Leitão, João; Alves, Helena; Edvardsson, Bo
Series Title	Special Issue: “The future of shared services”
Publisher	Springer Science+Business Media
Place of Publication	Leipzig, Germany
Ranking	CORE: A[4] VHB: B[5] h-index: 23[6]

4 http://portal.core.edu.au/jnl-ranks/?search=electronic+markets&by=all&source=all&sort=atitle&page=1
5 https://vhbonline.org/nc/en/service/jourqual/vhb-jourqual-3/complete-list-of-the-journals/
6 https://scholar.google.com/citations?hl=en&view_op=search_venues&vq=electronic+markets&btnG=

4.2 Summary

This study presents a conceptual reference framework for automotive SSs that shall support OEMs methodologically with the development of digital services. The artefact is suitable for use during the early stages of automotive service design, focusing on the idea generation and scoping of the service landscape with consideration of the relevant stakeholders by providing a customer-centric structure.
The article refers to RQ2: *How can original equipment manufacturers be supported in the conceptualization of automotive service systems taking into account relevant stakeholders?*

The research features an extensive literature review on automotive SSs (Fettke, 2006) coupled with a conceptual modeling approach (Rößl, 1990) formed by mapping the Business Model Canvas to the SS domain (Osterwalder & Pigneur, 2011) from an operational point of view (Alter, 2012). The selected BM constructs were adapted and abstracted to the SSs domain and further substantiated with the results of the literature review (see Table 13). The full categorisation table is provided in Appendix D and E: CRF Categorisation and Derivation of Constructs.

Table 13: Abridged substantiation with dimensions

	Category	Dimension
Service Value	Safety	**Safety & Security**
	Security	
	Resource efficiency	**Resource Optimization**
	Driving experience	**Emotion & Experience**
	Service experience & Usability	
	Customization	
	Accessibility	**Convenience**
	Comfort & Convenience	
Service Objective	Transportation & Navigation	**Intelligent Transportation**
	Connectivity enhancement	**Connectivity**
	Issue Detection & Driving support	**Driving Support & Assistance**
	Quality improvement	**Maintenance Assistance**
Service network infrastructure	Stationary infrastructures	**Physical Stationary Infrastructure**
	Areas	
	Mobile devices	**Physical Mobile Infrastructure**
	Information	**Digital Infrastructure**
	IT Infrastructure	
Customers	End Consumer	**External Service Recipient**
	Business Customers	
	Business Units	**Internal Service Recipient**
	OEM	
Key stakeholders	Service staff	**Physical Service Provider**
	Service Providers	
	Information service staff	**Digital Service Provider**
	Information service providers	
	Secondary beneficiaries	**Secondary Service Beneficiary**
Customer Involvement	Developmental Collaborators	**Active Participation**
	Active Involvement	
	Service Users	**Passive Participation**
	Information Provider	
	Actuator / Enabler	
Points of Interaction	Personnel	**Human Interaction**
	Vehicle Composition	**Physical Vehicle Attributes**
	Physical Environment	**External Environment**
	IVIS	**Virtual Interfaces**
	Virtual interfaces	

Thereby, the automotive services were synthesized and qualitatively analysed to derive constructs (Given, 2008), which are modelled in a UML class diagram to depict the relations among them. An initial artefact was built and iteratively advanced by means of multiple evaluation phases applying the Framework for Evaluation in Design Science Research, and by simultaneously pursuing a human risk and effectiveness strategy (Venable et al., 2016). The interviews are comprised of stakeholders from different organisations and hierarchies, ranging from chief digital officers to operant employees (Mayring, 2014). In addition, a case workshop was conducted (Crowe et al., 2011) in which the CRF was applied to a real problem scenario of a Swedish automotive supplier that wants to digitalise its service portfolio.

Both the interviews and the practical application suggest the CRF to be a supportive instrument for digital service development and that it meets the necessary requirements of correctness, completeness, comprehensibility, and usability.

The literature review demonstrates that only few of the identified articles take customer involvement into account during service development, failing to explicitly identify them as collaborators in value creation processes. It suggests customer involvement as a theoretical concept in the automotive industry and has not been practically considered.

Figure 12 exhibits the CRF, which is a particular view on SSs taken from a BM perspective as it is intended to support organisations and be applicable in the early service development phase. In addition, it contributes to the general knowledge on SSs (Alter, 2017; Ferrario & Guarino, 2011).

The artefact organises and advances the knowledge of SSs, more specifically, their composition and structural arrangement. The analysis demonstrated the customer and the corresponding service value as being the nucleus of any service activity, supporting the importance of customer-centric development approaches. The resulting model synthesizes SSs research with BM concepts.

Additionally, the CRF was found to provide guidance in the shift from product-dominant organisations to integrated solution providers. It is a useful instrument for identifying and ordering automotive SS constructs and for relating them amongst each other. Further, it demonstrates how a SS can be conceptually designed by building on a manageable number of constructs, providing a structure to organise industry specific automotive services (Heikkinen, 2014).

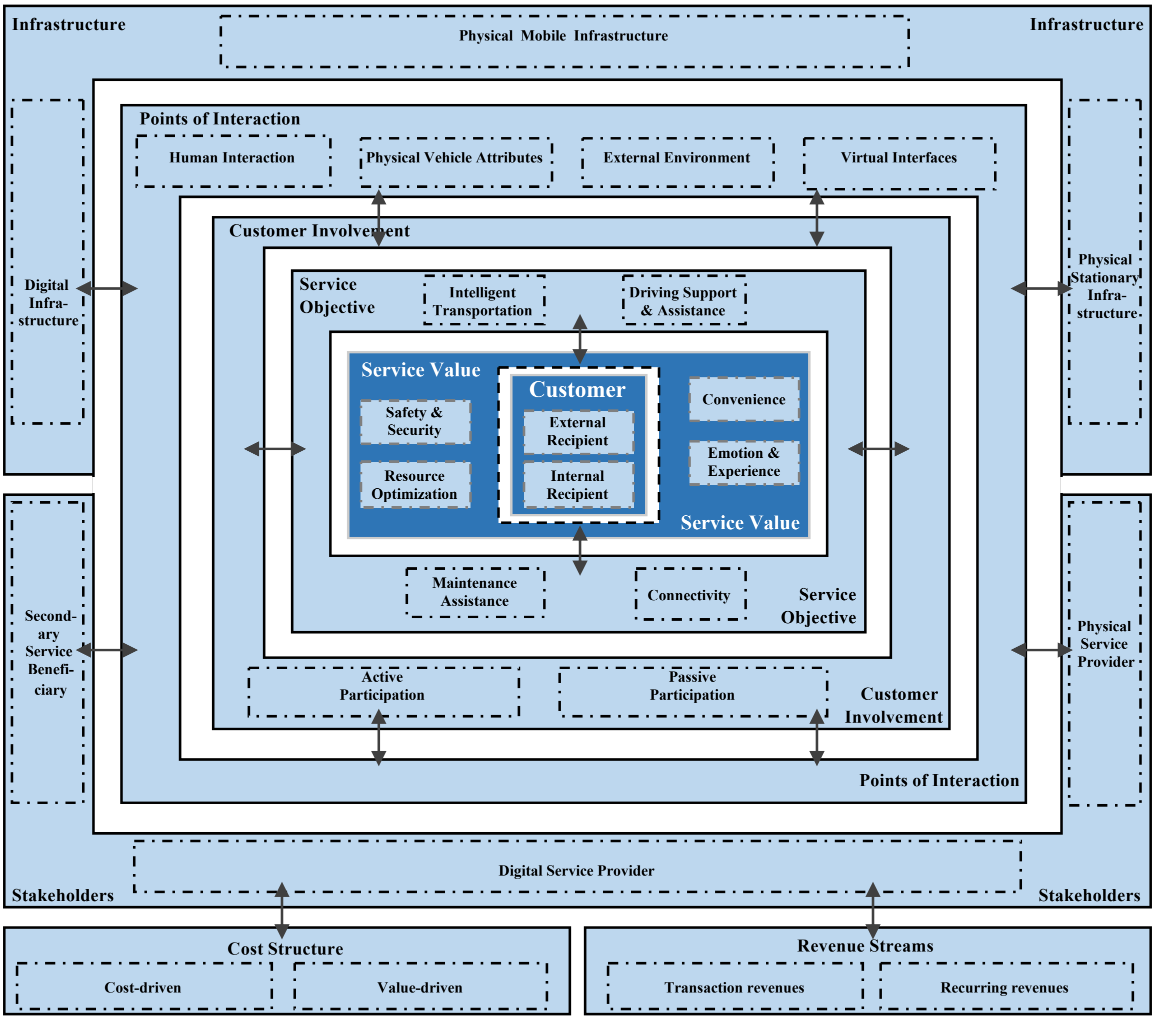

Figure 12: The Conceptual Reference Framework for automotive SSs

The framework illustrates that active engagement can be achieved by progressively designing interaction points that facilitate service accessibility for the stakeholders involved. The CRF incorporates the concept of customer value co-creation and supports the understanding of SSs being complex networks of various stakeholders who are contributors and beneficiaries at the same time (Mele & Polese, 2011). Managerially, a framework is provided by which the complexity of networked stakeholder systems can be structurally addressed. The CRF further serves as an instrument by which the concept of value co-creation is practically implemented and by which digital services can be efficiently conceptually outlined.

In using an industry-specific CRF, organisations and researchers can be more effective in solution finding and more efficient in the way of getting there, as was remarked during its practical application.

4.3 On the Move Towards Customer-Centric Automotive Business Models

Electronic Markets – The International Journal on Networked Business

On the Move towards Customer-Centric Business Models in the Automotive Industry - A Conceptual Reference Framework of Shared Automotive Service Systems

Article Title	On the Move towards Customer-Centric Business Models in the Automotive Industry - A Conceptual Reference Framework of Shared Automotive Service Systems
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Abstract:

Digitalization drives automotive original equipment manufacturers (OEMs) to change their value propositions and open-up towards greater collaboration and customer integration. The shift towards services implies a transformational change from product- towards customer-centricity. This study proposes a conceptual reference framework (CRF) out of a business model perspective to systematize automotive service systems. The CRF presents relevant dimensions and dependencies between the involved stakeholders and the necessary infrastructures in order to facilitate digital service conceptualization in the early phases of the service design. The artifact is developed based on a literature review and conceptual modeling, then iteratively evaluated by means of guideline-supported interviews from three different perspectives and applied to a real problem statement within a case workshop. The results suggest value creation for automotive services occurs in shared mobility networks among interdependent stakeholders in which customers play an integral role during the service life-cycle. Additionally, the results deepen the understanding of service business model development under consideration of industry-specific aspects and suggest the framework to be a beneficial structuring tool that can save resources and specify solution finding.

On the Move towards Customer-Centric Business Models in the Automotive Industry - A Conceptual Reference Framework of Shared Automotive Service Systems

1 Introduction

Industries, like products, proceed through distinct cycles and stages as they mature. Novel technologies and an alternating competitive environment pressure incumbents to react to these changes by updating and enhancing their business operations. Companies that fail to do so will be replaced by competitors that are “quicker or more efficient in bringing significant innovations to market” (Klepper 1997, p. 164). In this respect, digitalization challenges many manufacturing industries as prevalent business areas are rapidly evolving and are expected to continue in this way (Piccinini et al. 2015). Digital advancements and shifting customer expectations propel the development of new automotive business models (BM) (Hildebrandt et al. 2015) and change how value is concepted in companies (Ramaswamy and Ozcan 2018). Vehicles are no longer regarded as isolated tangible goods, but as objects that integrate different stakeholders, devices, functions, and data into coherent systems of value co-creation (Svahn et al. 2017).

The advent of these technologies has enabled new ways of providing mobility-related networked businesses (Firnkorn and Müller 2012), such as shared vehicle usage (Kessler and Buck 2017, p. 115), connected services (Kaiser et al. 2017), and autonomous and platform services (Yang et al. 2017). In addition, the view is spreading that customers are not just consumers of goods, but value adding contributors (Ramaswamy and Chopra 2014) and the center of gravity of developed services (Kowalkowski et al. 2017). Novel insights on how vehicles are used and the way in which mobility is consumed becomes accessible when the generated and platform-processed data is harvested (Pillmann et al. 2017).

In this context, OEMs and their suppliers have started to position themselves as both goods and service providers (Terler and Knöbl 2016; Bosler et al. 2017), which can be observed in cases such as Volkswagen’s MOIA project (Volkswagen Media Services 2016) or Daimler and BMW with their existing car sharing initiatives (BMW Group 2018; Daimler AG 2018). Providing automotive services is seen to be a differentiation instrument for both building competitive advantages (Porter and Millar 1985, p. 85) and generating new income sources (Suarez et al. 2013). Consequently, the focus of manufacturers’ business activities expands from producing goods towards developing integrated solutions by bundling vehicles with additional services. OEMs have opened up to foster interactional creational processes (Ramaswamy and Ozcan 2018) and gradually changed their perspective towards viewing vehicles as product-service offerings that provide both usage-based value (Schäfer et al. 2015) and additional values such as intelligent mobility, increased safety, or individualized comfort (Heinrichs et al. 2012).

However, the development of these solutions challenges OEMs as innovations in the automotive industry have historically been centered on the quality and features of manufactured goods (Firnkorn and Müller 2012). Providing services within their current value networks goes far beyond an OEM's present competencies, its suppliers, and its service providers (Schäfer et al. 2015). Initial efforts for differentiation by offering digital services in the early 2000s failed (Hoffmann and Leimeister 2011), and most OEMs remain mainly product-centered organizations (Mahut et al. 2015). Their predominant BM is largely unaltered, and service innovation proceeds to take place among industry newcomers, as are the cases of UBER, Lyft, and Tesla.

In this paper we investigate automotive services and their applications within service systems (SS) by reviewing literature with the objective of conceptualizing them within an ordering framework out of a BM perspective. An ordering framework is intended to help OEMs in their effort to develop service-based BMs and shall guide them in the conception phase by categorizing and systemizing SSs in the automotive industry. There has been extensive research on the notion of servitization and how it affects the BMs of manufacturing firms (Vandermerwe and Rada 1988; Baines et al. 2009; Vendrell-Herrero et al. 2016). However, the prevalent approaches only address parts within the field and industry specifics are mostly ignored or not taken into account (Adrodegari et al. 2017). So far, methods that support industry-specific processes are scarce and have not been sufficiently addressed (Chanias and Hess 2016). Most companies are challenged by the efforts to offer integrated solutions because of their inability to design and implement service BMs successfully (Bounfour 2016, p. 31). Further, it remains to be analyzed how customers and other stakeholders can be integrated into digital value-creation processes underlying a shared service offering, especially within the context of the automotive industry (Schumacher et al. 2018). Based on these preliminary considerations, we aim to answer the following research question:

How can original equipment manufacturers be supported in the conceptualization of automotive service systems taking into account relevant stakeholders?

We answer this question by systematically reviewing literature with the aim to discover a candidate set of terms. We categorize the terms by adapting and building upon the Business Model Canvas (BMC) by Osterwalder and Pigneur (2011) and conceptually modeling the connections between them. Upon this, we designed an initial reference framework and evaluated it by means of guideline-supported interviews with OEM representatives, a BM researcher, and an external automotive industry expert. Further, the reference framework was applied and refined after having conducted a workshop involving a real problem case.

The article is structured as follows. Section 2 describes the background of service-centered BMs and explains the methodology applied for creating the conceptual reference framework (CRF). Section 3 presents the findings and describes the processes for each step in detail. Section 4 presents the evaluation strategy and evaluation results, and section 5 discusses the scientific and managerial implications, as well as the limitations. Finally, the article concludes with a summary and outlooks on future research steps.

2 Background and Methodology

2.1 Background

Historically, OEMs have built their businesses around goods-oriented BMs, where customers are seen as consumers rather than collaborators in the value-creation process (Orsato and Wells 2007; Ibusuki and Kaminski 2007) and the way in which the goods or vehicles are used has been of less importance (Ng et al. 2012). In contrast to this goods-centered perspective, Vargo and Lusch (2004) introduced service-dominant logic (SDL) that assumes the customer as the center of value creation with goods being means of services. In this respect, automobiles are seen to be vehicles for the provision of services and work in SSs wherein stakeholders operate by "using information, technology, and other resources to produce specific product/services" (Alter 2017, p. 1828). SSs are thus a dynamic combination of resources that are connected through shared information usage in which value is co-created by technology and people (Maglio et al. 2009). Therefore, an automotive SS can be broadly defined as a network of people, technology, and organizations that create and deliver mobility-related services. Existing SS concepts offer few possibilities for OEMs to particularly plan the service development while factoring in relevant stakeholders and the necessary infrastructure. A recent literature review of Frost and Lyons (2017, p. 228) found that present research lacks the application of SS concepts to specific domains and propose to direct research towards "ontologies that are more responsive to the intentionality of actors in the system, as well as the effects of their interactions."

Service provision and innovation will only occur if an organization is able to monetize them via its BM. Research on BMs arose with the proliferation of the electronic market in the 1990s and its novel approach of doing business (Morris et al. 2006; Bucherer et al. 2012; Gibson and Jetter 2014). Though a generally accepted definition of what constitutes a BM does not exist (Bankvall et al. 2017), we follow the definition by Osterwalder and Pigneur (2011) who describe a BM as the way in which companies capture, deliver, and create value. As the research on BMs has matured, understanding has grown with regards to definitions (Timmers 1998; Morris et al. 2006), classifications (Timmers 1998; Burkhart et al. 2011), evaluations, dimensions, frameworks (Osterwalder 2004; Al-Debei and Avison 2010), and the relationship between BMs and strategy (Massa et al. 2017). A variety of concepts and frameworks has been introduced to capture and initiate BMs that differ in extent and depth, which comprise: Timmers' (1998) three step-approach, the six core components by Morris et al. (2006), Osterwalder and Pigneur's (2011) nine-component BMC, and the St. Gallener Business Navigator methodology by Gassmann et al. (2014) among others.

The focal concept of any BM is the creation of value (Amit and Han 2017) that is closely aligned to the perspective one applies, distinguishing between supplier-centric, customer-centric, and stakeholder-centric views (see Table 1 following Mele and Polese 2011). As creational procedures occur in complex global networks rather than isolated local processes (Maglio and Spohrer 2013), the value-creation paradigm shifts from a single "service system managing particular stakeholders" (Mele and Polese 2011, p. 41) towards the collaboration as partners of multiple SSs in networks. Within these networks, tangible and intangible resources are exchanged and shared among the participants to achieve certain objectives, suggesting that the customer is one of many beneficiaries, as all stakeholders co-create value to the SS and expect it in return.

Logic Representation	Value Relationship	Perspective	Co-creation Practice
Goods-dominant logic	Value-in-exchange	Supplier-centric	Value creation of product or service provider
Service-dominant logic	Value-in-exchange / Value-in-use	Customer-centric	Value co-creation
Co-creational network	Value-in-exchange / Value-in-use / Value-in-experience	Stakeholder- centric / Balanced-centricity	Value co-creation among SS actors

Table 1: Logic representation and co-creational practices

Generally, these BM concepts have only taken generic aspects into account without considering industry specifics (Veit et al. 2014) and the enhancement towards product-service BMs (Beuren et al. 2013; Massa et al. 2017; Reim et al. 2017), leaving both academic and industrial comprehension needs with regards to their design and implementation (Leitão et al. 2013; Alt and Zimmermann 2014; Massa et al. 2017). Studies demand support in the understanding of an OEM's servitization process along with the research on relational aspects and value-creation networks (Brax and Visintin 2017). In addition, existing concepts on SSs lack usability and design orientation (Alter 2012). The majority of studies focus on the customer-service provider interaction within the SS (Andreassen et al. 2016; Atiq et al. 2017), but do not consider that value creation happens in complex networks involving multiple stakeholders that can act as both customers and service providers.

2.2 Methodology

In order to support OEMs in the conceptualization of digital services, we develop a reference framework by which we intend to assist the understanding of the automotive services domain and provide an enhanced communication base for academic and business stakeholders (Frank 2007, p. 120). A CRF is useful for both researchers and practitioners at different levels (Fettke and Loos 2007, p. 5) and, thus, can be effectively applied in an integrated way for decision making process support (Colledani et al. 2008, p. 260). During the development process, we thoroughly research the automotive domain, put characteristic components in order, and identify relevant relationships. To be useful for OEMs during the conception of automotive services, the CRF must be correct, the incorporated constructs must be complete, and the overall arrangement as well as interdependencies must be comprehensible.

Following the development approach outlined by Rößl (1990, p. 101) (Fig. 1), we first selected the constructs based on Osterwalder and Pigneur's (2011) BMC. The BMC is a good analytical and visualization tool (Freiling 2015) and is suited for becoming acquainted with BM thinking within an investigated domain (Fielt 2013; Bilgeri et al. 2015). Following, we adapted the BMC elements by abstracting them to the SS domain from an operational point of view (Alter 2012).

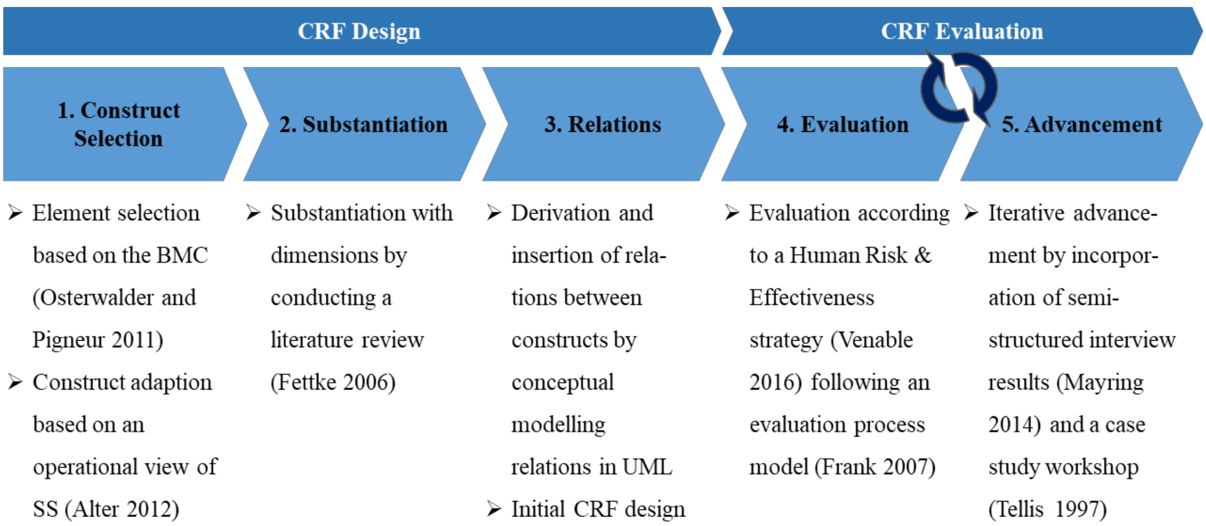


Fig. 1 Reference framework development procedure

After having identified the framework constructs, we substantiated them by reviewing literature of automotive SSs, following the steps outlined by Fettke (2006). We collected data regarding the latest automotive SSs, analyzed and synthesized it, and then derived construct dimensions. Based on these findings, relations between the constructs were identified by conceptually modelling a class diagram in UML. The class diagram is particularly useful in structuring the constructs and the relations between them (Gomaa 2005). From this, we were able to derive relations, integrating and ordering them, resulting in an initial CRF design. Next, the CRF was evaluated in regards to correctness, completeness, comprehensiveness, and applicability by applying a five-phase evaluation process following Frank (2007, p. 120). Thereby, we evaluated the CRF from three different perspectives by conducting five guideline-supported interviews. In addition, we ran a workshop by applying the CRF in a case scenario concerning a real problem statement. Throughout the evaluation the CRF was iteratively modified based on received feedback.

3 A Conceptual Reference Framework for Automotive Service Systems

3.1 Constructs

For the conceptualization of SSs, a framework is necessary by which organizations can effectively analyze and facilitate the communication of automotive services. Mapping the business model concept to SSs provides us with a set of constructs that “allows the representation of the customers’ integration and thus the co-creation” (Zolnowski and Böhmann 2014, p. 4). In doing so we make use of Osterwalder and Pigneur’s (2011) BMC, which is a framework that is widely adopted in academia and practice, aspires to be of general validity and is centered on the customer’s value proposition (Ojala 2016). The BMC is advantageous for centrally capturing and delivering value creational aspects of service business development and is a useful communication tool (Coes 2014). It provides a set of essential elements that are clustered in customers (channels, relationship, customer segments,), infrastructure (key resources, key partners, key activities), offering (the value proposition) and financial (revenue stream, cost structure) categories (Widmer 2016). Thus, the elements take into account the pivotal role of the customer as an essential premise of value co-creational practices (Vargo and Akaka 2012). By abstracting the building blocks, reflecting on their meanings and applying them to the SS domain, we identify the framework constructs (Lee et al. 2011; Alturki and Gable 2014) as can be seen in Table 2. Therein, we take an operational point of view as Alter (2012) proposed, which emphasizes viewing the SS from a managerial perspective for services that are, or ought to be, in operation.

BM Categories	BMC Building Blocks	Constructs	Description
Offering	Value Proposition	Service Value	Service value is the central element of an SS and inherent in every service (Maglio and Spohrer 2008)
Customers	Customer Segments	Customers	Customers determine contextually and phenomenologically the co-creational derivation of value (Vargo and Lusch 2008)
	Customer Relations	Customer Involvement	Value creation in an SDL involves customer participation (Vargo 2008)
	Channels	Points of Interaction	Customer points of interaction serve as the link between the service provider and the recipient (Clatworthy 2011)
Infrastructure	Key Resource	Service Infrastructure	Infrastructures are a collective investment of humans, information and technology, in other words, resources within SS (Alter 2008)
	Key Partners	Service Stakeholders	Various stakeholders are involved in service operation within SS networks that form relationships of value (Mele and Polese 2011)
	Key Activities	Service Objective	Stakeholders within automotive SS collaboratively perform distinct activities to collectively pursue one or multiple common SS objectives (Gummesson 2008)
Financial	Cost Structure	Cost Structure	The cost structure is comprised of the costs incurred from operating and delivering specific services distinguishing between cost- and value-driven costs (Osterwalder and Pigneur 2011)
	Revenue Streams	Revenue Streams	Revenue streams are generated from customers and involve transaction and recurring revenues (Osterwalder and Pigneur 2011)

Table 2 Literature review constructs

The focal point of any BM is the value proposition and the reason for customers to seek a specific service to fulfill their needs (Osterwalder and Pigneur 2011). Characterizing the CRF in this way provides the company with an outlook on the overall value per actor, i.e. consumers, partners and the organization itself. (Zolnowski and Böhmann 2014). The value proposition is created for customers (Andreassen et al. 2016) who thus determine contextually and phenomenologically a service (Vare and Lusch 2008). Everyone participating in the SS network can be both a contributor and beneficiary at the same time, underlying a stakeholder-centric point of view (Mele and Polese 2011). For the sake of this research and the following systematization, a customer is defined as an individual or organization that demands a mobility-related service. Both the customers and the service value are chosen to be the central constructs as every service offering is initiated with them (Maglio and Spohrer 2008). Third, customer relations include the types of relationships a firm establishes with its customers (Osterwalder and Pigneur 2011). From an SDL perspective, “value creation always requires customer involvement” (Vargo 2008, p. 212). Thus, understanding and integrating this concept within service networks is crucial (Skålén and Edvardsson 2015). Third, key activities comprise the most important steps for a firm to successfully implement its business models (Osterwalder and Pigneur 2011). This study does not focus on the case of a single firm, but on an entire industry and their SS. Therein, stakeholders perform key activities collaboratively to pursue one or more service objectives (Mele and Polese 2011). The fulfillment of these service objectives can be seen as the driving motives upon which stakeholders ultimately create value for the service recipient. Fourth, channels demonstrate the way in which customers are reached and the value proposition is delivered (Osterwalder and Pigneur 2011). Customer points of interaction, or touchpoints, characterize the points of contact during the service provisioning process (Clatworthy 2011) and in this sense, can also be used to evaluate a service's effectiveness (Shostack 1984; Clatworthy 2011). Fifth, key partners are required to operate the business model successfully (Osterwalder and Pigneur 2011). They are stakeholders of the automotive SS and are involved in the service operation, contributing with their own resource investments (Mele and Polese 2011). The sixth element to be considered is resources. Resources are required in every step of the service fulfillment process, and include investments a company has to commit to operate a business model (Osterwalder and Pigneur 2011). Automotive SSs are collective investments of manpower, information and technology. As manpower is comprised within the construct stakeholders, the resources, information and technology can be specified as infrastructures that are shared with other SSs and are both operated and managed outside of the automotive SS (Alter 2008).

The BMC elements "cost structure" and "revenue streams" are included as constructs within the CRF but were not substantiated by the literature search. These elements are results from the previously established building blocks and are organization-specific. Revenue streams are established through the generated value proposition for the customer (value-driven or cost-driven), and the cost structure is substantiated once all the previous elements have been defined (transaction revenues or recurring revenues) (Osterwalder and Pigneur 2011).

3.2 Substantiation by means of a literature review

Following the steps outlined by Fettke (2006), the review procedure stretches over five phases, as shown in Fig. 2.

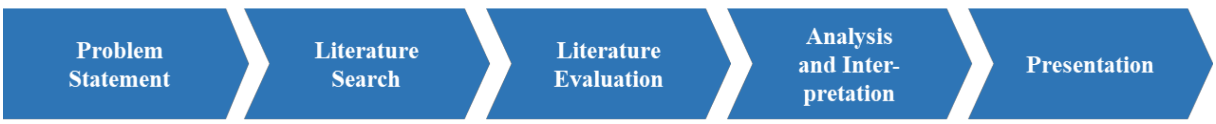


Fig. 2 Literature review process

The literature review was conducted between October and December 2016 to identify relevant SS dimensions for the CRF. Five major databases were queried: Business Source

Complete (EBSCO), Elsevier ScienceDirect, IEEE Xplore, Springer Link, Scopus, which represent relevant conferences and journals in the field of information systems. The goal was to substantiate the automotive SS constructs with dimensions and identify the relations. Several search phrases were tested and iteratively adjusted until satisfactory outcomes could be determined using the following search string: "(automobile OR automotive OR vehicle) AND (service systems OR information systems OR digital services)." In total, 2,522 English sources were gathered comprising only peer-reviewed scientific journal articles, published between 2006 and 2016, with a focus on information systems (step 2).

The sources were evaluated (step 3) with regard to relevance of the possibilities given by the databases, which were further narrowed down by filtering out topics that did not connect with vehicle-related automotive SSs. During the first (gate I) and second refinement stage (gate II), duplicates were eliminated, and the terms were searched within keywords and title to gather a set of relevant articles in the field of focus. The articles were selected by reading the abstracts (gate III) and skimming the remaining articles (gate IV). As a result, we identified and fully read 31 relevant papers (see Fig. 3).

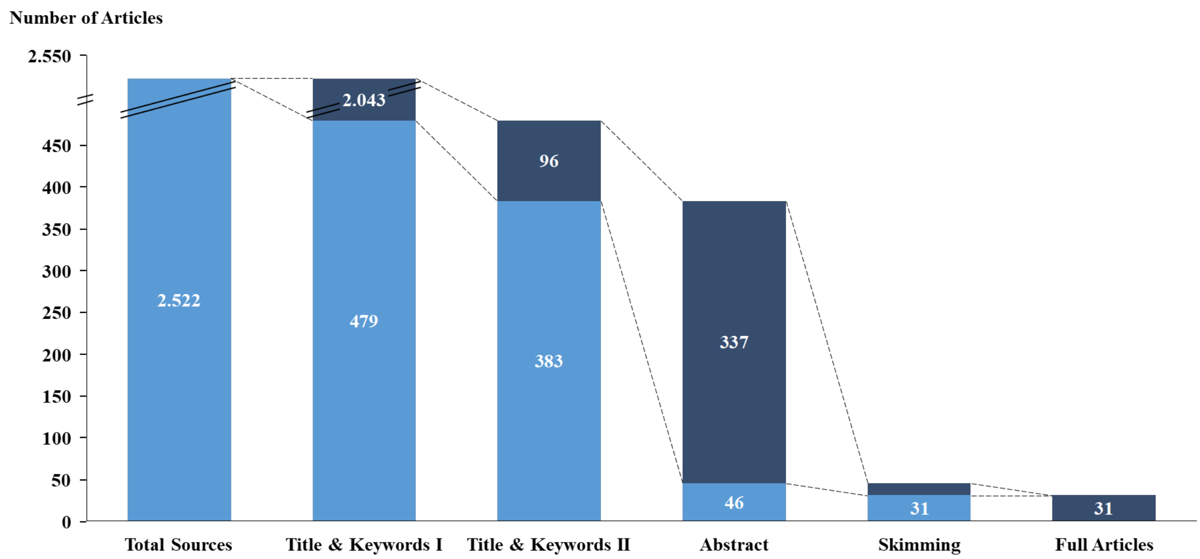


Fig. 3 Article selection process

While analyzing the articles, we identified and extracted expressions that correspond to the identified CRF constructs. An exemplary excerpt of the analysis is listed in Table 3 and the full analysis can be viewed in Appendix D and E.

Abbreviations:

1. DAS – Driver Assistance System
2. RTIS – Real-time and temporal Information Service
3. RSU – Road Side Unit
4. IVS – Intelligent Vehicle System
5. OBD – On-Board Diagnostic
6. VIS – Vehicle Information System
7. ICT - Information and Communication Technology
8. IVIS – In-Vehicle Information Systems
9. TP - Telematics Platform
10. PSS – Product Service Systems
11. CAS – Computer Aided System
12. RTM - Remote Technology Management
13. ITS – Intelligent Transport System
14. ATIS - Advanced Traveler Information System
15. APTS - Advanced Public Transportation System
16. AVHS - Advanced Vehicle and Highway System
17. HMI – Human Machine Interaction
18. MCC - Mobile Cloud Computing
19. VCPS - Vehicular Cyber-Physical Systems
20. GIS – Geographic Information System
21. V2V – Vehicle-to-Vehicle

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
Bengler et al. 2014	- State-of-the art of DAS1 and future research fields	- DAS	Assistance	Drivers	- Service Provider; driver; supplier; 3rd party beneficiaries; service provider for V2V[21]-communication; traffic participants; OEM	- Vehicle; communication infrastructure; sensors; information, DAS	- DAS goal provide active and integrated safety; intelligent transportation for an efficiency increase	- Driver as the trigger of the DAS	- Vehicle; in-vehicle display and projections (virtual interfaces); infrastructure that provides sensor data
Bohnsack et al. 2014	- Exploration of the evolution of business model development between incumbent and entrepreneurial firms	- General consideration of movement to service-based business models by means of EVs, e.g. battery leasing etc.	Resource Efficiency	Incumbents, End Customer	- OEM; supplier (battery provider e.g.); financial service provider; driver; dealer; swapping service station provider; charging grid operator	- Battery; EV; virtual application; mobile phone; communication infrastructure; grid	- Intelligent transportation through car-sharing and increase in mobile sustainability; comfort & convenience, when charging at home; battery swapping (technology enabler services) financial service systems	- Customer involvement in the service usage; customers may appear as service providers for grid balancing, when charging at home	- Vehicle; mobile applications; infotainment system; service personnel; financial services; dealer who can change the car; battery swapping personnel
...	…	…	…	…	…	…	…	…	…

Table 3 List of abbreviations and excerpt from the literature analysis

To achieve comprehensiveness, we iteratively discussed, clarified and refined the expressions until we conceptually derived a list of dimensions. Therefore, we first aggregated and ordered the expressions with regard to their constructs: service value, service objectives, customers, stakeholders, infrastructures, customer involvement, and points of interactions. Following, we analyzed the expressions by discussing and reflecting upon them, removing redundancies and merging expressions when needed, for instance, automotive OEMs, automotive manufacturers, and electric vehicle manufacturers were merged into OEMs. Next, we proposed classes, reflected upon them and ordered the expressions accordingly before we repeatedly discussed the classes and allocation results. Subsequently, we defined categories (Given 2008, p. 72) and again discussed them as well as simultaneously refined the previous processes until an agreement on completeness and satisfactory clarity was reached. Lastly, we abstracted categories into dimensions of general validity that are meant to be mutually exclusive and collectively exhaustive (MECE) of the identified literature (see Table 4). The completed substantiation results, ordering and classification can be seen in Appendix D and E. However, collective exhaustiveness cannot always be ensured since the literature review comprises only a selection of the entire literature on automotive services.

	Category	Dimension
Service Value	Safety	Safety & Security
	Security	
	Resource efficiency	Resource Optimization
	Driving experience	Emotion & Experience
	Service experience & Usability	
	Customization	
	Accessibility	Convenience
	Comfort & Convenience	
Service Objective	Transportation & Navigation	Intelligent Transportation
	Connectivity enhancement	Connectivity
	Issue Detection & Driving support	Driving Support & Assistance
	Quality improvement	Maintenance Assistance
Service network infrastructure	Stationary infrastructures	Physical Stationary Infrastructure
	Areas	
	Mobile devices	Physical Mobile Infrastructure
	Information	Digital Infrastructure
	IT Infrastructure	
Customers	End Consumer	External Service Recipient
	Business Customers	
	Business Units	Internal Service Recipient
	OEM	
Key stakeholders	Service staff	Physical Service Provider
	Service Providers	
	Information service staff	Digital Service Provider
	Information service providers	
	Secondary beneficiaries	Secondary Service Beneficiary
Customer Involvement	Developmental Collaborators	Active Participation
	Active Involvement	
	Service Users	Passive Participation
	Information Provider	
	Actuator / Enabler	
Points of Interaction	Personnel	Human Interaction
	Vehicle Composition	Physical Vehicle Attributes
	Physical Environment	External Environment
	IVIS	Virtual Interfaces
	Virtual interfaces	

Table 4 Abridged substantiation with dimension

According to Juehling et al. (2010), automotive services comprise all services that provide benefit for customers over the vehicles' life cycle and can generally be distinguished between technical and non-technical services. We derived the service value based on the SS objective. For instance, Hung and Michailidis (2011) investigate the deployment of battery charging station infrastructure for electric vehicles (EVs). The service objective is to minimize the overall routing costs for EV drivers, such as travel time and distance. Hence, the perceived customer value can be increased with the accessibility of EV charging stations, convenience, and other factors. Besides safety and security, we identified resource optimization, emotion and experience, and convenience as general service value dimensions. Most articles investigate technical services, particularly some form of assisted driving systems (e.g., Bengler et al. 2014; Mahut et al. 2015; Guériau et al. 2016). Their primary aim is to increase the carriers' safety, such as early brake support, collision mitigation, anti-lock braking systems (ABS), and electronic stability programs (ESP). The improvement of driving support and assistance in order to increase safety and security is identified to be the predominant service objective, accounting for 23 of the articles (e.g., Yeh et al. 2007; Vashitz et al. 2008; Stevens et al. 2010; Park and Kim 2015). The trigger of these technical services occurs through sensory input, and the computation takes place inside the vehicle. Technology related to driving assistance systems is progressing toward more automatic and cooperative driving (Bengler et al. 2014), upgrading the potential influence of the vehicle to semi-autonomous or autonomous driving. Other service dimensions identified were intelligent transportation, such as car sharing, maintenance assistance, and connectivity through vehicle or in-vehicle information systems (VIS or IVIS1) (Lisboa et al. 2016).

IVIS partly provides access to non-technical automotive services, such as navigational services. For non-technical services to be operable, infrastructures need to be in place in various fields (e.g., Wan et al. 2014; Park and Kim 2015; Olia et al. 2016). Vehicles should be able to communicate with multiple infrastructures and partly with other stakeholders within complex networks (V2V2, V2I3, V2R4, VANET5, V2C6). Thus, the necessary telecommunication infrastructure would have to be implemented (Kakkasageri and Manvi 2014; Gao and Zhang 2016). For the service provision, backend systems need to be in place, which would have to be able to process the data that can be converted into information and fueling the value creation processes. These systems hold the identity and access management data, service context, legacy systems, vehicle master data, customer context, and application logics, and are callable via web application programming interfaces (APIs) (Frey et al. 2016). Generally, the infrastructure can be distinguished as physical stationary, physical mobile, and digital.

Accordingly, the SS stakeholders can be dimensioned as physical service providers (e.g., mechanics) and digital service providers (e.g., car sharing platforms and service recipients), which can be individuals, organizations, or the general public. Customers can be actively or passively involved in the value creation process. From an OEM perspective, customers are mostly the initiators of the service action while driving the vehicle. Even though they trigger the service, such as the intervening of the driving assistance system (DAS), they remain passive throughout the service delivery process. Digital services, however, have the potential to actively involve and engage customers during the service life cycle.

Points of interaction exist throughout various stages of the service delivery process and essentially involve stakeholders and many resources or infrastructural components being in place at the same time. Most identified interaction points are connected to the physical vehicle attributes (e.g., buttons) or vehicle environment. Further identified touchpoint dimensions are human interactions (e.g., via the service staff), the external environment (e.g., traffic signaling devices), or virtual interfaces via information system devices (e.g., smartphones).

3.3 Relations

After having identified constructs and dimensions, the relations among them were derived by conceptually modeling the constructs in a UML class diagram (see Fig. 4).

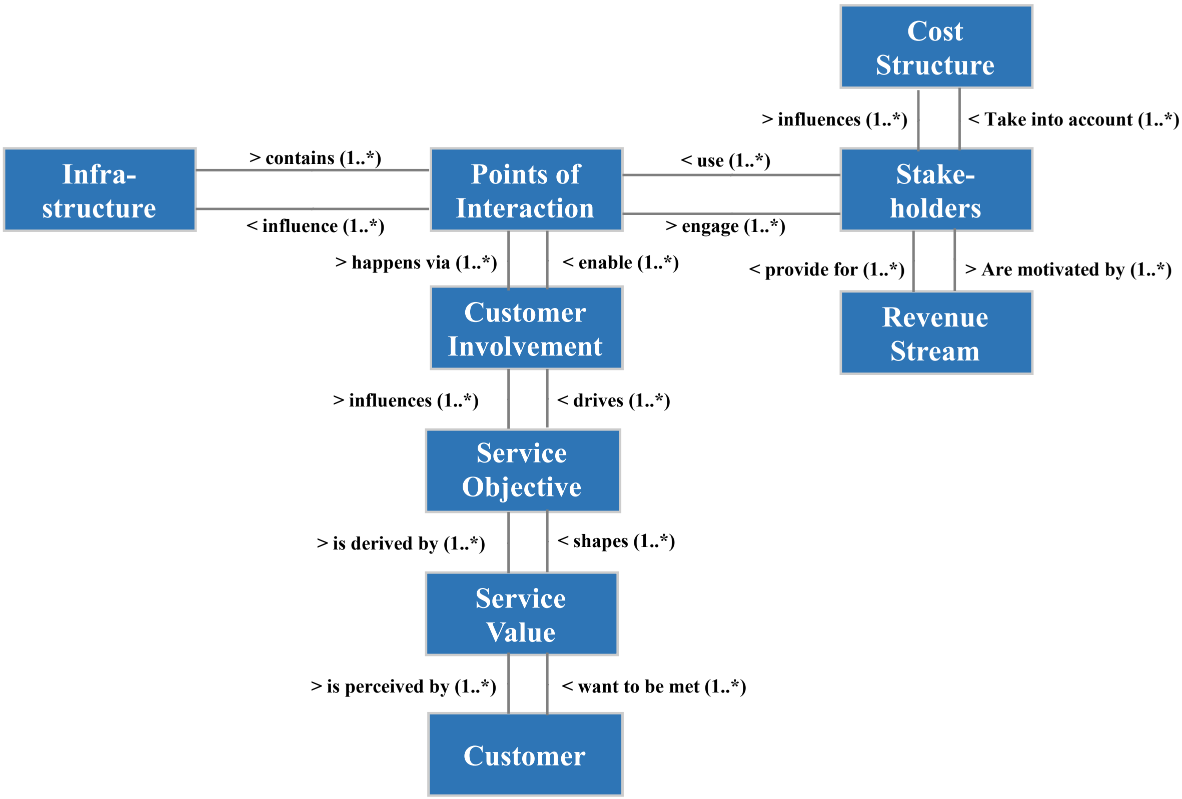


Fig. 4 Relations between constructs in UML

The customer is the focal point of any SS (Vargo and Lusch 2008) and wants one or many service values to be met (Osterwalder and Pigneur 2011). One service value perception can relate to multiple service objectives, and vice versa. For instance, having enhanced collision avoidance software can serve customers' safety values and satisfy their convenience needs. In return, the service value can be related to collision avoidance systems and enhanced IVIS, which reduce driving distraction. The service objective directly influences the customer involvement in the value creation process. Customers that trigger DAS act as service actuators by moving the vehicle, but can also benefit from the service as passengers or as other traffic participants. In return, multiple forms of customer involvement are possible for the same SSs. For digital services, for instance, customers could passively participate by providing user data or by actively engaging in the product's value creation by giving feedback. Customers are engaged via points of interaction in the value creation process, which in turn are connected to stakeholders (such as the service providers) and the service infrastructure (such as the vehicle itself, mobile devices, backend systems, etc). Though services are centered around fulfilling customer needs and delivering service values, stakeholders are inherently motivated by and need to consider financial dimensions as well, i.e., revenue streams and cost structures.

Building upon the constructs, the identified dimensions, and the UML model, we developed an initial version of the CRF that we iteratively advanced and adapted. We arranged the CRF constructs, as depicted in Figure 5, through internally discussing the automotive service delivery process and externally validating our line of thought by means of multiple evaluation phases (see section 4). Therefore, we reasoned utilizing the example of an intelligent parking spot search. The customer is the central construct of any automotive SS around which the other constructs are independently layered. Thus, the notion that value creation is collaboratively pursued within the SS network is emphasized. The constructs contain the dimensions that are typical expressions of automotive SSs as identified in Table 4.

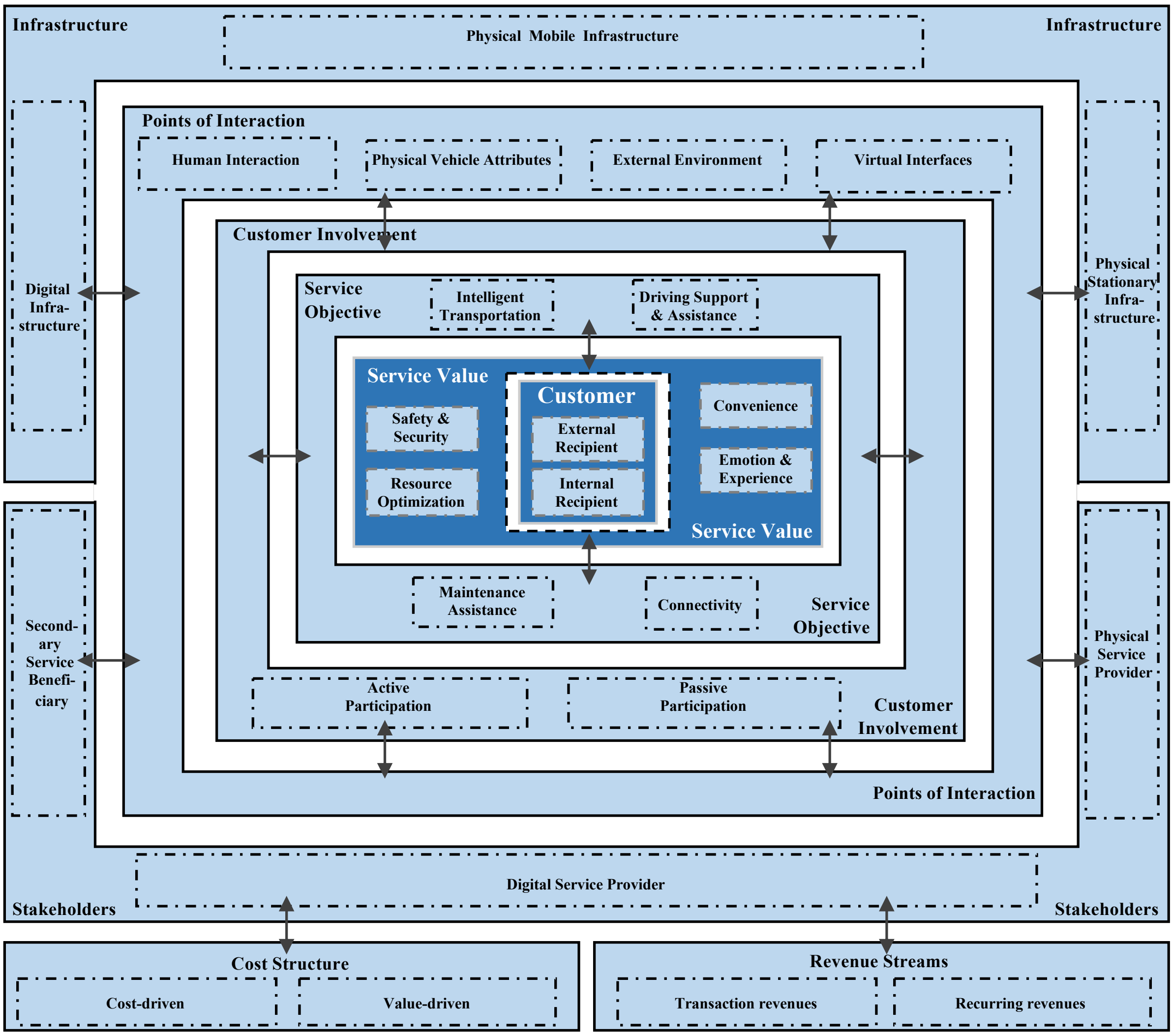
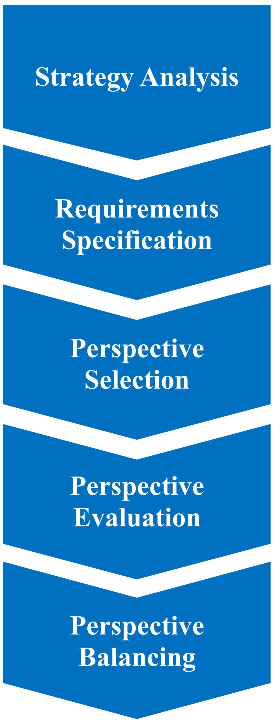


Fig. 5 CRF of automotive service systems

To illustrate the reasoning process (Recker 2013, p. 15), a driver (external service recipient) wants to quickly find a free parking spot while driving through a congested city. He or she is demanding a convenience value to be met by reducing the time of search. On that basis, the service objective of optimizing resources, such as time, gasoline, etc., can be derived. Therefore, the vehicle's sensors could spot and detect free spots, their range and calculate the possibility of it being an appropriate parking gap. For an OEM to provide the service in an engaging way, the customer could be solicited for active involvement by making the data of the free parking spot available to be shared among other drivers and ancillary service providers. To provide a holistic customer experience, the OEM ought to consider customer points of interaction, which could be physical vehicle attributes, such as vehicle buttons, and virtual interfaces, such as the IVIS, or the customer's mobile application. To successfully set up this service, a set of infrastructures need to be in place and integrated, such as a cloud and telecommunication infrastructures. In addition, other stakeholders need to co-creationally collaborate, such as telecommunication providers, the customer, mobile device providers and others. Lastly, the OEM has to balance the development costs and expected revenue stream of the provisioned service, e.g. through subscription models, referred to as recurring revenue streams.

4 Evaluation and Advancement

Fig. 6 outlines our five-phase evaluation process following Frank (2007, p. 120). First, we chose the evaluation strategy to be a Human Risk and Effectiveness Strategy for evaluating design science research suggested by Venable et al. (2016). We chose this strategy as the major design risk is user oriented and "a critical goal of the evaluation is to rigorously establish that the utility/benefit will continue in real situations" (Venable et al. 2016, p. 82). Primarily, it shall ensure that users can apply the CRF beneficially. Since naturalistic evaluations are always empirical, the artifact should be evaluated by real users in their actual context.



- Human Risk & Effectiveness Strategy (Venable 2016): Conduction of five evaluation episodes by means of five guide-line supported interviews and one case work shop

- Test and evaluation of requirements with regard to *completeness*, *correctness, comprehensibility* and *usability*

- CRF evaluation from three different perspectives: OEM, external industry expert and a service business model researcher and digitization consultant for an automotive spare parts supplier

- Consecutive interview analyses by summarizing protocols (Mayring 2014)
- Work shop by means of a real problem case (Crowe et al. 2011)

- Three OEM representatives with different scope and area of responsibilities
- One external industry expert of a managing position
- One business model innovation researcher of a leading position
- One digitization consultant for an automotive spare parts supplier

Fig. 6 Evaluation process

We specified the primary requirements to be completeness, correctness, comprehensibility, and usability. The framework was found to be correct if no objections for the selected constructs, identified dimensions, or drawn relations could be observed. By evaluating the CRF's completeness, we intended to determine whether any construct or dimension was missing. In addition, we asked whether the overall arrangement and scheme is comprehensive – that is, if the interviewees could interpret the CRF and the corresponding drawn relations. Usefulness was ensured by whether interviewees perceived the CRF to be beneficial for an OEM during the task of conceptual service planning. Next, we outlined the evaluation perspectives. For the purpose of gaining the most insights and prolific feedback, we incorporated the OEM perspectives of two industry experts and that of a leading researcher on business models and digitalization into our evaluation process. Therefore, we conducted five guideline-supported interviews, of which we analyzed and iteratively incorporated their feedback (Mayring 2014). In doing so, we improved the CRF in five evaluation phases. In addition, we applied the CRF in a workshop with an underlying real problem case (Crowe et al. 2011).

4.1 Interviews

We chose to interview three OEM employees from two different firms, who have different scope and areas of responsibility. Additionally, we interviewed one external industry expert with an extensive background in IT consultancy with a managerial position serving OEMs, contributing an external, inter-company perspective. Finally, the interviewed researcher contributes to the latest state-of-the-art knowledge about business model innovation.
The interview guideline comprises a short introduction, the interviewer’s goal, open questions with regard to the evaluation criteria and the initial CRF construct. The guideline was sent to interviewees prior to the interview appointment to provide time for reviewing the material. All five interviewees reported to have read through the guideline and the CRF prior to the scheduled telephone call. The interviews were recorded and transcribed. Subsequently, the text passages were ordered in a category system composed of the defined requirements. Via a two-step reduction process relevant text passages were selected and subsequently clustered (Mayring 2014). Finally, the text passages were abstracted and summarized as a new statement, which are displayed in Fig. 7.

	1st Interview:	2nd Interview:	3rd Interview:	4th Interview:	5th Interview:
Evaluation Episode	**OEM Representative:** ▪ Innovation and idea manager ▪ Executing position	**OEM Representative:** ▪ In-house IT Consultant ▪ Leading position	**IT Consultant:** ▪ Automotive IT management consultant ▪ Leading position	**OEM Representative:** ▪ Chief digital officer ▪ Leading position	**Researcher:** ▪ BM engineering and innovation researcher ▪ Leading position
Correctness	▪ Perceived to be correct	▪ Perceived to be correct	▪ Constructs not orthogonal ▪ Relations correct ▪ Dimensions not MECE	▪ Perceived to be correct	▪ Perceived to be correct
Completeness	▪ Generally complete ▪ Emotional dimensions are missing	▪ Perceived to be complete	▪ Perceived to be incomplete, as dimension are not MECE- could be further abstracted	▪ Constructs and dimension perceived to be complete ▪ Too few relations between the constructs	▪ Perceived to be complete, but dimension "other" in constructs problematic
Comprehensiveness	▪ CRF is very extensive ▪ General use case description helpful	▪ Without specific use case intuitively not comprehensible	▪ Without higher research question CRF purpose not intuitively comprehensible	▪ Generally perceived to be comprehensible	▪ Comprehensible
Usability	▪ Usable as a system of ordering and classification	▪ Usable as a system of ordering and classification	▪ Conditional usable to categorize and classify as dimensions are not MECE and constructs not orthogonal	▪ Assessed that CRF cannot reflect all possible autom. service cases and each BM would need an own CRF	▪ From an OEM perspective difficult to answer ▪ Pos. research contribution
Adaptation, Operationalization	▪ Dimension extension "Emotion & Experience" ▪ Explanation with regard of a specific point of view ▪ General use case description	▪ Cancel connecting line for infrastructure and stakeholder dimensions ▪ Explain CRF by means of a specific use case	▪ Dimensions abstracted to a higher degree to be MECE ▪ Format modification ▪ Deletion of dimension manifestations	▪ No adaptation	▪ Deletion of dimensions "Other" ▪ Clearly communicate perspective and CRF aim

Fig. 7 Evaluation episodes, categorized findings and derived CRF adaptations

After each evaluation episode we analyzed and reflected upon the recommendations and internally discussed them. Therefore, we also looked for research evidence that supports the evaluator's point of view and suggested alteration. For instance, the first reviewer remarked to add an emotional dimension to the construct service value as many OEM customers purchase a vehicle or other products connected to the OEM's brand based upon an emotional experience. Investigating the remarked point research indicates similar behavior to be true for digital services, (Zarantonello and Schmitt 2010; Powers et al. 2012, p. 479) which is why we decided to implement the suggestion in the artifact.

Four of the five interviews resulted in CRF adaptations and were very beneficial for the CRF evaluation and its subsequent advancement (see steps 4 and 5 of Fig. 1). Over the course of the interviews the framework was simplified as dimension constructs were excluded. The CRF was generally perceived to be correct – that is no false constructs, dimensions or relations could be detected. The third interviewee, however, noted that the construct and dimension should be orthogonal to each other in order to ensure they are mutually exclusive and collectively exhaustive. For instance, it was proposed by the interviewee to merge the constructs "service value" and "service objective" as both are similar to each other and contain similar dimensions. The dimension "emotion" was added as a service value in order to complete the spectrum of individual value perceptions. Again, four of the five interviewees perceived the CRF to be complete, whereas the 3rd interviewee criticized the identified dimensions as not following the MECE principle. Not surprisingly, the CRF was not intuitively comprehensible for the surveyed practitioners. They demanded a functional explanation by means of a service example. The BM researcher, however, could interpret and comprehend the CRF representation. Although, the interviewee had received the representation after four evaluation episodes. This can indicate that the comprehensiveness of the representation improved, and by giving a practical example, the comprehensiveness had significantly increased overall. Mostly, the interviewees value the CRF for its ordering purposes. The practitioners however, implicitly demanded for a functional methodology that is more applicable in identifying and designing service business models than a classification framework.

4.2 Case Workshop

In addition to the interviews we applied the CRF in a 90-minute workshop with a researcher that did a PhD on the development of automotive industry in the Asia-Pacific region, who is referred to as participant hereafter. Within an extensive research project, the participant consulted a major Swedish spare parts supplier, which is named case company hereafter. The case company generates the majority of its revenue via own physical shops, where they source, produce and deliver spare parts. Due to digitalization, the company faces the challenge to enhance their physical value propositions into the digital sphere. Beforehand, we sent the participant the CRF with an explanation and an exemplary case on how to apply the artifact in which an OEM intends to create a service in order to facilitate finding parking spots for its customers. While conducting the workshop, we formulated a hypothesis to expand the case company's current online activities and develop a platform to transfer and integrate physical and digital services.

We began by shortly introducing the constructs with its dimensions and clarifying their purposes as well as relations among each other. For each dimension, we formulated examples and suggested the main service value. During the process we noticed that applying categories led to the formulation of dimensions and provided further support towards more specific and relevant ideas on how to shape an online platform whilst keeping focus on the intended end-consumer. In addition, we noticed explicitly stating customer involvement possibilities and dimensions of customer interaction points helped the participant to take in, and maintain, a customer-centric perspective.

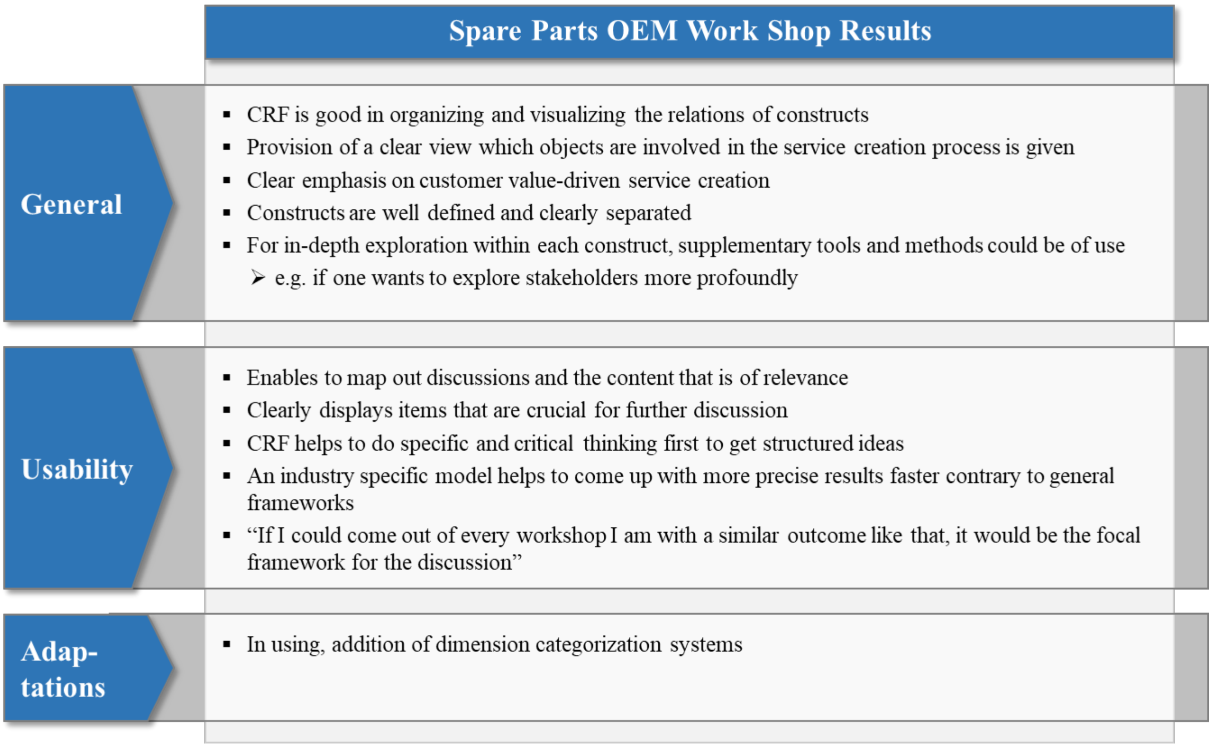


Fig. 8 CRF evaluation during case workshop

The participant noted the CRF as being a good framework in organizing and visualizing the relations of constructs as it provides a clear view on the objects of relevance. Further, the participant highlighted that there is a clear emphasis on customer-centric service design during the exploration phase. However, it was also noted that implementing and designing the service would require supplementary tools in order to reach completion. In general, the CRF was found to be useful for service conception and its industry-specificity was remarked as beneficial in saving resources and providing more precise results. To increase CRF applicability, we added the provision of the CRF categorization table that led to the derivation of the dimensions (see Table 4).

5 Discussion

5.1 Research Implications

The SDL has been fundamental in the understanding of the service provision, the role of the customer, and its market consequences (Vargo and Lusch 2004; Kuzgun and Asugman 2015). Previous studies on these concepts "lack the strategic, functional and tactical directions for organizations to apply" them (Gaiardelli et al. 2015, p. 1165). Further, industry characteristics were not taken into consideration (Reim et al. 2014; Freiling 2015) and methodological applicability has been low. Within this study we intend to investigate how digital automotive services as part of SSs can be conceptualized and how OEMs can be supported in their design under consideration of essential stakeholders.

A conceptual reference framework was found to be a useful instrument for identifying and ordering automotive service system constructs and for relating them amongst each other. The CRF supports the importance of customer-centricity within complex stakeholder networks by synthesizing SS research with BM concepts. The artifact organizes and advances the knowledge of a SS as a work system. First, it demonstrates how a SS can be conceptually designed from a small amount of constructs by incorporating industry-specific dimensions. The constructs, interplaying with the dimensions, provide not only an adequate range and depth towards the understanding of the characteristics of automotive services, but also on how to use them to design services from a customer-centric perspective. Moreover, it provides a structure for organizing SSs in the automotive industry such as those which were identified through the literature search and listed in Appendix D. The range of possible automotive services is expanding through ongoing digitalization. The CRF presents a particular view on SSs from a BM perspective as it is intended to support organizations and be applicable in the early service development phase. In addition, it contributes to the general knowledge on SSs (Ferrario and Guarino 2011; Alter 2017). Following up the discussion on how a SS can enhance value co-creation and customer interaction (Alter 2017), the present framework demonstrates that active engagement can be achieved by progressively designing interaction points that facilitate service accessibility for the stakeholders involved. The study further suggests to organize SSs around the focal point, its purpose of existence in the first place. From a customer-centric perspective, it delivers service values that can only be achieved if collaboration and interaction is optimized, which in turn, depends on an ubiquitous domain understanding of all stakeholders. As digital services “are closely related to and rely on ICT”, it remains to be investigated on how these technologies can be systematically put to use to stimulate service innovation (Stoshikj et al. 2016, p. 219) and facilitate collaboration for these networked businesses (Akaka and Vargo 2014, p. 367).

In this sense, the CRF helps with gaining a fundamental understanding of the stakeholders and objects surrounding the value-creation processes of automotive SSs, contributing to the service business model knowledge. The framework endorses previous works which conclude that value creation happens in stakeholder-centric networks, where each stakeholder is both a beneficiary of the SS and a contributor to it (Mele and Polese 2011). However, the study also demonstrates, only few of the identified articles take customer involvement into account during service development, and fails to explicitly identify them as collaborators in value-creation processes. It suggests customer involvement as a theoretical concept in the automotive industry is not practically considered. We strongly support further research on how to translate service science insights on networked value co-creation and customer centricity into communicable methods and applicable tools for manufacturers that increasingly turn towards the development of digital product-service offerings.

5.2 Managerial Implications

Research presumes that one of the biggest obstacles in the process of digital service expansion is the change in mindset from offering a produced good towards "an integrated product and service offering that delivers value-in-use" (Baines et al. 2007, p. 1545). To do so, the creation of value has to be seen from a customer-centric perspective (Johnstone et al. 2009), which represents a great challenge for manufacturing firms as their business logic tends to focus on product-based thinking (Ng et al. 2012). VISs are becoming increasingly important as a carrier of services and a field of differentiation among OEMs. VISs provide multiple touchpoints for service providers to interact and manage customer relationships via human machine interaction (HMI). Managing these links is essential for a company's interaction with its customers and for involving customers in the value creation process (Lee et al. 2013). From a managerial point of view, the CRF adopts this perspective as it is structured along this understanding and, at the same time, offers to be a tool by which firms can practically implement this concept.

Managerially, the CRF proved to be useful on a practical dimension for OEMs as well as automotive suppliers, as it provides industry specific concepts and enhances the practitioner's potential to communicate and design digital services themselves. Within a condensed period of time, a service proposition could be sketched and conceptually outlined within a networked system. One key challenge during conceptualization is "handling the many composed elements related to need, context, intention, possibilities, etc." (Andreasen et al. 2015, p. 33). Therefore, the CRF provides a structured framework by which to address this complexity. By practically applying it, the CRF was found to be useful in effectively organizing automotive services and formulating customer-centric service narratives. It is both a tool for saving resources, such as time and effort, and for structured, analytical thinking.

Additionally, the CRF meets the demand for an industry-specific framework (Heikkinen 2014). The construct dimensions are derived from automotive services and contain an arrangement by which automotive services can be categorized. In using an industry-specific CRF, organizations and researchers can be more effective in solution finding and more efficient in the way of getting there, as was remarked during its practical application. General frameworks, such as the BMC are either designed for different purposes or their practical applicability is limited. The CRF in cooperation with the categorization scheme helps to generate more precise results and also highlights areas that have not been traditionally observed in the industry, most notably, customer involvement and touchpoint design. As the constructs are relevant SS objects that ought to be considered in service design independent of the domain, we support further research on other industries by developing a different set of dimensions and further advancing the framework.

It must be noted, however, that the shifting of product-centric organizations towards a focus on service value creation leads to numerous organizational challenges as well. The introduction of digital technologies accompanies growing dependencies on them and new personnel capabilities have to be established. In addition, processes have to be aligned and adapted so that the changes are adequately represented in the organization's operations. Pursuing a digitalization strategy possibly increases risk exposure due to field inexperience and the need for new technological competencies. Furthermore, as value creational activities are changed "the new digital activities deviate from the classical – often still analog – core business" (Matt et al. 2015, p. 341).

5.3 Limitations

However, this study's outcome is subject to subsequent limitations. It must be noted that only a part of the literature could be considered during the research process, therefore, the CRF is not all-embracing. The identified CRF dimensions are results of the literature review process and are subject to selection and analyses constraints. Furthermore, the CRF was evaluated by means of interviews and one case study workshop. Hence, the selection of interviewees, the number of evaluation phases and existing case could possibly influence the research results. As typical for empirical cases, not all boundary conditions could be controlled, such as the case company problem or external time constraints. Further, the chosen methods, such as conceptual modeling, the literature review approach, and the qualitative data analysis procedure may also influence the results of our findings.

6 Conclusion

This study proposes a CRF for automotive SSs, that was developed as part of an extensive research in which we investigate how to methodologically support OEMs during their shift from product-dominant to product-service offerings from a BM perspective taking into consideration relevant stakeholders. The reference framework constructs were abstracted from the BMC and adapted to the SS domain. In order to substantiate the constructs with dimensions specific to the automotive industry, we conducted a comprehensive literature review. By modeling the dependencies in UML, we derived the relations between the constructs and designed a CRF draft. The CRF was evaluated and iteratively improved by conducting five guideline-supported interviews. Further the CRF was applied in a case workshop underlying a real problem statement. Two specific applications were initially proposed. First the CRF shall support OEMs during the early development stage of automotive services, the idea generation and conceptualization phase, by giving a structure and a customer-centric direction. We observed the artifact to meet the requirements of correctness, completeness, comprehensibility, and usability.

The novelty of the outlined framework is the SS classification out of a business model perspective emphasizing both customer-centricity and shared participation of the various stakeholders involved in the value-creation processes. The CRF shows that customers are not merely consumers, but the focal point of any SS, as their value offering is the starting point for its development. This article provides an applicable categorization theme for the service conceptualization and is an integral component for further methodological advancements that support companies in these transitional processes. This research demonstrates that automotive SSs are networked businesses that involve the collaboration of a variety of stakeholders to meet customer demands. The artifact supports the notion that service innovation occurs in shared mobility networks involving a variety of stakeholders, who positively contribute to the service value and fulfill its objectives. Shared service networks enable OEMs to operate complex services that they cannot realize alone (Hoffmann and Leimeister 2011). The study primarily focuses on customer-oriented automotive SSs, neglecting the value of physical goods. However, vehicles themselves remain important and are ultimately the basis for services to run and be delivered to customers. As Lenfle and Midler (2009, p. 2) point out, “Servitization does not lead to an eradication of physical goods, but rather an enlargement of value, with the opportunity to monetize this by new business models.”

Footnotes

VIS or IVIS – In-vehicle Information Systems - technology that provides additional information to drivers, e.g. traffic, navigation, weather, etc. (Vashitz et al. 2008)

V2V – Vehicle-to-Vehicle

V2I – Vehicle-to-Infrastructure

V2R- Vehicle-to-Road Side Unit - "Communications […] between vehicles and roadside infrastructure" (Campolo and Molinaro 2011)

VANET – Vehicular Ad Hoc Networks - "a wireless network based on short range communications among moving vehicles [...] and between vehicles and roadside infrastructure" (Campolo and Molinaro 2011)

V2C – Vehicle-to-Cloud services

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5 Artefact 3: Agile Software Readiness Assessment Procedures

Grieger, M., Ludwig, A., & Shen, J. (2018). Adding Agility to Software Readiness Assessment Procedures - A case on digital transformation from the automotive industry. In *Proceedings of the 26th European Conference on Information Systems (ECIS2018)*, Portsmouth, UK.

Ludwig, A., Shen, J., & Grieger, M. (2018). Continuous Software Readiness Assessments for Agile Product Development – A case of how an OEM transformed its IT development operations. In *Communications of the ACM.*

5.1 Meta Data

Table 14: Meta data of the publication Agile Software Readiness Assessment

Title	**Adding Agility to Software Readiness Assessment Procedures - A case on digital transformation from the automotive industry**
URL	http://ecis2018.eu/
Type	Conference Proceedings, Research Paper
Publication in	ECIS (European Conference on Information Systems) 2018 Proceedings
Status	Published
Editor	-
Series Title	ECIS Proceedings
Publisher	Association for Information Systems
Place of Publication	Portsmouth, United Kingdom (ECIS 2018)
Ranking	CORE: A[7] VHB: B[8] h-index: 30[9]

7 http://portal.core.edu.au/conf-ranks/?search=ecis&by=all&source=CORE2018&sort=atitle&page=1
8 https://vhbonline.org/nc/en/service/jourqual/vhb-jourqual-3/complete-list-of-the-journals/
9 https://scholar.google.com/citations?hl=en&view_op=search_venues&vq=european+conference+on+information+systems&btnG=

5.2 Meta Data

Table 15: Meta data of the publication Agile Software Readiness Assessment

Title	**Continuous Software Readiness Assessments for Agile Product Development - A case of how an OEM transformed its IT development operations**
URL	https://cacm.acm.org/
Type	Journal Article
Publication in	Communications of the ACM (CACM)
Status	Under review
Editor	Andrew A. Chien
Series Title	-
Publisher	Communications of the Association for Computing Machinery (CACM)
Place of Publication	New York, NY, USA
Ranking	CORE: - VHB: B[10] h-index: 71[11]

[10] https://vhbonline.org/nc/en/service/jourqual/vhb-jourqual-3/complete-list-of-the-journals/

[11] https://scholar.google.com/citations?hl=en&view_op=search_venues&vq=communications+of+the+acm&btnG=

5.3 Summary

The third and fourth studies focus on the transformation of an organisation's operational backend processes. In this article, an empirical study with an automotive OEM is presented that introduced microservice (MS) architectures and methodologically switched to agile project development as part of a transformation initiative to enable fast digital product development.

The article intends to investigate RQ3: *How can an organisation transform its software readiness assessment procedure to enable agile product development within its current operational infrastructure?* The findings of study 3 were further utilized by abstracting and analogizing them to software development processes in general, represented in study 4.

To investigate the transformation of an organisation's software readiness assessment (SRA) procedure under consideration of its current operational infrastructure, a phenomenon-based research approach with an automotive OEM was conducted (Krogh et al., 2012). In a first step, existing deficiencies were identified by analysing the current assessment processes, screening documents and interviewing employees in charge of the procedure (Mayring, 2014). By applying conceptual modelling (Hoppenbrouwers et al., 2005) we analysed the OEM SRA procedure and developed a software readiness template (SRT) based on the current procedure and which MS projects can apply. The SRT formed the basis for the development of the Continuous Delivery Package (CDP). The CDP is a pre-checked bundle of basic conditions that MS projects accept and commit to comply with, therefore automatically answering a considerable amount of the SRA questionnaire identified in the previous analysis, as is displayed in Figure 13.

On the foundation of the SRT and CDP, the concept of the Continuous Delivery Checks (CDC) was created by providing an initial framework of basic conditions of constructs and processes that all MS projects use (see Figure 14). The SRT was validated by three MS projects and respectively adapted. Adapting the SRA to agile development procedures shall reduce the assessment effort and make the existing procedure flexible enough to suit the newly introduced agile development procedure. This allows for the assessment to be conducted by DevOps teams during their sprint cycles as the standardized answers significantly reduce the amount of time needed to fill out the assessment.

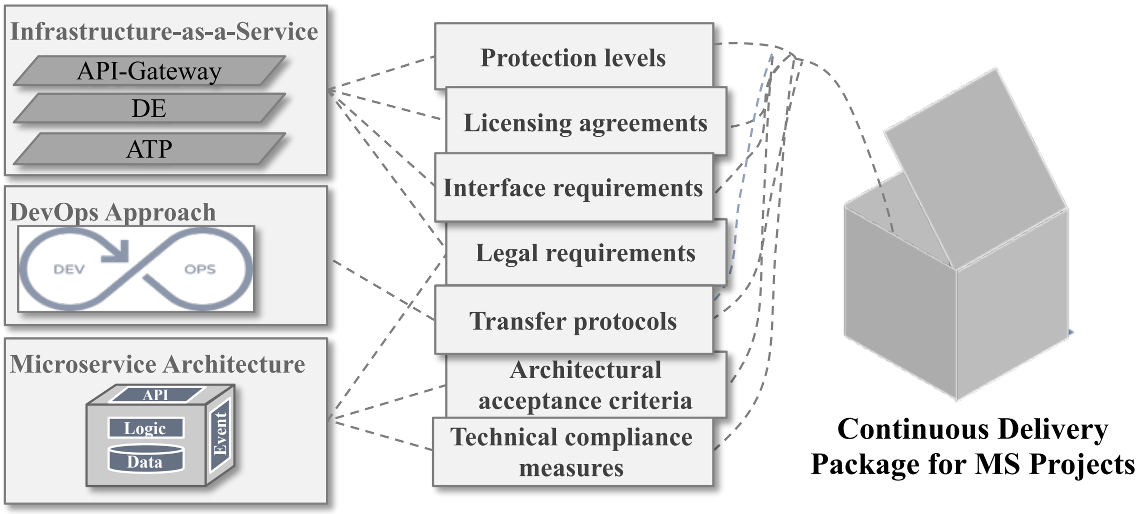

Figure 13: The Continuous Delivery Package

Having evaluated the SRT by means of actual MS development projects using the Framework for Evaluation in Design Science Research (FEDS) (Venable et al., 2016), it could be observed that the designed solution is a useful intermediary step but successful implementation and adoption is dependent on the integration of all contributing departments as it cannot be executed independently. Additionally, the artefact was found not to utilize the full savings potential without implementation of the CDC and a managerial mandate.

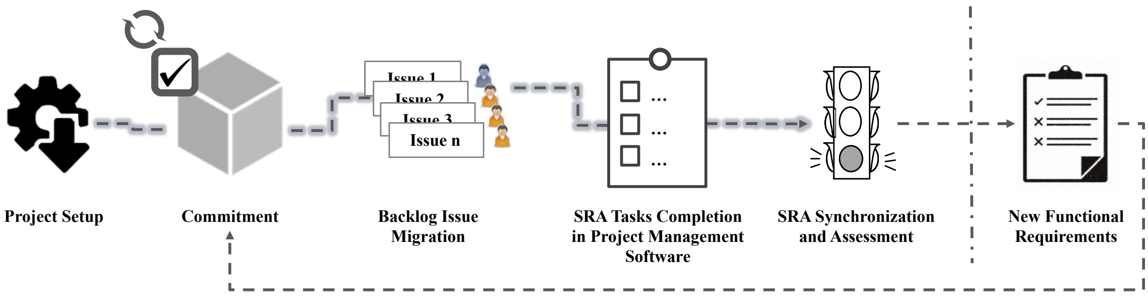

Figure 14: The Continuous Delivery Checks principle

This article provides an empirically developed methodology by which an organisation can transform its backend process to suit the agile development approach. The study reveals that the decision to implement agile project development approaches and technologies for fast digital product development affects the organisation's backend processes to a great extent as they have to be adapted accordingly in order to handle the newly demanded requirements. The implementation of the CDC is an approach for enabling fast product development as assessment processes are integrated continuously within the team's sprint cycles.

The SRT was validated by means of three MS projects of different scope and within different OEM departments. It was generally positively evaluated and was partly further advanced. In addition, the CDC approach was positively received and is planned to be organisationally implemented as an internal project further promoting the advancement and implementation of the CDC or agile SRA.

5.4 Adding Agility to Software Readiness Assessment Procedures

ADDING AGILITY TO SOFTWARE READINESS ASSESSMENT PROCEDURES – A CASE ON DIGITAL TRANSFORMATION FROM THE AUTOMOTIVE INDUSTRY

Research paper

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Abstract

In order to enable continuous and fast software development, manufacturers adopt agile development methodologies. In respect thereof, the organisation's operational processes need to be adapted to fit changing software project's needs. By means of a case study with an automotive OEM that introduces microservices (MS) architectures, the transformation of its software readiness assessment (SRA) procedure is investigated. The article introduces an artefact that builds upon standardized technical and organisational constructs inherent to MS projects. Further, by conceptually modelling a methodology is presented that guides an organisation in the transformation to implement agile SRA within its current operational infrastructure. The artefact is validated by means of three MS projects and respectively adapted. The findings suggest the artefact to be a useful intermediary step, but its successful implementation requires the integration of all contributing departments. The study deepens the knowledge about the transformation of an organisation's operational procedures by an empirical case and possible methodological paths.

Keywords: Digital Transformation, Software Readiness Assessment, Automotive Industry, Agile Software Development.

1 Introduction

Emerging technologies provide manifold possibilities to build novel digital services and respective business models in manufacturing industries (Matt et al., 2015). As a result, the competitive dynamics are increasing, propelled by both incumbents and market entrants that largely come from the internet industry or consumer electronics (Chanias and Hess, 2016). Consequently, original equipment manufacturers (OEMs) have servitized their portfolios, which manifests itself by an increased focus on the design and provision of digital services, and a shift from selling products to product-service solutions, driven by financial, strategic and marketing aspects (Baines et al., 2009). However, creating services alone is not a guarantee for success as this shift involves a "transformational journey" as well (Gaiardelli et al., 2015, p. 1165). OEMs need to accelerate their innovation and service development processes in order to be able to compete with IT companies and startups (Tian et al., 2016). In this context, many organisations use and adapt digital technologies to enable new value creating activities, generally referred to as digital transformation (Gimpel and Röglinger, 2015, Bounfour, 2016).

Although a universally accepted definition of digital transformation does not exist (Ferreira, 2017), the domain has been investigated alongside other topics with regard to different dimensions (Bounfour, 2016), business strategic aspects (Bharadwaj et al., 2013, Hess et al., 2016), driving factors (Gimpel and Röglinger, 2015, Chanias and Hess, 2016) as well as implementation processes (Dremel et al., 2017). A variety of companies among different sectors were surveyed and specific fields of action for executing an organisation's digital transformation could be identified, namely being the customer, the accrued data, the transformation of the value proposition, the organization, a firm's operation activities, as well as its transformation management (Gimpel and Röglinger, 2015). A large number of these studies demonstrate how digital transformation is a complex venture that "affects many or all segments within a company" (Hess et al., 2016, p. 2). Generally, manufacturing firms recognize the need for digital transformation and, in turn, many have formed units in respect thereof (Chanias and Hess, 2016). Current research on digital transformation has mainly focused on detecting obstacles and necessary fields of action for a successful implementation and management of the according processes. But, executing this shift challenges traditional manufacturers (Baines et al., 2009, Beuren et al., 2013, Reim et al., 2014, Chanias and Hess, 2016) as the tools and methodologies that guide the realisation of these transformational areas are scarce (Wallin, 2013, Bounfour, 2016), and empirical studies, such as Hess et al. (2016), focus on the strategic transformation implications, but do not give guidance on how to practically conduct specific tasks.

Since digital products and services become more individualized and fragmented into smaller features (Olsson et al., 2012), the demands software development projects need to meet change too. Flexibility, incremental releases and development speed, i.e. the reduction of a product's time to market, are primary project requirements and are a necessary precondition to stay competitive (Al Alam et al., 2016). Therefore, OEMs increasingly introduce agile development methods (Piccinini et al., 2015) that promise greater productivity, product and service quality, and shorter development cycles in return (Dingsøyr and Lassenius, 2016). However, organisations are struggling to adapt their internal operations to these requirements, especially to provide an integrated IT infrastructure that enables collaborative, fast and flexible product development (Gimpel and Röglinger, 2015).

In product-centric organisations, particularly those in the automotive industry, security and quality assurance have been central pillars around which value-creating processes are structured, both culturally as well as operationally. In order to assure these quality demands are met, organizations set-up mechanisms and processes to assess a product's market readiness (Goicoechea and Fenollera, 2012), so-called software readiness assessment (SRA) procedures. When these organisations adopt agile development methodologies, their operational processes have to be transformed accordingly, as digital products need to be assessed quickly and continuously in order to support effective decision making (Nierstrasz and Lungu, 2012). Empirical studies on how to transform SRA procedures within operational units do not exist and the need for applicable processes that fit into existing IT environments is evident.

The aim of this paper is to complement the current theoretical understanding of the digital transformation of operational processes. More specifically, we want to clarify the transition of an organisation's SRA procedures to suit agile development methodologies. Managerially, we want to support decision makers with practical guidance on how to facilitate this transition in an approach that is integrable within an existing operational infrastructure. Based on the preliminary considerations, we derive the following research question for our investigation:

How can an organisation transform its software readiness assessment procedure to enable agile product development within its current operational infrastructure?

We answer this question by conducting an empirical study with a major automotive OEM, which introduces microservice architectures to address the need for more flexible and faster software development. The automotive industry is well-suited to conduct this study, as OEMs have already established IT departments and provide digital services, which are qualitatively assessed before going live. Furthermore, they are in the process of digital transformation, which is a topic of great concern to them. Despite that, the industry is still looking for applicable solutions to guide this process. As Tian et al. (2016, p. 6) point out, a major "challenge for automotive companies is to operate and innovate like IT companies and make the car a central part of an ecosystem that merges cyber-physical content and social networking, as well as agile processes for development".

The remainder of this article is structured as follows: In section 2 we present the theoretical background on digital transformation, SRA procedures and agile product development. Section 3 outlines the applied methodology for the investigation. Section 4 comprehensively describes the procedure within the case company as well as an applied modelling approach. Subsequently, section 5 discusses the validation of our approach by means of three software projects. Section 6 discusses the findings in terms of its managerial and scientific implications. Finally, section 7 gives a brief summary, outlines the research limitations and points out room for future scientific activities.

2 Theoretical Background

Microservice Architecture

As digital products and services become more individualized, fragmented into smaller features and time-to-market-cycles shortened (Olsson et al., 2012), microservice architectures have gained in popularity. Microservices (MS) are not firmly defined but can be approximated by a number of characteristics (Wolff, 2017). MS are inspired by service-oriented architectures and are small, self-contained services that are independently processed and communicate event-based, e.g. via APIs (Dragoni et al., 2017). They are introduced to split large software systems into smaller components (Wolff, 2017). MS can be independently deployed, function autonomously and possess their own data storage (Hasselbring and Steinacker, 2017). They are built around business capabilities and overcome the limited scalability of monolithic systems. Typically, they are created and owned by one team, following a DevOps approach (Dragoni et al., 2017), characterized by limited scope and limited functional requirements (Nadareishvili et al., 2016).

Agile Software Development

In order to meet flexible and fast product delivery, more and more large companies adopt agile development methodologies (Henriques and Tanner, 2017) replacing the predominantly traditional ones, such as the waterfall procedure, as they are not suited for immediate requirement changes (Kotaiah and Khalil, 2017). To specify agility, most researchers rely on the definition of the Agile Manifesto that is based on practitioner's experience (Hummel, 2014) and comprises four values and twelve principles (Beck et al., 2001). In adopting agile methods, organizations expect to raise productivity, product and service quality, and accelerate their software development cycles (Dingsøyr and Lassenius, 2016). Many researchers have investigated a number of agile software development methodologies, such as eXtreme programming, Crystal, SCRUM and Feature Driven Development. Generally, the agile development process iteratively goes through the multiple phases, i.e. requirements definition, design, implementation, testing, review and completion (Kotaiah and Khalil, 2017), by promoting small release cycles, which continuously integrate customers into the development process, that is iteratively in defined periods (Hummel, 2014), and new code as soon as it is ready (Abrahamsson, 2002). Software is developed lean and fast, following a minimal viable product (MVP) approach, thus allowing to grow incrementally over time. Agile development methodologies emphasize continuous product delivery, enabled by the regular integration of code during development (Dingsøyr and Lassenius, 2016). Software shall be kept constantly in a releasable state. Therefore, organisations have to automate software building, deployment, testing and release processes (Humble and Farley, 2011). In addition, continuous delivery makes it necessary to adopt a development team composition and assigning responsibility within an organisation. Teams are vertically structured and follow a DevOps approach, taking an end-to-end responsibility for the product where software development and operations are combined (Dingsøyr et al., 2014). In order to instantly know when software is in a releasable state respective assessment processes also have to be set-up.

Software Readiness Assessment

Before a software product is released to the market or integrated into the goods, assessing its readiness is critical to ensure correct operations. Operational readiness refers to a concept that attempts to quantify the “probability that, at any point in time, the system is ready to be placed into operation on demand when used under stated conditions” (Kececioglu, 2003, p. 24). Subsequently, procedures to predict operational readiness have been investigated and developed by researchers and practitioners in the form of software maturity (SM) (Mankins, 2009), release readiness (RR) (Al Alam et al., 2017) and software readiness (SR) (Asthana and Olivieri, 2009). All of these research streams examine the assessment of software by certain criteria in order to support the decision between releasing software too early or too

late (Quah, 2009). The division among them is blurred as the definitions for RR (Al Alam et al., 2016), SM (Schaefer, 2009), and SR (Olivieri, 2012) are not well-defined and the terms “maturity” and “readiness” are used synonymously (Gove and Uzdzinski, 2013). Nevertheless, we use the term “software readiness” without the intention to exclude relevant publications on “software maturity” or “release readiness”, since it is the designated term within the case company. Typically, SRA are conducted at several points during a software’s life cycle and, depending on the organization, can be either a small or an extensive, highly formal process that involves external peer reviewers. However, assessing technologies poses various organizational and methodological challenges, from choosing the right metrics to ensuring and achieving the right technology level across multiple systems (Mankins, 2009). The purpose of SRA methods is the identification of a discrepancy, which will be resolved by subsequent improvement actions (Pfeffer and Sutton, 1999; Mettler, 2011). Common approaches to assess SR are checklists, industry standards and academically developed methodologies (Asthana and Olivieri, 2009). Since Gibson and Nolan (1974) first introduced a four-stage maturity model, (Gibson and Nolan, 1974) many more assessment models have been developed over the years: the capability maturity model (CMM) (Paulk et al., 1993), the ISO/IEC 15504 norm for software process improvement and capability determination, a defect tracking method using predictive modelling approaches (Quah, 2009) or the IT Capability Model Framework (IT-CMF) (Curley and Kenneally, 2012).
Deciding the readiness of software “requires continuous and customized measurement” (Al Alam et al., 2017, p. 382), and often these decisions are based on good practices subject to an informant’s bias (Mettler, 2011). Further investigation on how methods can be used and applied in existing maturity assessment methods, that is, the existing operational infrastructure of an organisation, is needed. The models are highly complex and specialized, which is why the majority of the information gathering tasks are still carried out manually (Proença and Borbinha, 2016). Research on assessing SR is ongoing and as Mettler (2011, p.82) points out “lots of these models do not describe how to effectively perform these actions. As software development methodologies shift towards agile, SRA procedures have to transition as well, and researchers are even calling for an agile software assessment discipline, which is the “study of the tools and techniques that will allow developers to integrate analysis tools into the daily workflow of software development” (Nierstrasz and Lungu, 2012, p. 3).

3 Research Methodology

Case Research

To investigate the transformation of software readiness assessment processes, we conducted an interpretative case study with an automotive OEM using a phenomenon-based research approach. We chose to conduct a case study as it allows the investigation of organizational problems in their natural environment. In essence, case studies aim to clarify the reasons for decisions, how they are implemented, and what are their outcomes (Schramm, 1971). Thus, we are able to gain valuable insights into understanding the complexity of operational transformations of SRA procedures that are considered in the problem-solving process and artefact design (Recker, 2013). Phenomenon-based research enables us to study an organization in its real-life environment and allows us to consider the restrictions and impediments organizations face (Krogh et al., 2012). Corresponding with the four key

characteristics outlined by Paré (2004), case research in this context is useful as the subject of investigation is complex, it cannot be studied outside its environmental context, there is insufficient theoretical knowledge and a holistic approach is needed.
Following the activities for phenomenon-based research outlined by Krogh et al. (2012) (see Figure 1) we began by identifying the research problem (Yin, 2014). Further, we intensified the exploration of the subject by collecting data on the OEM's SRA processes, screening documents and conducting semi-structured interviews with employees (Mayring, 2014). By applying conceptual modelling (Hoppenbrouwers et al., 2005) we analysed the OEM SRA procedure and developed a software readiness template (SRT) based on the current procedure. Subsequently, we developed the continuous delivery checks (CDC), thus aligning the OEM's assessment procedure to it prevalent agile infrastructure. Following a Human Risk and Effectiveness Strategy for evaluating design science research strategies, the SRT was validated by means of three MS development projects (Venable et al., 2016).

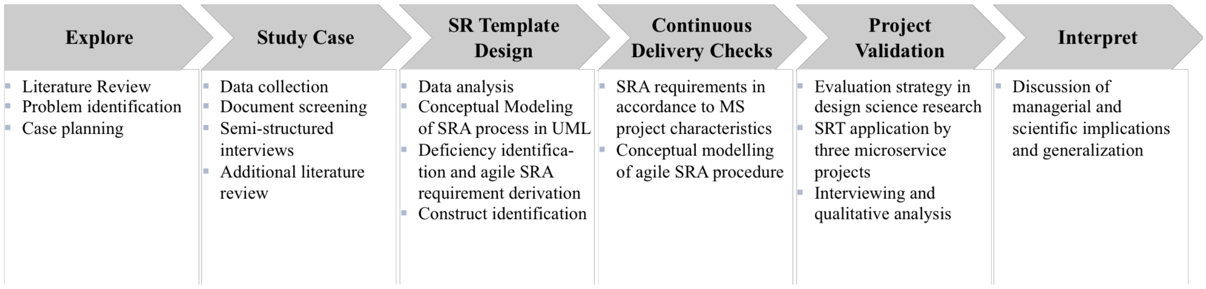

Figure 1. Methodological approach following (Krogh et al., 2012)

Case Description

The study took place at the central headquarters of an automotive OEM where the corporate IT department is situated. The time period of observation and collaboration stretched from 01.02.2017 to 15.08.2017. The case company has an annual turnover exceeding 10 billion Euros and over 100,000 employees of which the large majority works in production. The OEM produces vehicles at multiple facilities throughout the world and is a public limited company. The OEM's product portfolio ranges from compact to premium segment vehicles. In the course of its digitization strategy, the OEM wants to increase the number of digital products, that is digital services. The company has an IT department that not only provides infrastructural IT services, but also takes responsibility for software projects on both product and corporate levels. Software development projects primarily act within waterfall environments, but occasionally proceed in an agile way. The OEM's SRA approach is owned and supported by a separate unit within the IT testing department. The OEM intends to transition its software project development methodology from predominantly waterfall procedures to an agile delivery management. Therefore, the IT architecture has to be aligned with a more flexible and customer-centred focus that enables fast digital service developments within software projects. To meet these demands, the IT architecture department introduced the concept of microservice (MS) architecture and has supported several software development projects to implement it.

Data Collection and Analysis

During the time of the case study, we aimed to get a holistic understanding of the transformation process of SRA procedures. Accordingly, we used multiple means of data collection (Recker, 2013). The SRA information was provided by the department for the integration of customer and commercial processes in the forms of documents and access to the company's proprietary online tool. Further, we conducted semi-structured interviews with personnel from multiple departments, most notably, the head of the SRA advancement and management, SRA commissioning managers, software development project teams, the IT architecture department as well as contiguous business units that contribute to the overall procedure and qualitatively analysed these (Mayring, 2014).

Continuous Delivery Method

Following, we outline the research results. In section 4.1, we focus on the analysis of the OEM's SRA procedure, identify deficiencies out of a MS project perspective and derive agile assessment requirements. Section 4.2 presents the development approach of a Software Readiness Template (SRT) that supports MS projects and clarifies how to apply it. Finally, section 4.3 outlines the continuous delivery checks and the method of how to make the SRA procedure agile ready and, ultimately, integrable within the organization's operational infrastructure.

Software Readiness Assessment Analysis

All software projects within the organization have to complete SRA before going live. The objective of the SRA is to secure high software quality and adherence to the organization's governance and compliance guidelines. The SRA is an internally constructed online tool and consists of a questionnaire of 171 questions, which is structured in accordance to the categories of architecture (33/171), test (63/171) and operations (75/171). Within these categories, it is further divided into different criteria (see Table 1). The majority of the questions are open-ended, and multiple request for more than one answer, such as the first question of the assessment: "Have the functional requirements for the system been defined and documented?" As the focus of this article are the methodological aspects on transforming SRA procedures, the questions are quoted exemplary.

Architecture Criteria [33]	Test Criteria [63]	Operations Criteria [75]
Requirements	Test Planning and Test Controlling	Operation Preparation
Security and Compliance	Test Specification	Monitoring
Interfaces	Test Execution	Business Continuity
Monitoring planning	Test Evaluation and Test Closure	Organisation
Infrastructure (Hardware & Software)	Test Data and Test Environment	Release Management
	Defect Management	Service Level Management
	Code Quality	Configuration Management
		Incident / Problem Management
		Capacity Management
		Change Management
		Training, Rollout and Stabilization

Table 1. Criteria of SRA Checks

For each software development project an SRA is initiated with a set-up. The SRA is structured along five project development phases: "project setup" (8 questions), "exploration" (33 questions), "sprint" (87 questions), "go live" (21 questions), and "transition into line" (22 questions). These phases are typically traversed in a subsequent order. Each answer to a question has to be evaluated with a respective fulfilment degree that ranges in quartiles from 0 to a 100 %. If a certain score is reached at the end of one phase,

the project is ready to progress to the next development phase. Answering the entire questionnaire results in the calculation of a software readiness index (SRI) that has to reach a specified score to be formally accepted. Regardless of the outcome of the score, defined “must criteria” have to be met before any software goes live. So, for instance, if the overall SRI score is 95%, but one ”must criterion” was not met, the software will not be accepted to go live.
The SRA is monitored and supported by commissioning managers (CM) who fill the questionnaire with partial help from project team members. Thus, the independence of the assessment is secured. In some occasions, e.g. if a project is time-sensitive and further resources are needed, multiple CMs may work on one SRA and more may be hired on a contractual basis. For many answers, documents or some other form of verification needs to be created in order to be assessed as fulfilled, such as certifying the conclusion of interface contracts. Figure 2 illustrates the current process within a UML 2 activity diagram.
The SRA is so comprehensive that it is suitable for all of the OEM’s software projects. However, it is a one-size-fits-all solution as the questionnaire is a monolithic construct and therefore is not adaptable to individual projects' needs. Regardless of the project development methodology, such as waterfall or agile, and scope, such as small or large, the SRA has to be filled in the same way. The SRA phases typically follow the course of a project’s progress. The organization's current process is best-suited for large-scale, long-running software development projects, but imposes a significant overhead for digital products which follow a minimal viable product (MVP) approach and grow incrementally over time (DevOps). Contrary to the agile principle of response to change, a defined functionality or feature cannot quickly be implemented and tested under market conditions as verifications, documents and detailed answers have to be given ex ante in order to be ready for the release. The online tool offers no central storage management for documents or any other verifications. Documents and answers cannot be transferred from one project to another. So, for every project set-up the documents and verifications have to be re-created. MS projects that are developed agile, have a set of different characteristics, see Table 2, from which we derived SRA requirements that took into account the artefact design.

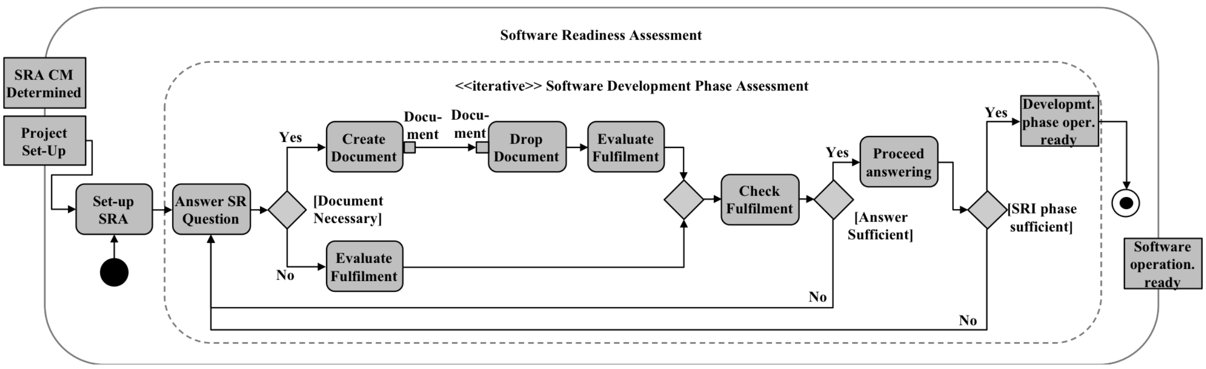

Figure 2. UML 2 Activity Diagram of SRA Procedure

MS Projects	SRA Requirement
Minimum viable product development	Minimal viable assessment
Automatic performance scaling	Flexible assessments that adapt with scaling
Continuous delivery of new features	Assessment as an iterative process
Use of standardized constructs:	Standardised assessment criteria that projects
Automated test pipeline up to production	can accept to comply, build upon and
API gateway for communication	revisit (reusability)
Development environment	
DevOps enabled processes	
Agile product delivery of build, measure, learn	Reactive software assessments

Table 2. SRA Demands for Agile Product Development

In order to get the SRA agile ready, we follow a two-step process. First, we aim to reduce the answering effort for MS projects and, secondly, integrate the SRA into the OEM's agile workflow.

Software Readiness Template

Independent of their size and scope all MS projects share certain architectural features (Wolff, 2017). Following the SRA analysis (Sec. 4.1), document screening and analysis and interviews we identified that these projects rely on standardized technical constructs and organisational implementations. Hence, a set of SRA questions should be answerable by referring to the basic conditions these standards provide. The first standards we determined are the characteristics of the MS architecture (see Sec. 2), inherently used by any MS project. Secondly, MS projects use an automated test pipeline (ATP), a defined tool-based workflow, an API gateway, that operates as a standardized communication entry point, and a development environment (DE) that provisions, manages and scales the microservices. Finally, MS projects follow a DevOps approach. After having identified these standards, we transferred the SRA questionnaire from the online tool to an excel spreadsheet, which serves as the working basis. Subsequently, we analysed each one of the 171 SRA questions, and parts of them, taking an MS perspective of whether required verification can be provided within a package, is automatable by the use of the ATP, the API gateway and DE, or simply not applicable anymore. Thereby, we defined the terms as seen in Table 3, and reinsured our evaluations with two CMs.

Packable:	Automatable:	Not Applicable:
- SRA questions that can be answered by the basic conditions that the DE, the API gateway and ATP provide as templates	- SRA questions that are automatically answered for MS projects which use the DE, the API gateway and ATP for communication, automated staging, logging and testing	- SRA questions that are not applicable to MS development projects
- E.g. is the life-cycle for the infrastructure components checked (SRA question 31) by the persons responsible for the DE	- E.g. automated tests will be executed in the background for every code commit and can be viewed at any time	- E.g. responsibilities for hardware operations
SRA Analysis 85/171 (ca. 50 %) are packable* 17 architecture criteria 42 test criteria 26 operations criteria	**SRA Analysis** 51/171 (ca. 30 %) are automatable* 10 architecture criteria 27 test criteria 14 operations criteria	**SRA Analysis** 15/171 (ca. 9 %) are not applicable 0 architecture criteria 1 test criterion 14 operations criteria

*"Packable" and "Automatable" are not mutually exclusive

Table 3. Evaluation criteria of the SRA questionnaire analysis

As the results in Table 3 show, over 50% of the 171 SRA questions could be answered in a pre-packaged way. Around 30 % of the assessment verifications can even be automated, most notably queried test criteria by using the ATP and DE. The 15 questions that were identified as no longer applicable, mostly relate to the changed application operation through the DevOps teams. 56 SRA questions were identified to be neither packable nor automatable and would still need to be manually answered for every MS project. The majority of MS projects start small and grow over time, for instance, when new functional requirements are added. Thus, the projects are required to answer certain SRA questions once or iteratively, e.g. per sprint, depending on certain triggers. In total 18 triggers were identified by working through the software readiness questionnaire with 2 CMs and elaborating on which changes/alterations/conditions require a software project to update or readjust the given answer. Subsequently, we abstracted these triggers and categorized them within the dimensions: product, business, operations & infrastructure and governance & compliance, see Table 4.

Trigger Category			
Product	**Business**	**Operations & Infrastructure**	**Governance & Compliance**
New functional req.	Scaling and performance	API specification changes	New security req.
Scaling and performance	Global Rollout	End-of-life infrastr. compon.	New compliance req.
Personal data use	Extreme scaling changes	Change in test cases	Personal data use
New service or mainten. req.		New operation critical defects	
New Data types		DevOps team changes	
New functional req. that necessitates user training		Emergence of new interface	
6	**3**	**6**	**3**

Table 4. Trigger Categories and Triggers

Based on these preliminary SRA evaluations, we formulated generalized target picture answers out of the perspective of an MS development project and checked each proposal with a commissioning manager. As a result, we created a template of the SRT answers that could be provided to MS projects as a working basis for their SRA procedure, see Figure 3. Utilizing the SRT, MS projects get immediate support within the prevalent procedure to fill the SRA since the answers can be copied and adapted to application specific needs. Subsequently, project teams can derive tasks and integrate them within their project management tool. In accordance with agile principles, the SRT template displays if the question has to be answered once or recurring.

Phase	Must Criteria	#	SRA Question	Infra-structure	Trigger Category	Once / Iteratively	SRA MS Project	Fulfill-ment	MS Project Tasks
			Architecture-Criteria						
			Requirements						
			Functional and non-functional Requirements						
SPR		3	Are the main KPIs for the non-functional requirements such as load, performance, availability, restart, re-connectivity, data backup etc. specified?	yes	scaling, performance	continually	- I as a MS Project accept base KPIs from the Development Environment and prove scalability of own Microservices by automatic tests - Key non-functional requirements have to be defined as Backlog entries (User Stories)		

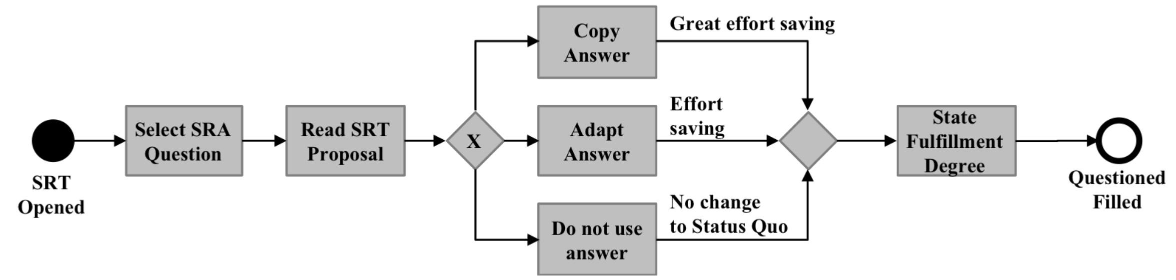

Figure 3. Using the MS SRT

4 Continuous Delivery Checks (CDC)

The SRT is the foundation for the conceptual development of the Continuous Delivery Package (CDP). The CDP is a pre-checked bundle of basic conditions that MS projects accept and commit to comply with, therefore automatically answering a great amount of the SRA questionnaire, identified in the previous analysis. According to the MVP approach, MS projects start small and are advanced with every sprint or when new functional requirements are added to the service. In order to reduce the time-to-market for MS projects, the CDP is provided to them. Projects have to check if the basic conditions specified in the CDP are sufficient for them and if they can ensure to comply with them at their current development state. For larger projects that cannot agree to commit to the basic conditions, the respective SRA criteria have to be specified and evaluated as usual.

The CDP is formed by the identified infrastructure components, architectural criteria or procedures that all MS projects share and is manifested in form of bundled documents, templates, agreements, lists and links among others, see Figure 4. For instance, the 99.9% guarantee of the availability of a DE in its standard configuration should be enough for most MS projects in their initial phase.

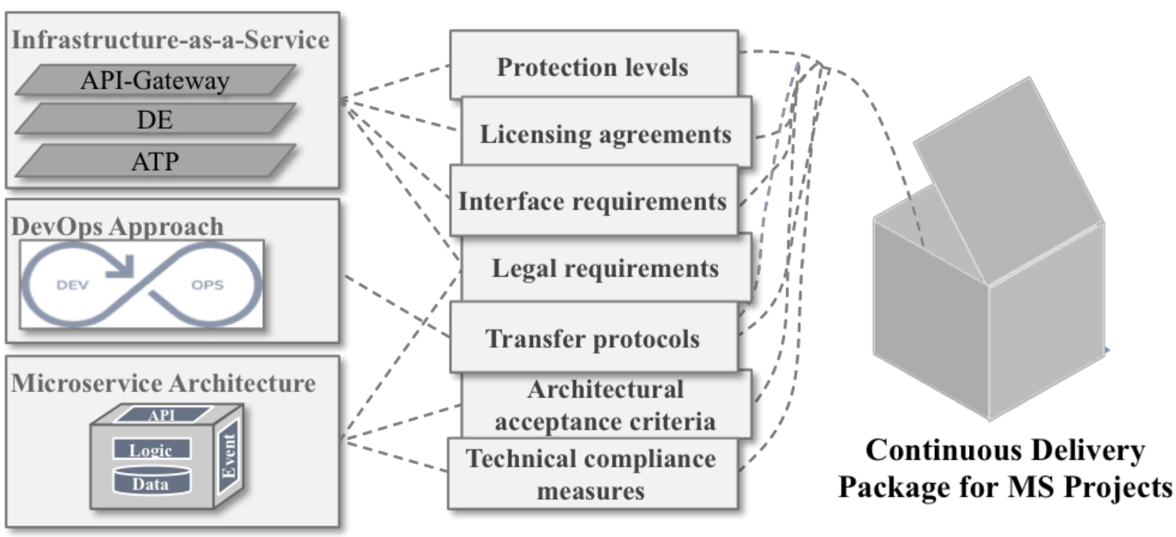

Figure 4. Building the Continuous Delivery Package

The CDP is part of the Continuous Delivery Checks (CDC), which is a concept that integrates the SRA procedure within the OEM's agile development methodology and conforms to the requirement to continuously deploy software, see Figure 5. Upon project set-up, a set of the SRA questions is automatically migrated into the project's backlog. If MS projects agree to comply with the CDP, a significant amount of these backlog issues is answered with the pre-defined basic conditions. The residual amount has to be answered by the project in the respective sprints. The answering and acceptance of backlog issues by the CM satisfies the SRA when calculating the readiness index. The CDC are conducted iteratively in accordance to a project's agile development state and whether a trigger requires a project to adapt an answer. If MS projects follow the Scrum methodology, sprint cycles can be a period determining factor. For the increasing variety of software development projects, e.g. MS projects, this configurable readiness assessment approach can reduce the evaluation effort as only criteria relevant to the project's current circumstances and development state are considered. The CDC provide a solution for an agile SRA by making the existing procedure flexible to scale with the software.

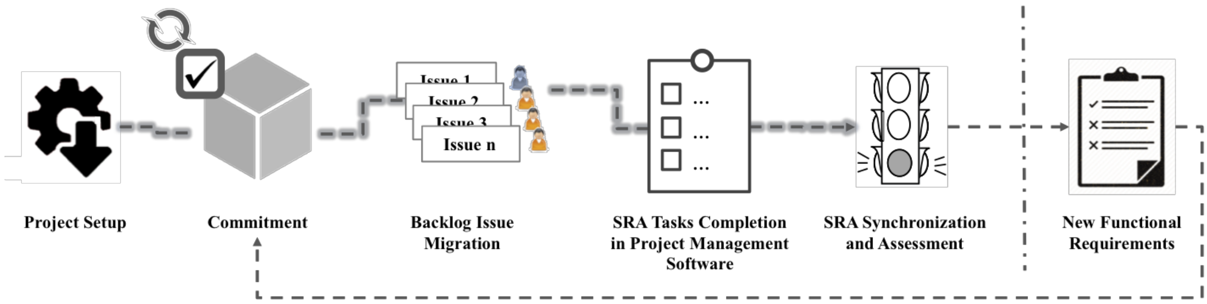

Figure 5. The Continuous Delivery Checks Principle

SRT Test and Validation by Software Development Projects

In accordance to Frank's (2007) evaluation process model, we first chose a Human Risk and Effectiveness Strategy for validating a design science research artefact (Frank, 2007; Venable et al., 2016). As this strategy entails an empirical validation in the natural context, it is well-suited for case research (Venable et al., 2016). In order to validate the artefact, the SRT was given to the commissioning managers of three MS projects to perform the company's SRA, see Table 5. In this context, the CMs received an introduction about the structure, how the document is best used and the intentional future implementation of the CDC. After the application of the SRT, we conducted semi-structured interviews and qualitatively analysed their feedback, following the summarising content analysis proposed by Mayring (2014). The CDC methodology relies on the correctness and usability of the SRT. The SRT is an artefact, which MS development projects should be able to immediately use, as general, applicable answers are provided. We discuss and interpret the results via a cross-case analysis (Khan and VanWynsberghe, 2008).

The MS projects were of different scope and addressed distinct services, as can be seen in Table 5. Project A intended to develop a service that shows which vehicles are in stock in a certain region to support the point-of-sale representatives. Project B wanted to centralize the authorization and authentication management for digital products. Project C developed a remotely connectable infotainment service. Apart from project A, only one CM primarily worked on the SRA of their respective MS. The interview data was analysed along the dimensions usefulness, correctness, completeness, and comprehensibility.

Generally, the projects remarked the SRT to be useful for MS projects to a certain degree, however their assessment differed, whereas the project context affected the amount of answers that could be copied. The SRT answers were assessed to be partially correct and due to the generalist aspiration provide room for interpretation. Therefore, Project A and B had to adapt many of the suggested template answers. Project A and C noted most of the SRT answers to be complete. Project B did not disclose any information regarding this dimension.

	Project A	Project B	Project C
Service	Stock locator service (B2B)	Authorisation & Authentication Mngmt. Service (B2C, B2B)	Remote vehicle services (B2C)
CMs	2 (internal & external)	1 (internal)	1 (external)
Useful-ness	- To a certain degree helpful - Conceptually yes, but without too lintegration for now an extra effort	- To a certain degree, as general answers often still need to be adopted - but indicatively useful - For smaller projects more usefull than for bigger ones	- A significant number of answers were copied and adapted to project needs
Correct-ness	- Partially correct answers and additions were provided	- Not wrong, but some proposals are too general and give room for interpretation	- SRT mostly correct, but is not enough as the SRA has to be aligned to agile tools
Complete-ness	- Mostly complete, but additional processes, such as licence agreements, could be added	- (No remark)	- Complete, but additional standards may be identifiable
Compre-hensibility	- External CM: comprehended Internal CM: difficult to comprehend	- Initial difficulty, but during the application learning effects	- SRT functioning comprehended, however some compr. problems due to missing knowledge about the infrastr. tasks and processes
Remarks	- For proper usage, agile integration necessary - External CM: useful	- For proper usage, agile integration desirable - Further improvement by more categorisation and filter option	- The SRT was helpful, but is not enough as the SRA still needs to be aligned to agile tools

Table 5. Overview of test MS projects and validation results

However, both Project A and C provided suggestions that more standards might or could be supplemented. All projects stated to have had initial comprehensibility concerns, which could be overcome with progressing SRA answering (Project B and C). Project A's internal CM had difficulty comprehending the SRT's concept. The CM particularly noted that infrastructural components, such as the DE and ATP, could not give basic conditions, and instead, the MS projects must state them. The idea of reversing the operational readiness principle by providing restrictions and not asking for all eventualities was noted to be difficult to imagine. Contrary, the external CM stated to comprehend its intentional use, and noted, for proper usage, an integration within the organisation's agile toolchain to be necessary for a full, potential benefit exploitation, as did the CMs of Project B and C. Based on the remarks, especially of the external CM, we adapted certain answers and provided additional filter features that would make the document more usable. The conceptual idea of the CDC was regarded to be primarily good and necessary in order to transform the current rigid process, but a managerial decision to actually transform the SRA was at the time of the project's assessment missing, which caused insecurities to arise and employees to conduct the SRA procedure as usual parallelly.

Discussion

Scientific Implications

Previous studies on digital transformation have focused on current challenges and the identification of necessary fields of action (Baines et al., 2009, Gimpel and Röglinger, 2015, Bounfour, 2016). It was suggested that operational procedures need to be adapted, but methods that support their execution have been scarcely researched. Building on these findings the present article presents a methodology on the operational level derived from an empirical case and therefore contributes to the identified demand (Gimpel and Röglinger, 2015). Further, the research on agile SRA is still in its infancy, but is gaining in importance (Nierstrasz and Lungu, 2012). Our study provides a foundation to the understanding of the far-reaching implications a setup of agile readiness assessment has. By identifying constructs and standards that all projects within an organisation use, and further by deriving restrictions and developing the necessary SRA answers, an approach is provided that may be applicable to other kinds of software development projects as well.

In addition, agile SRA requirements for MS projects were identified. Contrary to many studies on the strategic level (Hess et al., 2016, Khan, 2016) with regard to digital transformation, the novelty of this study is the provision of a transformation methodology by means of empirical data and the identification of impediments when trying to initiate its implementation. Finally, as for the research on microservice architectures this study provides further insights about their implementation difficulties.

In sum, this article contributes to the understanding of how manufacturing organizations can transform their SRA procedure to suit agile development methods by providing a methodology that takes the existing operational infrastructure into account. This study demonstrates on an operational level that the decision to become a solution provider and its resulting consequences challenge an organisation's operational procedures as a transformation is a process, stretching over a period of time. Consequently, existing software readiness assessment (SRA) processes have to be managed and maintained, while new ones have to be implemented. In this respect, the study highlights the notion of previous findings that digital transformation is a complex venture that affects many sections within an organisation (Hess et al., 2016).

Managerial Implications

On a managerial level, we can learn from this study that deciding to implement a new architecture pattern in order to improve software development processes, has far more reaching consequences than can be previously envisioned. Setbacks have to be accepted and key stakeholders need to be aware that transforming processes can result in additional efforts. That is why it is crucial to include, if possible, all contributing parties. Further, manufacturers that aspire to be leading digital service providers, have to be able to enable fast and flexible product development if they want to stay competitive in the market. Processing IT projects in accordance to these requirements poses difficulties to OEMs as their current structures cannot operationally handle these requirements. It could be observed that the SRA procedure is a reflection of the organization's product-centric structure, which is oriented around the development and advancement of physical goods. Software development projects are processed in a rather waterfall environment, where it is required to answer to all eventualities ex ante rather than respond to change. As Hess et al. (2016, p. 2) point out, ”managers often lack clarity about the different options and elements they need to consider in their digital transformation endeavours“. This study demonstrates these different elements and the methodology provides instructions of how to adapt agile assessment procedures.

Conclusion

In this study, we conducted an empirical investigation with an automotive OEM that introduced microservice (MS) architectures as part of a transformation initiative to enable fast digital product development. Thereby, we investigated the question of how to transform the organisation’s software readiness assessment (SRA) procedure under consideration of its current operational infrastructure. We therefore analysed the existing process by reviewing literature, screening documents, conducting interviews, and by identifying current deficiencies and agile assessment requirements. Based on these results, the SRA was transferred into a working document to provide a basis for the development of an applicable software readiness template (SRT) for MS projects. On the foundation of the SRT we created the concept of Continuous Delivery Checks (CDC) by providing an initial framework of basic conditions of constructs and processes all MS projects use. The intention of the CDC is to reduce the answering effort and makes the organisation’s SRA flexible, as well as integratable within its agile toolchain or its operational infrastructure. It allows DevOps teams to administer the SRA as part of their tasks of the respective sprint within one project management tool. The SRT was validated by three MS projects and respectively adapted. We observed the SRT to be a useful intermediary step within the transformation process to an agile software assessment procedure, but its successful implementation and adoption depends on the integration of all contributing departments and cannot be executed independently. In this context, we noticed employees to have difficulties to change their mindset, though majoritarian they supported the concept of the CDC. In addition, without the implementation of the CDC and a managerial mandate the created artefact was not as beneficial to the MS projects, as it could have been.

The CDC is an approach to transform business operations and to contribute to propelling the development of digital products and services, thus leveraging the application of digital technologies, such as MS, in order to enhance customer value, both being focal points of companies leading digital transformation (Berman, 2012). Further, the approach demonstrates a way on how to integrate assessment processes within agile development processes, which increases the application benefit of the organisation’s agile tools in use. After all, the potential of agile project development supporting technologies cannot be exploited if an organisation’s operations remain unaltered and unintegrated. The methodology has been positively received by the person responsible for the SRA advancement and management. By the time of writing, a mandate within the organisation was created based on the findings of this study, which promotes the advancement and implementation of the CDC or agile SRA.

However, the findings of this study are subject to the following limitations. As is typical for case study methods research, not all variables could be controlled, despite the high dependence of observations and artefacts on the study context, thus complicating replication

(Recker, 2013). The case research was conducted with one manufacturing company and the question is whether the application in a different organisation, or set of organisations, from different industries would have resulted in a different methodological approach. Further, the validation of the SRT with different MS projects could have possibly yielded different feedback. In order to address these limitations, we endorse further empirical research on digital transformation ventures both with companies of the same, and of different, industries. This article can provide the background for further research on the transformation of agile SRA in operational procedures in more broader terms. Theoretically, the unification or clear differentiation of software maturity, release readiness and software readiness assessments by providing definitions or characteristics are topics of future interest. Also, investigating the applicability of the developed procedure across different industries as well as the research on complementing methods and further advancement of the existing ones, provide many points of reference for future research as generally applicable tools still need to be developed. Additionally, the integration of agile SRA procedure within agile development methods is a topic of growing concern. The current study could be expanded on in additional software development projects, other than MS, generalizing the results to formulate comprehensive transformation frameworks.

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5.5 Continuous Software Readiness Assessments for Agile Development

Continuous Software Readiness Assessments for Agile Product Development

A case of how an OEM transformed its IT development operations

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Agile software development empowers fast and continuous software delivery. However, in order to ensure that delivered software is constantly in a viable state, software readiness assessments need to be conducted continuously as well. Together with an automotive OEM that introduces microservices architectures and agile software development, we investigated the transformation of its software readiness assessment (SRA) procedure. In this article we present our findings and introduce a template and a methodology that guides an organization during their transformation. Our artifacts are further validated by means of three MS projects and respectively adapted.

KEYWORDS
Software readiness assessment, agile software development, microservices

To achieve continuous and fast software development, progressively companies are adopting agile development methodologies to increase productivity, improve product and service quality, and to shorten development cycles.[4] In doing so, software is developed incrementally over time while continuously integrating and deploying code following a minimal viable product (MVP) approach.

Nevertheless, companies are struggling to adapt their internal operations and IT infrastructures to these collaborative, fast and flexible product development methodologies. In particular, processes which are responsible in assuring that software is in a releasable state, i.e. it fulfills certain security and quality levels within a given IT infrastructure, are especially difficult.

Typically, organizations set up mechanisms and processes to assess a software's market readiness utilizing software readiness assessment (SRA) procedures.[7] They attempt to quantify the "probability that, at any point in time, the system is ready to be placed into operation on demand when used under stated conditions".[11] Common approaches of assessing software readiness are checklists, industry standards and academically developed methodologies, e.g. ISO/IEC 15504 and Capability Maturity Models (CMM).

As software development methodologies shift towards agile, SRA procedures require to be transitioned as well. Researchers and some software system practioners are even calling for an agile software assessment discipline, involving the "study of tools and techniques that will allow developers to integrate analysis tools into the daily workflow of software development".[16] Principles of agile software development must be applied to new software systems in a way which assures a quick and continuous assessment. Currently, there is a lack

of information on how to transform SRA procedures within operational units and the need for applicable processes that fit into existing IT environments is evident.
In this article we present an approach for the transformation of an organization's SRA procedures to suit agile development methodologies. We want to give practical guidance on how to facilitate this transition in an approach that integrates with the existing operational infrastructure. Our findings are based on an empirical study with a major automotive original equipment manufacturer (OEM). The OEM currently introduces microservice (MS) architectures to address the need for more flexible and faster software development. It has already established IT departments that provide software services, which are qualitatively assessed before going live. We build upon standardized technical and organizational constructs inherent to MS projects and introduce a template and methodology that guides an organization during the transformation. Our artifact is validated by means of three MS projects and respectively adapted. The findings suggest such an artifact to be a useful intermediary step that requires the integration of all contributing departments for a successful implementation.

SOFTWARE READINESS ASSESSMENTS DEMAND AGILITY

Microservice architecture. Fragmentation of software into smaller features has gained popularity as it allows for more individualization, dynamic composition and shorter time-to-market-cycles.[17] Microservice architectures, inspired by service-oriented architectures, allow us to split large software systems into smaller components of self-contained services that are independently processed and communicate event-based, e.g. via APIs.[21] They can be independently deployed, function autonomously and possess their own data storage.[8] MS are built around business capabilities, characterized by limited scope and functional requirements overcoming the narrow scalability of monolithic systems. Typically, they are created and owned by one team, following a DevOps approach.[6]

Agile Software Development. With the increasing dissemination of MS architectures, more and more companies are adopting agile development methodologies for flexible and fast product delivery.[9] They replace traditional procedures, such as waterfall approaches, as they are not suited for ongoing requirement changes.[12] Agile software developments as defined by the Agile Manifesto[2] has led to a number of agile approaches, such as eXtreme programming, Crystal, SCRUM and Feature Driven Development. They usually encompass iteratively short release cycles that permanently produce new code following an MVP approach. Agile development methodologies emphasize continuous product delivery, enabled by the regular integration of code during the development stage.[4] Thus, software needs to be kept constantly in a releasable state and organizations have to automate software building, deployment, testing and release processes as much as possible.[10] Development teams that are vertically structured (DevOps) and take an end-to-end responsibility for software development and operations, are typical examples of groups employing continuous delivery.[5]

Software Readiness Assessment. While MS architectures and agile software development have obvious advantages before a software product is released, assessing its readiness for correct operation is crucial. Therefore, over the last few years several procedures attempting to quantify the probability of correct operation and that can predict operational readiness have been developed. Prominent examples are the capability maturity model (CMM),[18] the ISO/IEC 15504 norm for software process improvement and capability determination, a defect tracking method using predictive modeling approaches[20] and the IT Capability Model Framework (IT-CMF).[3] While the division among them is partially blurred and terms such as *maturity* or *readiness* are used synonymously, they have the common purpose of identifying discrepancies to be resolved by subsequent improvement actions.[15] SRA procedures are conducted at several points during a software's life cycle and can be more or less extensive, which poses both organizational and methodological challenges from choosing the right metrics to ensuring and achieving the right technology level.[13] Many of those procedures are highly complex and specialized, which is why the majority of information gathering tasks are still carried out manually.[19] Research on SRA is ongoing and as Mettler[15] points out, "lots of these models do not describe how to effectively perform these actions". As software development methodologies shift towards agile, SRA procedures must transition as well. Deciding on the readiness of software requires continuous and customized measurements as well as tools and techniques that integrate SRA into incremental software development processes.[1]

PROGRESSING TOWARDS AGILE SOFTWARE READINESS ASSESSMENTS

For the generation of an approach that transforms SRA procedures to be integrable with agile development, we conducted an interpretative case study with an automotive OEM. We began by identifying the underlying problems and further intensified our exploration by collecting data on the OEM's SRA processes by screening documents and conducting semi-structured interviews. After having analyzed the OEM's SRA procedure we conceptually modeled and built a software readiness template (SRT). Based on the SRT we developed the continuous delivery checks (CDC), a method that aligns the OEM's assessment procedure to its prevalent agile infrastructure. At the end, the SRT was validated by means of three MS development projects.

Our case study was conducted at the central headquarters of an automotive OEM with its corporate IT department between January 2017 and August 2017. The OEM has an annual turnover exceeding 10 billion Euros and over 100,000 employees, producing vehicles ranging from the compact to the premium sector. The OEM's digitization strategy involves increasing the number of IT services around its vehicle environment. The company has an IT department that not only provides infrastructural IT services, but also takes responsibility for software projects on both product and corporate levels. The OEM's SRA approach is owned and supported by a separate unit within the IT testing department. The OEM intends to transition its software project development methodology from predominantly waterfall procedures to agile delivery. Therefore, the IT architecture must be aligned with a more flexible and customer-centered focus that enables fast software service developments. To meet these demands, the IT department introduced the concept of microservice architecture and has supported several software development projects implementing it.

To support our investigation the OEM's IT department provided SRA information in the form of documents along with access to the company's proprietary tool set. Further, semi-structured interviews were conducted with personnel from multiple departments, most notably, the SRA advancement and management department head, SRA commissioning managers (CM), software development project teams, the IT architecture department as well as the contiguous business units that contribute to the overall procedure.

THE CONTINUOUS DELIVERY METHOD FOR AN AGILE SRA

To get the SRA agile ready we followed three steps. First, we analyzed the OEM's current SRA procedures, identified deficiencies out of a MS project perspective and derived agile assessment requirements. Second, we developed a more concise version of a checklist for MS projects and created a Software Readiness Template (SRT). Third, we integrated the SRA into the OEM's agile workflow.

Analysis of the current state and deficiencies of SRAs. Before going live, all software components must complete an SRA to secure high software quality and adherence to the

organization's governance and compliance guidelines. The SRA was implemented in an online tool and consists of a questionnaire with 171 questions categorized into architecture (33/171), test (63/171) and operations (75/171) (see Table 1 for an overview).
For each software development project, an SRA is initiated that goes through five subsequent phases with associated questions: "project setup" (8 questions), "exploration" (33 questions), "sprint" (87 questions), "go live" (21 questions), and "transition into line" (22 questions). Each answer to a question is evaluated with a respective fulfillment degree that ranges in quartiles from 0 to a 100%. If a certain score is reached at the end a phase, the project progresses to the next development phase. Completion of the questionnaire is followed by the calculation of a software readiness index (SRI) which requires meeting a specified minimum score to be formally accepted. Regardless of the outcome of the score, defined "must criteria" is to be met before any software goes live.
The SRA is monitored and supported by CMs who fill the questionnaire with assistance by project team members. Thus, the independence of the assessment is secured. For many answers, documents or other forms of verification needs are created. Figure 1 illustrates the current process within a UML 2 activity diagram.

Architecture Criteria [33]	Test Criteria [63]	Operations Criteria [75]
Requirements	Test Planning and Test Controlling	Operation Preparation
Security and Compliance	Test Specification	Monitoring
Interfaces	Test Execution	Business Continuity
Monitoring planning	Test Evaluation and Test Closure	Organization
Infrastructure (Hardware & Software)	Test Data and Test Environment	Release Management
	Defect Management	Service Level Management
	Code Quality	Configuration Management
		Incident / Problem Management
		Capacity Management
		Change Management
		Training, Rollout and Stabilization

Table 1. Criteria of SRA Checks.

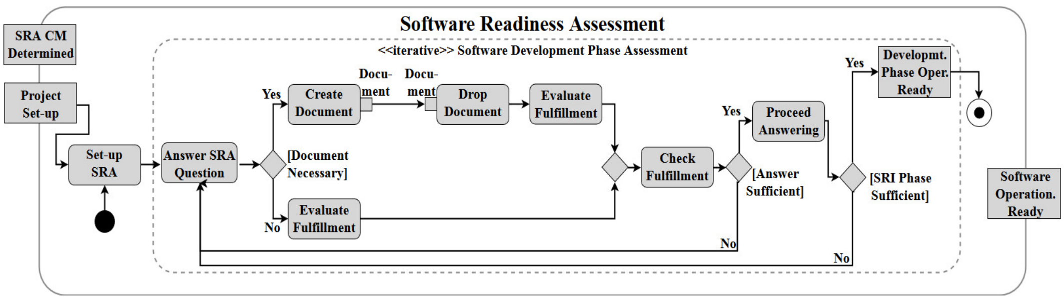

Figure 1. **UML 2 Activity Diagram of SRA Procedure.**

The current SRA is used as a one-size-fits-all solution for all software projects and the monolithic questionnaire construct is not adaptable to individual projects' needs. Regardless of the project development methodology, such as waterfall or agile, and scope, such as small or large, the SRA must be filled in the same way. It is best suited for large-scale, long-running software development projects, but imposes a significant overhead for those that follow an MVP approach and grows incrementally over time (DevOps). Contrary to the agile principle of response to change, a defined functionality or feature cannot quickly be implemented and tested under market conditions as verifications, documents and detailed answers need to be given ex ante to be ready for the release. The online tool offers no central storage management for documents or any other verification. Further, documents and answers cannot be transferred from one project to another. So, for every project set-up the documents and verifications must be re-created. MS projects that are developed agile, have a set of different characteristics, see Table 2, from which we derived SRA requirements for our artifact design.

MS Projects	SRA Requirement
Minimum viable product development	Minimum viable assessment
Automatic performance scaling	Flexible assessments that adapt with scaling
Continuous delivery of new features	Assessment as an iterative process
Use of standardized constructs: Automated test pipeline up to production API gateway for communication Development environment DevOps enabled processes	Standardized assessment criteria that projects can accept to comply with, build upon and revisit (reusability)
Agile product delivery of build, measure, learn	Reactive software assessments

Table 2.

SRA demands for agile product development.

Reducing SRA efforts with software readiness templates. Independent of size and scope all MS projects share certain architectural features.[21] Following the SRA analysis described above along with interviews, we were able to identify that these projects rely on standardized technical constructs and organizational implementations. Hence, a set of SRA questions should be answerable by referring to the basic conditions these standards provide. The first standards we determined are the characteristics of the MS architecture inherently used by any MS project. Secondly, MS projects use an automated test pipeline (ATP), a defined tool-based workflow, an API gateway that operates as a standardized communication entry point, and a development environment (DE) that provisions, manages and scales the microservices. Finally, MS projects follow a DevOps approach. After having identified these standards, we analyzed each one of the 171 SRA questions, taking an MS perspective of whether required verification can be provided within a package is automatable using the ATP, the API gateway and DE, or simply no longer applicable. Thereby, we defined the terms as seen in Table 3, and reinsured our evaluations with two CMs.

Packable:	Automatable:	Not Applicable:
- SRA questions that can be answered by the basic conditions that the DE, the API gateway and the ATP provide as templates	- SRA questions that are automatically answered for MS projects which use the DE, the API gateway and ATP for communication, automated staging, logging and testing	- SRA questions that are not applicable to MS development projects
- E.g. is the life-cycle for the infrastructure compenents checked (SRA question 31) by the persons responsible for the DE	- E.g. automated tests will be executed in the background for every code commit and can be viewed at any time	- E.g. responsibilities for hardware operations
SRA Analysis 85/171 (ca. 50%) are packable* 17 architecture criteria 42 test criteria 26 operations criteria	**SRA Analysis** 51/171 (ca. 30%) are automatable* 10 architecture criteria 27 test criteria 14 operations criteria	**SRA Analysis** 15/171 (ca. 9%) are not applicable 0 architecture criteria 1 test criterion 14 operations criteria

*"Packable" and "Automatable" are not mutually exclusive

Table 3.

Evaluation criteria of the SRA questionnaire analysis.

As the results in Table 3 show, over 50% of the 171 SRA questions could be answered in a pre-packaged way. Around 30% of the assessment verifications can even be automated, most notably queried test criteria by using the ATP and DE. The 15 questions that were identified as no longer applicable mostly relate to the changed application operation through the DevOps teams. 56 SRA questions were identified to be neither packable nor automatable and would still need to be manually answered for every MS project. Most MS projects start small and grow over time, for instance, when new functional requirements are added. Thus, the projects are required to answer certain SRA questions either once or iteratively, e.g. per sprint, depending on certain triggers. In total, 18 triggers were identified by working through the software readiness questionnaire with 2 CMs and elaborating on which changes/alterations/conditions require a software project to update or readjust the given answer. Subsequently, we abstracted these triggers and categorized them within the dimensions: product, business, operations & infrastructure, and governance & compliance (see Table 4).

Trigger Category			
Product	**Business**	**Operations & Infrastructure**	**Governance & Compliance**
New fictional req. Scaling and performance Personal data use New serviceor mainten. req. New Data types New functional req. that necessitates user training	Scaling and performance Global Rollout Extreme Scaling Changes	API specification changes End-of-life infrastr. compon. Change in test cases New operation critical defects DevOps team changes Emergence of new interface	New security req. New compliance req. Personal data use
6	3	6	3

Table 4. Trigger categories and triggers.

Next, we transferred the 171 questions to an excel spreadsheet and formulated generalized target picture answers out of the perspective of an MS development project based on our preliminary SRA evaluations. In this process, we checked each proposal with a CM and built a template of the SRT answers that could be provided to MS projects as a working basis for their SRA procedure, see Figure 2.

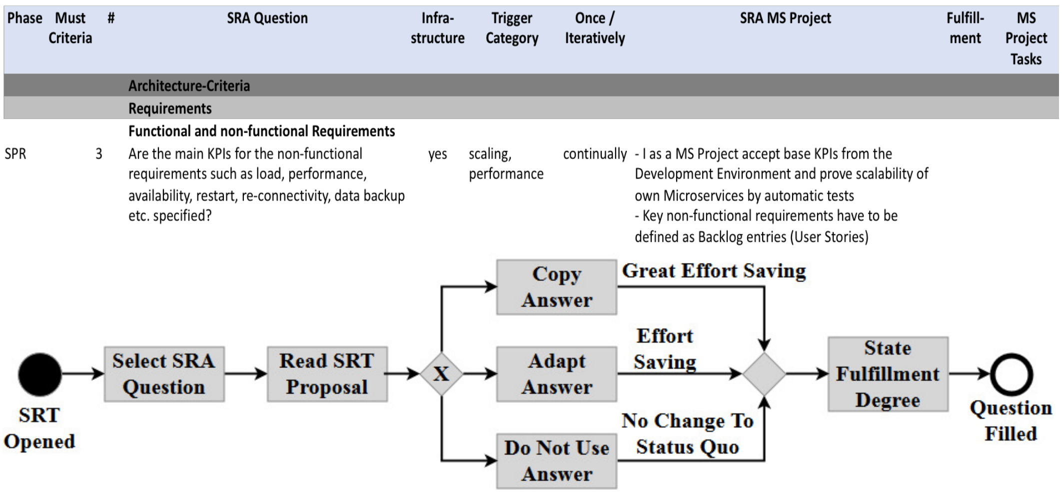

Figure 2. Using the MS SRT.

Utilizing the SRT, MS projects get immediate support within the prevalent procedure to fill the SRA since the answers can be copied and adapted to the specific application. Subsequently, project teams can derive tasks and integrate them within their project management tool. In accordance with agile principles, the SRT template displays if the question must be answered once or recurrently.

Continuous Delivery Checks. The SRT is the foundation for the conceptual development of the Continuous Delivery Package (CDP). The CDP is a pre-checked bundle of basic conditions that MS projects accept and commit to comply with. Thus, they can automatically answer a large amount of the SRA questions identified in the previous analysis. According to the MVP approach, MS projects start small and are advanced with either every sprint or when new functional requirements are added to the service. To reduce the time-to-market for MS projects, the CDP is provided to them. Projects must check if the basic conditions specified in the CDP are sufficient for them and if they can ensure to comply with them at their current development state. For larger projects that cannot agree to commit to the basic conditions, the respective SRA criteria must be specified and evaluated as usual.

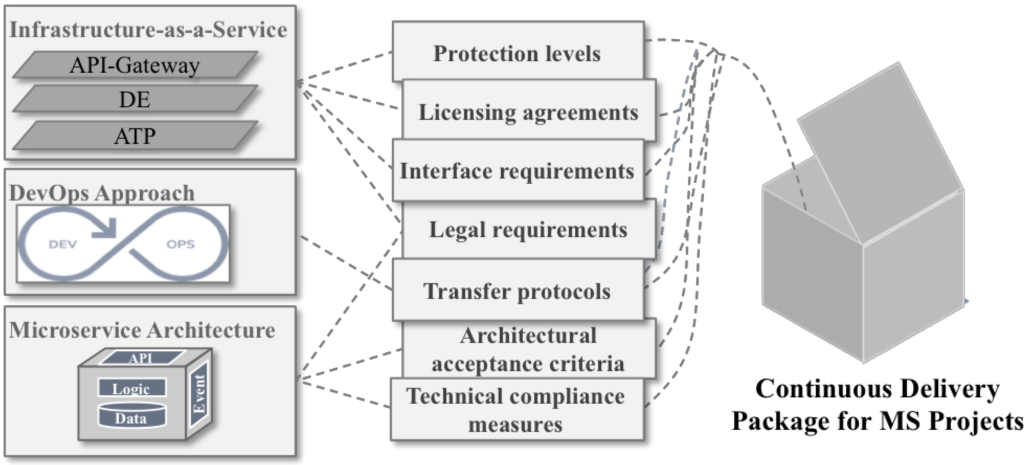

Figure 3. Building the Continuous Delivery Package.

The CDP is formed by the identified infrastructural components, architectural criteria and procedures that all MS projects share and is manifested in the forms of bundled documents, templates, agreements, lists and links among others, see Figure 3. For instance, the 99.9% guarantee of the availability of a DE in its standard configuration should be enough for most MS projects in their initial phase.

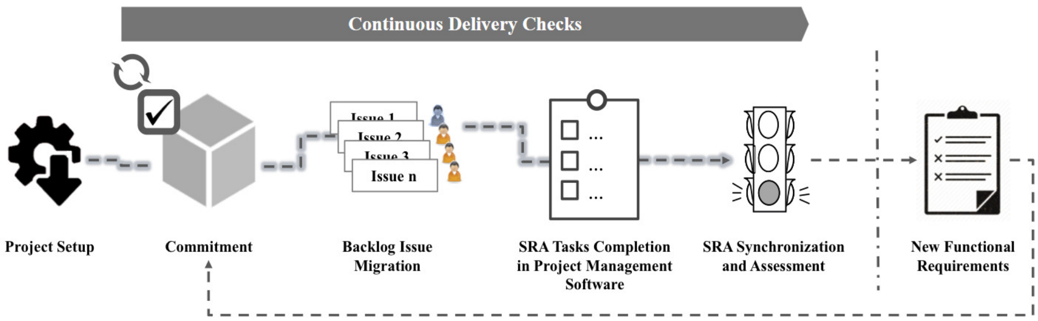

Figure 4. The Continuous Delivery Checks Principle.

The CDP is part of the Continuous Delivery Checks (CDC), which conceptually integrates the SRA procedure within the OEM's agile development methodology and conforms with the requirement of continuously deploying software (see Figure 4). Upon project set-up, a set of SRA questions is automatically migrated into the project's backlog. If MS projects agree to comply with the CDP, a significant amount of these backlog issues is answered with the pre-defined basic conditions. The residual amount must be answered by the project in the respective sprints. The answering and acceptance of backlog issues by the CM satisfies the SRA when calculating the readiness index. The CDC are conducted iteratively in accordance to a project's agile development state and whether a trigger requires a project to adapt an answer. If MS projects follow the Scrum methodology, sprint cycles can be a period determining factor. For the increasing variety of software development projects, e.g. MS projects, this configurable readiness assessment approach can reduce the evaluation effort as only criteria relevant to the project's current circumstances and development state are taken into consideration. The CDC provides a solution for an agile SRA by making the existing procedure flexible to scale with the software.

TESTING AND EVALUATING THE SRT

We conducted an empirical validation in the natural context to test and evaluate our approach. We gave the SRT to the commissioning managers of three MS projects to perform the company's SRA. The CMs received an introduction about the structure, how the document is used and how we propose to embed it in a future implementation of the CDC. Afterwards, we conducted semi-structured interviews and qualitatively analyzed their feedback following the content analysis proposed by Mayring[14] along the dimensions of usefulness, correctness, completeness, and comprehensibility.

The MS projects had different scopes and addressed distinct services. Project A develops a service that shows which vehicles are in stock in a certain region to support point-of-sale representatives. Project B centralizes authorization and authentication management. Project C develops a remotely connectable infotainment service. Apart from project A, one CM primarily worked on the SRA of their respective MS.

Generally, the CMs of the projects remarked the SRT to be useful for MS projects, however their assessments differed. The SRT answers were assessed to be by the majority as correct but, due to the intention of generalization in some parts, too open for interpretation. Therefore, Project A and B had to adapt a number of the suggested template answers. Project A and C noted most of the SRT answers to be complete whereas project B did not disclose any information regarding this dimension. Both Project A and C suggested that more standards could be supplemented. All projects stated to have had initial comprehensibility concerns, which only projects B and C overcame after progressing through the SRAs. Project A's internal CM had difficulty comprehending the SRT's concept. The CM particularly noted that infrastructural components, such as the DE and ATP, could not give basic conditions and that the MS project must state them. The idea of reversing the operational readiness principle by providing restrictions and not asking for all eventualities was noted to be difficult to imagine. The external CM stated to have comprehended its intentional use, and noted that for proper usage, integration within the organization's agile tool chain is necessary for full potential benefit exploitation, as did the CMs of Project B and C. Based on the remarks, we adapted certain answers and provided additional filter features to make the document more usable. The conceptual idea behind the artifact was regarded to be primarily good and necessary by the person responsible for the SRA advancement and management to transform the current rigid process. By the time of writing, a mandate could be created based on the findings of this study, which promotes the advancement and implementation of the CDC within the organization.

CONCLUSIONS AND OUTLOOK

In this article we reported an empirical case study conducted with an automotive OEM. We investigated the question of how to transform the organization's software readiness assessment procedure to suit agile development methods. On a managerial level, we can learn from this study that deciding to implement a new architecture pattern to improve software development processes has far more reaching consequences than can be previously envisioned. Our study provides a foundation to the understanding of the implications an agile readiness assessment setup has. By identifying constructs and standards that all projects within an organization use, and further by deriving restrictions and developing the necessary SRA answers, an approach is provided that may be applicable to other kinds of software development projects. The novelty of this study is the provision of a transformation methodology by means of empirical data and the identification of impediments when trying to initiate its implementation.

This article can provide the background for future work on the transformation of agile SRA in operational procedures in broader terms. One starting point for future work could be a clear differentiation of software maturity levels, release readiness and software readiness assessments by providing definitions or characteristics of these topics. The current study could be expanded within additional software development projects, other than MS, generalizing the results to formulate comprehensive transformation frameworks. As our investigation has only been conducted with one manufacturing company, application within different organizations from different industries would be interesting and could extend learning, and even be a basis for future work.

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6 Conclusion and Future Work

6.1 Contributions

6.1.1 Strategic Dimension: Artefact 1

Research and Managerial Contributions

Concerning the strategic dimension of DT, the first study aimed at investigating how to topologically represent a DAE and identify its essential elements. Inspired by a practical demand from an OEM and then theoretically substantiated, it was identified that developing a DE around a digital service portfolio challenges manufacturers as it is unclear what constitutes these environments and how they are structured.

Primarily, the study's objective was to contribute to the body of knowledge of an analysis theory by analysing and describing digital automotive ecosystems (Gregor, 2006). To that effect, the DAE model contributes multi-disciplinarily to the body of knowledge in distinct areas of academic literature, such as DP (Thomas, Autio, & Gann, 2014), DE (Reuver et al., 2017; Sørensen et al., 2015), and to the empirical studies on stakeholder networks (Buchmann & Pyka, 2015).

First, the structure and scope of an industry-specific DE model was clarified upon by identifying relevant elements as well as the corresponding interdependencies (Reuver et al., 2017). To the authors' knowledge, this is the first visual representation of a structure of a DE related to the automotive industry. Thereby, the DAE suggests boundaries for a DE and structural layers (Adner, 2017), while considering that it is an open system that can integrate and connect with other DEs. It provides further insights into their explicit composition and structural interaction (Paulus-Rohmer et al., 2016), and adds clarity on aspects such as specifications and scoping of DEs (Sørensen et al., 2015) as well as constituting roles, relations and elements (Reuver et al., 2017).
Second, the artefact contributes to the debate differentiating platforms from ecosystems (Reuver et al., 2017). It allows for a better demarcation between these two theoretical concepts by clarifying central, constitutive elements and stakeholders of the latter as well as presenting the related layers within this dynamic network structure. Hence, each platform can be seen as a contributing entity for ecosystems so that each layer can contain a multitude of platforms (Adner, 2017), for instance, in the form of digital applications, service developments, data analyses and infrastructural cloud platforms. It is precisely this

topological structure that could be specified by the layered, conceptual model and thus enriches distinct areas of academic literature (Sørensen et al., 2015; Thomas et al., 2014).

Third, earlier research on the view of DEs as environments of collaboration and partner integration could be confirmed by the results of this study (Adner, 2017; Gomes et al., 2016). Fourth, on a company level, an OEM's decision-making process is supported as the DAE facilitates "where and how to allocate and align digital capabilities within their organisational structures" (Bilgeri et al., 2017, p. 2). It thus also demonstrates aspects necessary for the service fulfilment that nowadays exceeds existing capabilities and indicates areas in need of strategic collaboration, such as data analytics capabilities.

Fifth, the DAE contributes to the practical body of knowledge by providing a visual topology by which organisations can fill in themselves and identify the critical elements to provide the desired service. Thusly, it provides a starting point in conceptualizing digital service journeys and an understanding of the necessary requirements of backend processes, such as service integration, data analyses and cloud services. The illustration of the individual components, layers and relations facilitates strategic measures for focusing more precisely on specific platforms or selected technologies, therefore making it easier to identify the necessities or possibilities for external collaborations and partnerships (Chanias & Hess, 2016). Therein, the DAE also adds to the understanding of internal resource allocation and supports translating strategies into action-oriented decisions (Kohli & Melville, 2018; Ramaswamy & Ozcan, 2018).

Sixth, the DAE supports the analysis of the transformational path towards a customer-centric culture as it provides focused support by consequently placing the customer in the centre of the ecosystem and defining him as the point of origin for every digital service journey (Capon & Senn, 2017). As traditional mindsets and structures are seen as a major barrier of DT (Piccinini et al., 2015), this explicit representation provides a target picture by which an organisation can orientate itself to decrease these obstacles.

Finally, the study also contributes to the empirical body of knowledge on DEs (Weill & Worner, 2015), in particular, to the automotive industry (Bilgeri et al., 2017). The study was motivated by an OEM and intervened within the organisation in multiple iterations. The DAE adds knowledge regarding the role of quality gatekeepers within the composition and identifies its relevance in terms of content as well as technical dimensions.

6.1.2 Business Dimension: Artefact 2

Research and Managerial Contributions

Concerning the business dimension of DT, the second study aimed at supporting OEMs in the conceptualization of automotive SSs under consideration of relevant stakeholders. The development of digital services and the expansion of the corresponding BMs, challenges OEMs as these operations go beyond the organisation's present competencies and that of their suppliers (Schäfer et al., 2015). It is evident they are in need of modifying and expanding their skills (Pagoropoulos et al., 2017), building up digital service competencies (Dremel et al., 2017), and require incorporating new ways of collaboration into their value creation processes (Lusch & Vargo, 2014).

The second study's objective was to contribute to the body of knowledge to the explanatory theory (Gregor, 2006) regarding digital service conception specific to the automotive industry. In this context, the findings aim to provide explanations of why and how to conceptualise automotive SSs. Furthermore, the CRF contributes to the body of knowledge in distinct areas of academic literature, such as service science (Alter, 2017), automotive PSSs (Hess et al., 2016; Reim et al., 2017), and BM research (Bankvall, Dubois & Lind, 2017).

First, an extensive literature review was conducted from which digital automotive services were categorised for the substantiation of the conceptual reference framework. An initial set of essential areas of focus for automotive SSs displaying the respective stakeholders and infrastructural elements was created. By mapping the Business Model Canvas (BMC) to the SS domain, the practical applicability of SSs as a work system (Alter, 2017) could be strengthened and the concept's understanding extended with domain specific knowledge (Frost & Lyons, 2017).

Second, the study contributed to the automotive industry knowledge of OEMs as product-service solution providers (Freiling, 2015; Reim et al., 2017). Manufacturers are provided with a framework (Heikkinen, 2014) by which digital automotive services can be conceptualised. As the CRF was specially developed for automotive SSs (Frost & Lyons, 2017; Hoffmann & Leimeister, 2011; Massa et al., 2017), it could be shown that digital automotive SSs are networked businesses that require collaboration on multiple fields, such as digital infrastructure integration and physical infrastructure provisions.

Third, the study created an applicable instrument for the conception of automotive SSs as demonstrated by the evaluation results. Thus, the artefact satisfies the specific need for tools that give "strategic, functional and tactical directions for organisations to apply" (Gaiardelli et al., 2015, p. 1165). Relevant elements specific to the automotive industry were identified and described, facilitating OEMs in structurally ordering and managing them (Andreasen et al., 2015). By drawing on the CRF, relationships and dependencies between the intended service, the different stakeholders as well as infrastructural elements, are clearly defined. It is thus a tool for saving resources, such as time and effort, as well as for structured, analytical thinking.

Fourth, the framework provides support for manufacturers during their transitional process towards customer-centric thinking as the artefact places the customer in the centre of all service activity (Reim et al., 2017). Consequently, the artefact can support customer-centric value creation, as the CRF helps to keep the value proposition in focus with its structured presentation. The CRF structure can guide organisations to proceed systematically during the service development process, initiating from the service value that ought to be fulfilled. By demanding to consider active customer participation and designing the according points of interaction, the CRF also contributes to the demand for more customer integration into value creation processes (Schumacher et al., 2018). The CRF suggests usefulness in promoting consistent communication and keeping a customer-centric focus, while enabling organisations to build their service value proposition around it. The continuous maintaining and encouraging of this logic throughout the development of services, as compared to the predominantly product-centric perspective of manufacturing companies (Ng et al., 2012), is ultimately seen as a primary obstacle when transforming a company's processes (Baines et al., 2007).

Lastly, the CRF serves as a supportive instrument for communication within an organisation regarding service concepts and their specific configuration. The fundamental roles of technical, infrastructural elements in the framework of a SS can be illustrated by applying the artefact with its unique facets of industry characteristics and industry-specific dimensions being taken into account.

6.1.3 Process Dimension: Artefact 3

Research and Managerial Contributions

With regards to the process dimension of DT, the third study aimed to support an OEM with the transition of its software readiness processes to suit the agile software development methodologies applied by DevOps teams. Generally, the aim was to transform supportive backend processes already in operation to fit into an agile development approach. Thus, considering that DT affects all levels in the hierarchy of a company (Hess et al., 2016), this study looked at what DT means for the work processes dimension and what far-reaching, sometimes unexpected, implications arise when a company decides to become a solution provider.

The third study's objective was to contribute to the body of knowledge within design and action theory (Gregor, 2006) about agile software readiness approaches. During an empirical research study, a methodology was developed, the CDC, that allows an OEM's software readiness assessment to be aligned to agile software development. It thus contributes to the question "How to transform?" existing operating processes.

First, the CDC contributed to the body of knowledge with reference to agile development, by giving specific actions on how to dismantle a linear, rigid approach and make it applicable for agile software development, which was previously identified as a research need (Gimpel & Röglinger, 2015; Piccinini et al., 2015).
Second, the CDC provides OEMs with a methodological solution to support internal transformation processes by providing an empirically tested, practical tool, and thus extends the companies implementation capabilities and guides OEMs throughout this phase of the DT process (Bounfour, 2016; Hess et al., 2016; Lindgren et al., 2015; Reim et al., 2017). To exploit all new possibilities in the context of DT, the respective work processes at the organisational level must be adapted. A clear overview and methodology that supports OEMs with adjusting the organisation as exact requirements and components of agile SRA and MS architectures can be identified.
Third, the software readiness template (SRT) for MS projects simplifies the testing process and thus enables fast software product development. Thereby, the company's specific IT capabilities are enhanced. The study shows how the artefacts could be used to reduce the processing effort of the SRA, including the required flexibility inherent to agile development projects. Even if workflows must be changed, the developed procedure of reversing the readiness principle for infrastructural components allows for an easier integration into both the existing infrastructures and into the newly introduced agile toolchain.
Fourth, by identifying obstacles as well as unexpected effects of these implementation processes on the entire company beyond the IT department, companies are enabled in taking preventive measures. As "managers often lack clarity about the different options and elements they need to consider in their digital transformation endeavours" (Hess et al., 2016, p. 2), the study provides companies with an instrument to better master the challenges of DT.
Fifth, the study further shows that it is not enough for companies to simply decide to change their software development processes and merely initiate the shift towards agile development

or provide innovative technology. Studies 3 and 4 could show how integral such IT processes are to general business processes of, for instance, service design and value creation as well as the questions arising regarding managing and guiding a company in the midst of DT (Piccinini et al., 2015).

Sixth, studies 3 and 4 could substantiate findings of DT being a continuous and complex process (Matt et al., 2015) that affects many sections within an organisation (Hess et al., 2016). As software development methodologies shift towards agile, SRA procedures must transition as well. The methodology outlines a way to integrate software readiness assessment processes into agile development processes and lies the foundation for continuing research on the transformation of agile SRA in operational procedures in more broader terms. Following the conceptualisation of digital services, the artefact provides a practical approach by which to propel the actual service delivery process by adapting an organisation's backend processes already in operation.

And finally, the study in general contributes to the knowledge on how to adapt an organisation's SRA processes to suit novel digital technologies and agile development approaches. More specifically, the studies add to the empirical body of knowledge regarding the introduction of agile methodology within an organisation (Piccinini et al., 2015).

Thus, the rather abstract, complex processes of the DT of a company could be broken down by this empirical study and the general problem of the adaptation of operational procedures specified. Even though it might still be a long way before an agile software assessment discipline (Nierstrasz & Lungu, 2012) will be established, this study brings it one step closer.

6.1.4 Synthesis of Contributions

The central contributions of the individual studies were discussed in this chapter, the three artefacts are related to each other hereafter. This thesis started from the overarching problem that not enough applicable tools are available for OEMs to carry out the DT process within their organisations. The aim of this dissertation was to work on a better understanding of these changes and challenges, as well as to clarify implications concerning DT. The research results aim at providing DT knowledge from the conception of a strategy to its translation into actionable outputs as the implementation of respective processes, as can be seen in the overview in Figure 15.

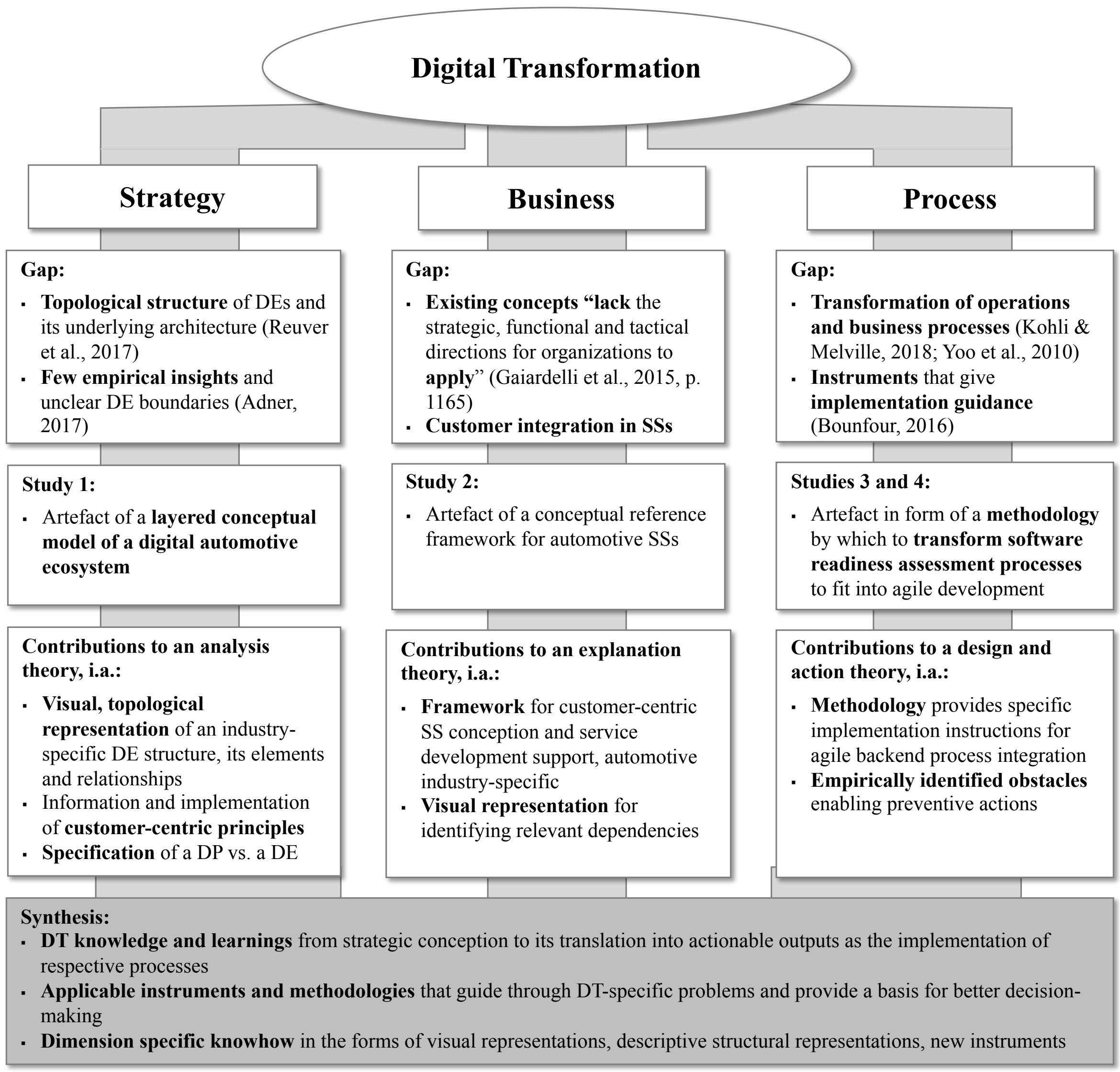

Figure 15: Overview of contributions

Further, researchers and practitioners are provided with applicable instruments and methodologies to guide them through DT-specific problem statements, and a basis for better decision-making. Each study partially contributes to this, but the conducted analyses and developed artefacts should not be understood as temporal processes or as mandatory successive steps with a causal, presupposed sequence of events. Rather, it is the case that DT affects different organisational dimensions entailing various possibilities and risks.

By means of the four studies, the OEM's ability to provide digital services was supported in all three dimensions as they deliver specific know-how and instruments in the forms of visual representations, descriptive structural representations, new instruments, and, as a special form of knowledge, also provide indications of obstacles and problems that can occur during the transformation process.

At first, manufacturers explicitly need strategic knowledge upon which they decide on a plan to align and shape future business activities. The conceptual model of a DAE enables manufacturers to provide a starting point for digital alignment, for identifying digital fields of focus and of necessary collaborations and partnerships. Ultimately, strategic decisions impact an organisation’s business activities by enhancing, transforming or reshaping its BMs. Based on the strategic decision to develop digital services, the CRF provides specific explanations on how to conceptualise automotive SSs from a customer-centric point of view (Kohli and Melville, 2018). The artefact proposes the solution of customer integration in value creation activities by explicitly demanding the investigation and design of the points of interaction and the desired degree of involvement (active vs. passive). Having conceptualised digital services, they need to be developed and assessed regarding its readiness, which respectively affects an organisation’s operational processes. The provision of an actionable methodology that was developed within a practical case setting, contributes to establishing new organisational routines. Therefore, the CDC and SRA of studies 3 and 4 provide support to enhance an organisation’s IT (Hanelt et al., 2015), and extend its implementation capabilities (Kohli & Melville, 2018).

In the context of changing the organisation’s work process and strategic realignment during its DT, it is necessary to bring about an open-mind and even establish a lean start-up mentality of failing fast and developing MVPs (Piccinini et al., 2015). All four studies could contribute to this aspect of change and to the maintenance of keeping up the novel logic.

All studies contributed to improve an organisation’s reactive and preventive abilities (Kahre, Hoffmann, & Ahlemann, 2017). These dynamic capabilities concern internal work processes as described above, e.g. ensuring flexibility in work processes (see studies 3 and 4), but also processes between an OEM and its environment, e.g. the ability to react quickly to altered customer requirements with a new service (study 2). The DAE (study 1), in turn, supports OEMs with their strategic orientation in balancing the different development speeds of the digital and traditional worlds of physical goods, i.e. agility versus stability, and thus serves specific ambidexterity capabilities (Piccinini et al., 2015). Studies 3 and 4, by empirically identifying DT obstacles, extends the scientific knowledge in this respect.

In total, the four studies address the identified research gaps in an effort to support OEMs during their DT process towards product-service providers, as well as contributing to the advancement of integrated product-service solutions by providing decision-makers with specific knowledge in different dimensions that affect one another. The different types of knowledge can be subsumed under decision-making aspects that significantly support the leading qualities (Kahre et al., 2017). Managers must have the willingness and ability to listen to employee's feedback, who are able to report problems first hand. A general ability to cooperate is therefore not only necessary at the execution dimension between organisations, which is supported by the contributions of studies 1 and 2, but is also important when departments are coordinated, responsibilities are redistributed, and any hierarchies within are reconsidered and revised. Thereby, the studies as a whole also contribute to the promotion of a corresponding learning culture among employees and managers (Kohli & Melville, 2018) that fundamentally increases the acceptance of new instruments, methods, and improves attitudes towards new approaches.

6.2 Implications

6.2.1 Scientific Implications

The DAE, as a layered conceptual model, can be further substantiated with regards to DE roles, e.g. the role of governing actors who fulfil curating functions in terms of quality and content (Uludağ, Hefele, & Matthes, 2016). These governing actors could potentially more precisely define what an ecosystem is constituted of, and thus its boundaries. If applied in future empirical research, the DAE can provide analytical consistency allowing the differentiated exchange and comparison of research work with regards to DE structures. The suggested boundaries could be disproved, confirmed or extended, thus further substantiating scientific knowledge in this area (Adner, 2017).

As "DT strategies serve as a central concept to coordinate, prioritise, and implement firm's digital transformation efforts" (Chanias and Hess 2016, p. 1; Matt et al., 2015), the DAE as a manifested artefact, could support research in making DT strategies more palpable.

Following SDL, customers are contributing actors in the service creation process. Though the concept is not new, the literature study on automotive SSs could demonstrate the importance of assimilating these findings into digital service conception, as the notions of customer involvement and value co-creation in the manufacturing domain are not proficiently implemented. It suggests that customer involvement as a theoretical concept in the automotive industry is not practically considered. Hence, this research considers it logical to arrange SSs for manufacturers around the customer's value proposition. In this context, the role of customers could also be specified when discussing the theoretical concepts of customer centricity and customer involvement (Schumacher et al., 2018; Veit et al., 2014).

The BMC is used as an instrument, a unit of analysis as well as a framework, and serves as an intermediary between a company's strategy and its underlying business processes (Veit et al., 2014). By mapping the BMC elements to the SS domain and developing the CRF for automotive SSs, the aim was to build a bridge between practical applicable instruments and theoretical concepts that capture the interdependencies between stakeholders. From a customer-centric perspective, artefact 2 delivers service values that can only be achieved if collaboration and interaction is optimised, which in turn, is another field of research.

Previous studies on DT have focused on current challenges and the identification of necessary fields of action (Baines et al., 2009; Gimpel and Röglinger, 2015; Bounfour, 2016). It was suggested that operational procedures need to be adapted, but methods that support their execution have been scarcely researched. Building on these findings, studies 3 and 4 present a methodology on the operational level derived from an empirical case and the findings, if applied within different case environments, could consolidate the identified demand (Gimpel & Röglinger, 2015).

The application of artefact 3, the CDC, indicates the importance of management's role "to carry the digital transformation of [a] company because it affects the company strategy" (Henriette et al., p. 5). It became apparent that strategic DT decisions lead to procedural conflicts within an organisation and have far reaching implications on different levels. Consequently, it is not possible to continue working in accordance with old logic and its static workflows and routines, since these collide with the current requirements of speed and flexibility.

Further, the research on agile SRA is still in its infancy but gaining importance (Nierstrasz & Lungu, 2012). By identifying constructs and standards that all projects within an organisation use, and further by deriving restrictions and developing the necessary SRA answers, an approach is provided that may be applicable to other kinds of software development projects.

All studies demonstrate the challenges an organisation in the process of DT faces, such as having to expand its skills in new and diverse areas, renewing its knowledge, and discarding outdated ways of thinking. Additionally, the resulting consequences that arise from the decision to become a solution provider challenge an organisation's operational procedures as transformation is a process that stretches over time. This research helps with gaining a fundamental understanding of the stakeholders of digital automotive networks and the dependencies of DT activities. The findings endorse previous works on DT which conclude DT to be a phenomenon that affects all areas within an organisation (Hess et al., 2016).

6.2.2 Managerial Implications

By using the DAE model, companies are supported in DE scoping and development. As the competitive pressure for incumbents increases (Piccinini et al., 2015), the need for explanatory and analytical instruments that support them in defining successful strategies is evident as illustrated by the research demand from the underlying case company. The DAE model was able to support them in their initiative to build DEs themselves, potentially helping them remain competitive in the long run.

By applying the DAE model, OEMs can potentially expand their abilities in the areas of external attention and entrepreneurial alertness (Kohli & Melville, 2018), as the conceptual model is a descriptive presentation, highlighting the important elements of stakeholders and technical conditions as well as their respective relationships. Thus, decision makers using the DAE gain the opportunity to better assess their competitive environment and potential opportunities for portfolio expansion. By filling the respective layers, they can scope and define commercial fields of action.

OEMs intending to operate in the digital market must assess which platform they aim to manage themselves, which respective technologies must be put in place, which capabilities to acquire and integrate, and what strategic partnerships to potentially initiate. Thus, the DAE model may broaden OEMs' views as decision makers are enabled to grasp the significant relationships between stakeholders and then convert this knowledge into value co-creating measures. The DAE could help turn management's focus towards the need of integrating their value propositions within customer journeys and carrying out an integration-based approach in setting up their strategy. The DAE has proved to be a useful instrument in imagining and designing service journeys starting from the customer's specific demand, down to the adjustment of necessary back-end operations.

Moreover, OEMs applying the DAE and thus classifying their current value proposition within the context of the entire value chain, can better detect what respective capabilities must be built for the service fulfilment process. Additionally, they could more consciously alter their strategic alignment and take a step towards becoming a product-solution provider (Hess et al., 2016).

Additionally, the model highlights the decisive role of quality gatekeepers during the whole service delivery process, since through these access points curated content is approved. An OEM as the producer of a physical platform infrastructure, i.e. the vehicle, could profit from its role and consequently leverage its brand in the digital sphere with the strategic implementation of quality gatekeepers. An example would be the provisioning of digital lifestyle experiences by a sports car brand. As vehicles, and physical products in general, are in the process of being commoditised, the assets offered by a brand are going to be a decisive factor in striving for digital experiences.

The application of the CRF could contribute to an OEM's DI processes as it supports scoping for promising business opportunities (Kohli & Melville, 2018). By using the CRF, OEMs could more clearly and quickly identify new areas for value creation throughout the course of conceptualizing digital services, and initiate a service-based BM. Eventually, the CRF could even be applied to the supplier industry as the practical workshop study has indicated. By following the guided representation through the CRF, OEMs could manage arising complexity in "handling the many composed elements related to need, context, intention, possibilities, etc." (Andreasen et al. 2015, p. 33).

OEMs can especially profit from applying touchpoint design within their business activities. As vehicle information systems and digital interfaces become more important as a channel of digital service provision, touchpoints and UI design are a promising field for differentiation and the maintaining of customer relations. Managing these links is therefore essential for a company. As the CRF adopts a customer-centric perspective, companies could be enabled in managing these aspects accordingly. As customers expect seamless experiences throughout the transition from analogue to digital applications, organisations desiring to meet these expectations could prevail in digital markets.

OEMs relying on the CRF are prevented from falling back into antiquated mindsets of sole product-centric thinking. Thus, the CRF could contribute to overcome the obstacle to focus on the customer during value creation activities (Capon & Senn, 2017).

OEMs using the CDC for their SRA could be able to manage their processes in a manner that meets the requirements of agile software development, supporting flexibility and speed. In the end, these abilities will make them more competitive, especially with their new rivals as IT-firms entering the market have already adopted these working modes. Thus, by following the proposed methodology and translating the results of studies 3 and 4 into concrete measures, OEMs could be in a better position to master the challenges of DT processes.

Therefore, companies are put into the position of potentially taking preventive measures as several obstacles blocking the implementation have been identified. Just deciding to implement a new architecture pattern to change software development processes has more far reaching consequences on the organisation than was previously envisioned.

All studies are united by their applied character. The objective was not only to provide situational descriptions and analyses, but to also identify opportunities for companies to improve. In providing industry-specific artefacts in each study, OEMs could be enabled to process the digital actions associated with the artefacts more effectively and more efficiently. The evaluations indicate the usefulness of industry-specific methods and instruments. Often the dimensions associated with them, e.g. service value, safety and experience, could be more easily translated into meaningful ideas. Hence, OEMs could foremost save resources in the form of effort and time using the artefacts for structuring and analyses.

As motivated in the introduction by the research on industry life cycles (Klepper, 1997), organisations must be able to handle changes proactively and should not just react to processes enacted by their competitors. In other words, organizations should be quick and efficient during change, thus strengthening the aim of the motivated artefacts. A fundamental change in attitudes, working routines, habits (Kohli & Melville, 2018) and supporting backend processes, plays a central role with the success of these measures being largely dependent upon all involved departments supporting the decision and cooperating during its implementation. A corresponding change of mindset must take place among employees and decision-makers, and further be reflected during implementation. Only then can the potential of agile product development be fully exploited. Unfortunately, employees are always in danger of falling back into traditional mindsets and not being able to adapt to the "digital world" (Piccinini et al., 2015, p. 14). Many companies in the process of digital transformation have problems in adapting to and accepting this unique process of DI/DT and are merely relying on their competencies in managing traditional IT (Piccinini et al., 2015), considering IT processes as subordinate to business processes (Kahre et al., 2017).

Also, strategy, business, and processes should not be independently managed in the course of DT. The findings of previous studies suggest IT, and therein DT, impacts an organization on multiple dimensions. If organizations decide to realign themselves, the greatest leverage can be achieved by synchronising the planning with future revenue models and specific implementation initiatives. Following, an example is given to illustrate how artefacts 1 through 3 can help an OEM to better manage its transformation process in the strategic, business and procedural dimensions.

6.2.3 Intelligent Parking Service Example (ParkSpotHelp)

The example shall demonstrate the interaction between the three artefacts and the additional value they collectively generate. In the example, it is assumed that an OEM plans to develop an intelligent parking service, branded "ParkSpotHelp". The service aims to improve the search for a parking space as it displays in real-time available parking spots and their limiting conditions, for instance, how long a vehicle can stay for free in a specific location, etc. ParkSpotHelp runs as an application on both mobile devices and on a vehicle's information system.

On the strategic level, the OEM will likely decide to offer digital services as this entails the development of respective products and the investments that must be made, among other things. In addition, the OEM not only desires to invest in offering such services, but to also build up a portfolio of digital services that will be provided via a platform. Thus, the OEM gets direct customer contact and advances his business activities. Ultimately, the organisation desires to develop a digital ecosystem, where it can build and maintain customer relations beyond the point of sale. The OEM intends to manage and operate this environment, a scenario that was practically experienced within the case company of study 1.

Using the DAE model (artefact 1), it becomes clear that the customer is the origin, or hub, of the ecosystem. The DAE illustrates that customers go through customer journeys by which the OEM must best integrate itself with its ecosystem. Therefore, the ParkSpotHelp service could also include functions that can be linked to other services such as having third-party advertisements, e.g. from retail stores.

To provide ParkSpotHelp, various backend (not customer facing) services would need to be implemented and would be categorised within the levels service, data, and infrastructure. ParkSpotHelp would need to be developed on a service development platform and integrated into both the OEM's systems as well as third party systems within a service integration layer. If the service functions as part of a composite service chain, such as the booking of an event ticket along with the reservation of a parking space near the venue, the service needs to be coordinated with other services. For ParkSpotHelp to work in real-time, data would need to be analysed and compiled within the respective platforms. In this regard, the OEM could leverage its position as the gatekeeper of vehicle sensory data, that is, a vehicle's sensors would detect free spaces and congregate this data into a platform where the data of all vehicles under that brand is collected. This amount of data, if rightly analysed, could to a certain accuracy indicate real-time parking spaces at shoulders within urban areas. Ultimately, infrastructural conditions must be met as well, which is the provision of cloud platforms or bandwidth over which the large amounts of data would be sent. ParkSpotHelp could be accessed via a variety of channels, the vehicle being just one. Thus, the DAE clarifies a fundamental paradigm of the digital world that the customer is the centre of all value-creating activity and not the product. The DAE illustrates the complexity of such a service and supports decision-making regarding their IT development, resource alignments and the necessary partnerships.

On the service conception level, the CRF (artefact 2) could be a useful instrument in the designing of ParkSpotHelp from a customer-centric perspective, as it is centred around the service value, i.e., the perceived customer value. In the example of ParkSpotHelp, the first question that needs to be answered is how to communicate the service value to the customer. For example, customers are to be spared a lengthy, time-consuming search, so the focus is on saving time and possibly money, i.e. increased "Comfort & Convenience". But a value promise is also fulfilled regarding the category "Emotion & Experience" if the customer is spared stress.

In the following, the question arises as to how the customer can be involved in the value creation process. Customers could provide the vehicles' location data without being actively involved, representing passive participation. Data can be displayed in real-time only if enough users agree to pass their data while driving. Another option would be that the customer actively involves themselves by sending free space data to the app. A similar example is the reporting of speed traps. The OEM must consider both communication possibilities in the design of the service as respective points of interaction, or customer touchpoints must be provided. These touchpoints, in turn, also represent interfaces of which the customer and participating stakeholders can access necessary infrastructures, e.g. telecommunications service providers, the service platform, the vehicle itself, etc. The CRF displays relevant dimensions for the service development of digital automotive services and provides constructs to be considered for the service design.

Now, after having conceptualized the service, it needs to be implemented. The OEM only releases service functions if certain quality criteria are met. As many organisations have switched to agile software development, or are expected to do so in the future, the quality assessment processes, or software readiness assessment processes, must be integrated in these approaches as well. In doing so, the OEM enables continuous integration and delivery, or in other words, regular innovations in accordance with agile principles. Innovation speed is a critical success factor in the digital world that not only enables fast development needs, but also the quick processing of the developed increments within the company. With the CDC (artefact 3), an instrument is available to adapt the SRA to the requirements of fast development and continuous integration without compromising on quality criteria such as adhering to the functional and non-functional requirements.

In total, all artefacts contribute to the successful implementation of DT initiatives and right decision-making. As the example illustrates by means of the service journey, DT is a complex undertaking. By no means shall it be suggested the artefacts as being the sole solution to all, or the majority of, challenges connoted to each dimension. They are instruments of support that must be seen in context and that could prove to be useful during a manufacturer's DT when trying to save resources in terms of time, investments and possibly even when generating improved ideas or concepts.

6.3 Concluding Remarks

6.3.1 Threats to Validity

The results of this cumulative dissertation are subject to certain limitations. For the literature analyses of studies 1 through 3, only selected parts on the topics DT, automotive SSs, and DEs could be included. Despite the careful examination of the samples, the results obtained in each case are subject to a restriction of choice and correspondingly limit the scope of this research.

As all studies involved practical exposure during the evaluation, for instance interviewing practitioners (studies 1 through 3) and validating the artefact by means of development projects (studies 3 and 4). Though particular attention was paid to balance and diversity from different affected areas, the selection and sampling size of interviewees as well as the development projects impact the data collection and thus influence the derived outcomes.

Studies 1, 3, and 4 involved research partner organisations. As is typical for case study methods research, not all variables could be controlled, thus complicating replication (Recker, 2013). Artefacts 1 and 3 were involved in only one corresponding organizational context. Choosing different partners, or accessing more partners, could have resulted in different expressions of the CDC and DAE accordingly. Although exhaustiveness was attempted in the contextual description and setting, the question of transferability to other companies or entire branches of industry must be considered with care.

Even if the chosen methods proved to be suitable and led to informative results, it cannot be excluded that other or extended results are possible by choosing other methodologies. To address these limitations, further research on DT is strongly endorsed within the automotive industry and, further, in other manufacturing industries as well.

6.3.2 Outlook and Future Research Recommendations

Across all studies it could be observed that DT affects a multitude of different processes and dimensions. Within this research, a manufacturer’s strategic orientation, stakeholder-integrated digital service development, and its procedural transformation under an existing operational infrastructure was investigated. By studying distinct dimensions, an attempt was made to derive overarching findings and statements. Nevertheless, these considerations are not all-encompassing and future research could tie in with the results achieved here in the following areas:

As digital services “are closely related to and rely on ICT”, it remains to be investigated on how these technologies can be systematically used to stimulate service innovation (Stoshikj, Kryvinska, & Strauss, 2016, p. 219) and facilitate collaboration for these networked businesses (Akaka and Vargo, 2014). Therefore, it would be desirable to extend the corresponding analyses to other industries outside the automotive realm, thus not only validating the applicability of the artefacts within different contexts, but also to derive industry specific criteria (Piccinini et al., 2015).

The CRF could be extended or specified to gain more insights on networked value co-creation and customer centricity. It could thus be turned into methods and applicable artefacts that facilitate communication for manufacturers that increasingly turn towards the development of digital product-service offerings. Differences and commonalities could also be determined, and the concept further developed by means of the application of the CDC within the framework of the SRA in other companies and industries which assume different conditions of software development and work routines. The application to other manufacturing industries would also provide additional insights for the DAE model and supplement its structure.

These findings can provide the background for further research on the transformation of agile SRA in operational procedures in more broader terms. Further investigation on how methods can be used and applied in existing maturity assessment methods, that is, the existing operational infrastructure of an organisation, is needed. Researchers even call for an agile software assessment discipline (Nierstrasz & Lungu, 2012).

Beyond this, future research could be devoted to a concretisation of the respective theoretical concepts: both regarding the terminological work in relation to software maturity, release readiness and software readiness assessments, but also to the further differentiation of digital platforms from digital ecosystems.

Even if the results of the four studies presented here have already made it possible to provide practical support, there is an expanding need for research on suitable instruments and the methodology of managing complex transformation processes.

Though it was not a focus of this investigation, the question of transformational capabilities could be posed even more strongly across studies, regarding both the introduction and control of the corresponding platforms within an ecosystem.

It would be highly encouraged to build on the findings within the strategic, business and process dimensions, and to substantiate these areas of research and practical interest.

Finally, it must be noted that potential beneficiaries of this study are not all automotive OEMs to the same degree, but those which aim to operate digital markets. Vehicles as a means of mobility and as a carrier of mobility-related services will remain important. In addition, in many regions in the world, both in industrialised and developing markets, vehicles will remain status symbols. So, digital services are seen to be a complementary way to enhance an organisation's BM portfolio in the prevailing current ownership model.

However, the commoditization of vehicles is progressing and highly industrialised areas, such as metropolitan centres, make innovation necessary as introductory motivated. In the long run, these innovations ripple down, spread throughout and permeate other areas as many industries that have already went through similar phases have revealed. As Lenfle and Midler (2009, p. 2) point out, "Servitization does not lead to an eradication of physical goods, but rather an enlargement of value, with the opportunity to monetise this by new business models."

Appendix

Appendix A: DAE Interview Guideline

Interview Topic	Question
Personal Information:	1. Would you please introduce yourself, as well as your company? What position do you have in the company?
Automobile Service Ecosystem:	1. How do you rate the future potential of the following value-adding dimensions of digitized automobiles? Value-adding Dimensions: Vehicle (Physical Product) - Sensors and Actuators - Connectivity - Data Analysis - Digital Services
	2. How / by which way will digital services be offered to customers according to your judgement (B2C as well as B2B)?
	3. Do you believe that access to the development of digital services will be open or closed? Why do you believe this?
	4. Which market roles will emerge in the course of the realization of automotive service ecosystems? Which role(s) will vehicle manufacturers occupy? - Importance of the role - Task spectrum / activities - Relationship with other market participants - Business model
Transformation Approaches:	1. What effects does digital transformation have on current OEM's business?
	2. How do you assess the impact of the following factors on transformation success to service-dominant business models? Factor: Organizational structure, Organizational culture, IT ability, Business processes, Perception of the firm's value proposition, Management, Market share and segment, Regulatory conditions, Data protection, Other
	3. Do you know approaches / methods for the transformation of business models? If yes, please name and describe them.
Requirements of Automotive Information Systems:	1. What role do information systems play in digital transformation? How should these be designed?
	2. What IT requirements must be met for the development of automotive service ecosystems?
	3. What are the challenges faced by car manufacturers in this context?

Appendix B: DAE Denomination and Distribution of Elements and Concepts

Concepts	Elements	# of times Concept Appears Overall	# times Elements Appears Overall	# of codes per Concept	# of codes per Element	# of Interviews Concept Is mentioned in	# of Interviews Element Is mentioned in	Variance	Standard Deviation
Data Analytics		56		29		20			
	• Artificial Intelligence		1		1		1	0,04	0,20
	• Big Data Services		7		3		7	0,20	0,45
	• Data Analysis Services		33		18		14	1,39	1,18
	• Insights Services		9		4		9	0,23	0,48
	• Processing Services		6		3		6	0,18	0,43
Data Compilation		105		48		22			
	• Customer Data		5		4		4	0,24	0,49
	• Data Platform		11		4		7	0,81	0,90
	• Data Safety & Security		38		13		14	2,03	1,42
	• Data Supplier Services		10		7		7	0,48	0,69
	• Environmental Data		9		4		8	0,31	0,56
	• Third-Party Data		5		4		4	0,24	0,49
	• Vehicular Data		27		12		15	0,58	0,76
Digital Service Applications		133		42		25			
	• Complementary Services		17		5		13	0,62	0,79
	• Connected Life Services		21		8		14	0,66	0,81
	• Entertainment		4		3		3	0,21	0,46
	• Mobility Applications		24		12		13	1,25	1,12
	• MobilityaaS		67		14		22	2,58	1,61
Enabling Applications		18	18	10	10	8	9	1,08	1,04
Cloud Infrastructure		4		4		3			
	• Cloud Infrastructure: Cloud aaS		4		4		3	0,21	0,46
Telecomminication Infrastructure		20		6		11			
	• Telecommunication: Connectivity		3		3		2	0,19	0,43
	• Telecommunication Network		17		3		9	1,04	1,02
Other Devices		10	10	4	4	6	6	0,38	0,61
Service Development		341		121		25			
	• Data Safety & Security		23		9		13	1,39	1,18
	• Digital content		129		49		25	4,11	2,03
	• Brokering Services		45		19		20	1,51	1,23
	• Delivery Services		76		22		1	1,01	1,01
	• Market Services		68		22		3	3,28	1,81
Service Integration		108		62		24			
	• Back-End Layer		33		17		19	0,93	0,97
	• Front-End Layer		16		11		9	0,81	0,90
	• Integration Layer		59		34		19	3,72	1,93
Service Orchestration		62		18		25			
	• Composite Services		20		5		13	0,72	0,85
	• Connected Services		42		13		19	2,24	1,50
Smartphone		36	36	14	14	15	15	1,49	1,22
Vehicle		66		20		24			
	• Autonomous Driving		38		3		18	1,10	1,05
	• Connectivity		25		15		15	0,83	0,91
	• Personlization		3		2		3	0,11	0,32

Appendix C: DAE Denomination and distribution of stakeholder

Stakeholders	# of times Concept Appears Overall	# of Interviews Concept Is mentioned in	Variance	Standard Deviation
Customer (B2C, B2B)	6	6	0,18	0,43
Data Providers	2	2	0,07	0,27
Digital Product Owner	1	1	0,04	0,20
Infrastructure Operator	2	2	0,07	0,27
Infrastructure Provider	5	4	0,24	0,49
Intermediaries	1	1	0,04	0,20
Neutral Infrastructure Manager	1	1	0,04	0,20
OEM	14	11	0,49	0,70
Physical Service Provider	2	2	0,07	0,27
Platform Operator	6	4	0,34	0,59
Platform Provider	7	7	0,20	0,45
Quality Gatekeeper	5	3	0,40	0,63
Regulator	1	1	0,04	0,20
Service Broker	2	2	0,07	0,27
Service Developer	5	4	0,24	0,49
Service Integrator	3	2	0,19	0,43
Service Orchestrator	2	2	0,07	0,27
Service Provider	15	13	0,40	0,63
Supplier (1st & 2nd Tier)	2	2	0,07	0,27
Supportive / Secondary Service Provider	1	1	0,04	0,20
Telecommunication Provider	4	4	0,13	0,37

Appendix D: Literature categorization in accordance to the identified constructs

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
Bengler et al. 2014	- State-of-the art of DAS[1] and future research fields	- DAS	Assistance	Society, Drivers, Road Participants	- Service Provider; driver; supplier; 3rd party beneficiaries; service provider for V2V[21] communication; traffic participants; OEM	- Vehicle; communication infrastructure; sensors; information, DAS	- DAS goal provide active and integrated safety; intelligent transportation for an efficiency increase	- Driver as the trigger of the DAS	- Vehicle; in-vehicle display and projections (virtual interfaces); infrastructure that provides sensor data
Bohnsack et al. 2014	- Exploration of the evolution of business model development between incumbent and entrepreneurial firms	- General consideration of movement to service-based business models by means of EVs[2], e.g. battery leasing etc.	Resource Efficiency	Society, Incumbents, End Customer	- OEM; supplier (battery provider e.g.); financial service provider; driver; dealer; swapping service station provider; charging grid operator	- Battery; EV; virtual application; mobile phone; communication infrastructure; grid	- Intelligent transportation through car-sharing and increase in mobile sustainability; comfort & convenience, when charging at home; battery swapping (technology enabler services) financial service systems	- Customer involvement in the service usage; customers may appear as service providers for grid balancing, when charging at home	- Vehicle; mobile applications; infotainment system; service personnel; financial services; dealer who can change the car; battery swapping personnel
Dai et al. 2016	- Exploration of RTIS[2] system between vehicles and RSU[3] for vehicular networks	- Temporal information service system with RSU and RTIS; real time location-based services and routing services; autonomous intersection control; in-vehicle infotainment; efficient data services; media services; vehicle-assisted temporal data service	Multiple	Drivers, Information Service Consumer	- Communication infrastructure providers; OEM; drivers; service provider; RSU provider; platform provider or providers	- Vehicular information, sensors; application layer; virtual applications; network layer; MAC layer; RSU infrastructure; communication infrastructure	- Safety of vehicular networks; efficiency and sustainability gains of intelligent transportation systems	- Driver participation in a service network through vehicle movement	- Navigation system in the vehicle, which driver interacts with
Gusikhin et al. 2007	- Overview and a sampling of AI usage, soft computing and other intelligent system technologies in the automotive industry	- IVS[4] as optimal vehicle operation services; neural-network-based virtual sensors; speech recognition; proximity recognition; OBDs[5] and prognostics	Safety	Driver, Passenger	- Supplier; OEM; driver and / or passenger; 3rd party road user; service technician; engineer	- Vehicle; diagnostics and prognostics information technologies; Spare Parts; Repair space	- Increase in safety, intelligent transportation and comfort and convenience	- Driver triggers IVS actions when moving the vehicle	- Virtual interface of VIS[6]; service personnel for diagnostics

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
Einkorn and Müller 2012	- Investigates possible car-sharing strategies through interviewing Car2Go Users	- Mobility service provider; sharing service	Resource Efficiency	OEMs, Car Sharing Consumers	- OEM; service provider; communication infrastructure provider; municipality as space provider; driver or service user	- Vehicle; Service platform; Public parking areas in cities; Mobile application	- Car sharing as a form of intelligent transportation; Economic and ecologic benefits; Comfort and convenience regarding maintenance, repair or parking	- Active participation in the service system	- Website; personnel through a customer hotline; virtual interface via smartphone applications
Frey et al. 2016	- Promotes the role of a software architect for the successful development of connected vehicles	- Telematics services such as door lock functions; in-car parcel delivery; car sharing; concierge services	Comfort & Convenience	Driver and passengers; OEM business units	- Driver and passengers; suppliers; OEMs; service operators; back end provider; software architect	- Vehicle; IT; Backend systems, e.g. cloud; mobile applications; communication infrastructure	- Connected vehicles for safety, intelligent transport, comfort and convenience, security, e.g. remote door lock function	- Not specifically mentioned, but depending on the service a spectrum of potential forms of collaboration	- Virtual interface over mobile devices (tablets, smart phones); service personnel; physical environment via the vehicle
Gao and Zhang 2016	- Business model review of the car sharing economy in China	- Car sharing or ride sharing	Resource Efficiency	Car sharing consumer	- Mobile device manufacturers platform operators (Uber); mobile network operators; governmental regulatory agency; third party partners: investors and competitors; legislators	- Vehicle; platform; ICT[7] infrastructure, mobile phones, mobile applications; stores; staff for promotion	- Car sharing for intelligent transportation	- Active participation of customers is the foundation of the service	- Virtual interface via apps on mobile devices; physical environment, e.g. supermarket stores for promotion; service personnel in the stores
Guériau et al. 2016	- Discussion of Cooperative Intelligent Transport Systems (C-IST) for traffic management	- Advanced Driver Assistance Systems (ADAS); information exchange with the infrastructure; traffic management; traffic monitoring; provision of real-time info.	Assistance	Drivers, Road Participants, Society	- Service providers; technology suppliers; infrastructure providers; driver; OEM; driver; 3rd party customer, e.g. municipality	- IT Systems; Vehicle; RSU; Real-time information; ADAS technology	- C-IST fostering intelligent transportation and navigation through traffic management; ADAS provide safety	- A spectrum of potential forms of collaboration; driver as the initiator of the service system	- Vehicle; virtual interface on traffic information systems

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
Harvey et al. 2011	- Review of IVIS[8] in the context of task–user–system interaction; proposal of a modeling framework	- IVISs as the basis of secondary functions that enhance the driver experience; article talks about IVISs functions, which can be viewed as services in some regard	Driving Experience Enhancement	Users of IVIS	- OEM has content sovereignty; IVIS builder as the supplier; software provider	- Vehicle; IVIS technology; Communication infrastructure; staff; mobile phones	- IVIS ensure safety by providing relevant information without driver distraction, enhance vehicle efficiency and provide convenience functions	- Customer interacts with the IS to retrieve services, thus providing information to the system	- Vehicle as the physical interaction environment; virtual interfaces; Auditory via phones; Via staff through human beings
Hoffmann and Leimeister 2011	- Introduction of a design framework to systematically develop automotive services	- Several service systems covered: mobile software-based services; personalized news service; collection of brokerage fees for content displayed in the car etc.	Individualization	Automotive Service Providers	- Service system network partners; basic technical infrastructure for mobile business; network operators; content providers; OEM; customers as driver and passengers	- Mobile phones; Vehicle; Information (e.g. for news service); Communication Network; Software	- Software-based systems for safety and security; on-board navigation promoting intelligent transportation	- Customer actively involves when personalizing services	- Vehicle, virtual interface via mobile devices; personnel on hotline
Hung and Michailidis 2011	- Introduction of an electric vehicle service system modeling framework	- Charging station infrastructure deployment	Accessibility	Electric Vehicle Operators; Electric Vehicle Manufacturers	- Charging station operators, drivers or vehicle owners; EV manufacturers	- EVs; batteries; charging station; mobile phones; mobile application	- Minimization of the overall routing costs for EV drivers, such as travel time/distance	- Driver shares GPS real-time data of the EV location	- EV charging station; applications for real-time service information
Juehling et al. 2010	- Introduction of an integration framework of service and technology strategies	- After sales services	Resource Efficiency	End customer	- Customers; OEM; distributors; suppliers; staff; legislators	- Vehicle; Mechanic / technician performance; Legislative actions; real-time information; spare parts	- No particularly objective specified, but rather an approach for the industry to integrate services	- Customer initiates the service and mechanic order	- Via dealers; IVIS
Kakkasageri and Manvi 2014	- Review on information management techniques of vehicular ad hoc networks (VANET's)	- Distinction between driver services, passenger services, information services and public services	Intelligent Transport	Drivers, Society	- OEM; customers; sensor suppliers; communication infrastructure providers; platform provider	- Vehicle; telecommunication infrastructure; service platform; technology suppliers	- VANETs are a component of intelligent transportation systems and improve safety, convenience, commerce,	- No specific involvement mentioned; driving enables being part of a VANET	- On-board devices

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
							entertainment, infotainment		
Lee and Gerla 2010	- Survey on vehicular sensor network developments and identification of new trends	- Street-level traffic flow estimation; proactive urban surveillance; vehicular safety warning services; ride quality monitoring; location-aware micro-blogging	Connectivity	OEMs, OEM suppliers	- OEMs; drivers; smartphone producers; roadside communication infrastructure provider	- Vehicle; sensors; sensory information; communication network; service platform;	- Vehicular sensing for safety increase by better predicting environmental conditions	- Customers' smart phones as sensing platforms; no active involvement studied or focused on	- Smartphone and virtual interfaces
Lenfle and Midler 2009	- Case study on an OEM regarding the management of emergency / breakdown calls	- Management of emergency and breakdown calls	Safety	Automotive Manufacturers	- Service personnel; OEM; legislator; technology supplier; Communication infrastructure provider; service provider if not OEM; platform provider	- Vehicle; telecommunication technology; TP[9]; Service staff; Emergency infrastructure and staff;	- Emergency and breakdown calls service to increase safety as well as comfort and convenience	- Customers actively and / or directly engage with the personnel	- Directly via the phone; virtual interface on mobile devices
Lim et al. 2015	- Evaluation informatics-based services in the automotive industry and proposition of a conceptual design framework	- Vehicle operation and health manager; eco-efficiency improvement service; driving safety enhancement; consumable replacement support service; prognostic maintenance support service	Safety	Automotive service consumers; repair shops	- Telematics platform provider; OEM; service providers; consumers; repair shops; consumable management shops; insurance companies; application developers; service designers	- Vehicle; service platform; staff for service design; communication infrastructure; insurance tariffs	- Foremost to increase safety, as vehicle operation and health manager; driving safety enhancement services for commercial vehicles; comfort and convenience gains through monitoring, diagnosis & predictions	- Degree of participation differs with the service; customers as service demanders, but rarely involved in the service creation process; customer integration through information provision, but not actively involved	- Smartphone application (Fuel-efficiency improvement); onboard device for information display (Driving safety enhancement); Email (Consumable replacement support); Phone call (Prognostic maintenance support)
Lindkvist and Sundin 2016	- Research of the information transfer in the service development process	- Development of service maintenance instructions	Resource Efficiency	Automotive Service Developers; OEMs	- After-sales and sales staff; legal authority; service developm	- Vehicle; handbook; service development staff; publishing staff; spare parts	- Safety as well as comfort and convenience via service maintenanc	- Low customer involvement in the design process; recogniti	- Vehicle; handbook

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
	of two OEMs				ent department; terminologist; technical informant; translator; times study technician; service designer; illustrator; editor; spare part partner; publicist		e instructions	on of importance of utilization of information feedback	
Lisboa et al. 2016	- Identification of innovative IVIS through a Multi-Criteria Decision Making (MCDM) model	- Displays; augmented reality; touch screens and haptics; others digital assistants; gesture recognition; interactive projection; eye tracking; voice control and speech recognition	Service Experience Enhancement	Automotive Service Providers, OEMs	- Suppliers; service providers; distributors; legislators; OEM; staff	- Displays; augmented technology; ICT; Software for voice and gesture recognition; vehicle	- Instrumentation to increase safety and assist driving by conveying the car's internal state; comfort and convenience through infotainment, A/C controls and navigation (e.g. GPS)	- Drivers are service consumers; driving triggers service system	- Vehicle infotainment system or buttons, virtual interface through mobile applications
Mahut et al. 2015	- Exploration to the shift of PSS[10] and its applications with the focus on the automotive industry	- Emphasize on service development and provision of exemplary examples, e.g. diagnostics, assisted driving, embedded communication services, personalization	Product and service integration	OEM units	- OEM; driver; service designer; service provider	- Vehicle; service development staff; communication technology; DAS	- Increased safety through assisted driving; mobility as a service as an intelligent transportation service; remote diagnostics	- Recognizes customer involvement as an integral part of the methodology for PSS (MEPSS)	- Service channel for customer interaction; virtual interfaces through mobile phones
Mitsopoulos-Rubens et al. 2011	- Investigation of the usability of three IVISs regarding a human-centric design approach within a case study	- IVISs	Usability	Automotive Service Providers, OEMs	- Drivers; service designers; OEMs; engineers	- Vehicle; service design staff; IVIS technology; ICT	- Increase in safety foremost, but also comfort and convenience with respect to usability	- Usability evaluation of the prototypes by means of 30 end users; generally, no continuous UI gathering and testing considered; customer	- Virtual interface; physical environment within the vehicle

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
								s actively engage with the IVIS	
Mukhtar et al. 2015	- Provision of a survey about the state-of-the-art on-road vision-based vehicle detection and tracking systems for CASs[11]	- Vision-based vehicle detection techniques; active: collision and avoidance system, automatic braking, adaptive cruise control, lane departure warning systems; passive: vehicle safety systems (seat belts, airbags, crumple zones, laminated windshields)	Safety	Automotive OEMs; suppliers	- OEM; automotive suppliers; driver; passenger;	- Vehicle; DAS technology; CAS; control software	- Vision-based vehicle detection techniques for road safety improvement	- Driver is the initiator of the service through vehicle movement	- Screens as virtual interfaces
Nybacka et al. 2010	- Presentation of a RTM[12] solution for new innovative services in the automotive winter testing industry	- Remote Test Management: vehicle dynamics, vibration/noise, exhaust measurement, temperature and humidity measurements; audio /video communication	Safety	OEMs	- Service providers; OEMs; test drivers; staff	- Vehicles; tires; test drivers; service team; test site facility; RTM platform	- RTM for automotive winter testing services, which benefits safety	- Customers are OEMs and suppliers and work closely together with the test service providers	- Virtual interface of the RTM; service personnel; virtual interface
Olia et al. 2016	- Introduction of a traffic modeling framework for the interaction between vehicles and the infrastructure	- ITS[13]	Safety	Society, Driver; OEMs	- Driver; Road network providers; OEMs; Legislators; suppliers; service providers; 3rd parties such as pedestrians and residents; platform provider; infrastructure provider	- Vehicle; RSU; Traffic infrastructure; sensory information; communication infrastructure; control software	- Safety improvement and mitigation of traffic congestion by the usage of advanced ICT; environmental aspects	- Customers provide geographic information and contribute to the network, resulting in mutual benefits, e.g. fewer travel time, less accidents, fewer congestion, better environment	- Vehicle and mobile phone applications

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
Park and Kim 2015	- Proposition of an adaptive multimodal in-vehicle information system (AMiVIS)	- ITS; ATIS[14]; APTS[15]; AVHS[16]	Safety	OEM, Service Provider	- Driver; OEM; service provider; mobile technology providers; navigation suppliers; road authority	- Vehicle; communication infrastructure; IVIS; geographic information	- Increase in safety and intelligent in-vehicle navigation systems	- No involvement in the service development process	- HMI[17], e.g. infotainment systems etc. – physical and virtual interface
Sharples et al. 2016	- Study on dynamic electric information on motor highways and its driving decision making influence	- Dynamic information road signs	Assistance in driving decision making	Public Infrastructure Managers	- Road sign authority; technology suppliers (no active involvement); drivers	- Vehicle; highway authority agency; road signs; application; platform;	- Display dynamic info. in highway environments to increase safety and provide intelligent transportation	- Drivers participate e.g. by following the instruction, in the overall service objective	- Virtual interfaces on signs, smartphone applications and websites
Stevens et al. 2010	- Investigates the safety issues arising from an increase of IVIS through distraction	- Distraction measurement of IVIS	Safety	IVIS Display Designers	- Usability experts; drivers; human factor analysts	- Vehicle; IVIS; designer staff; Legislator actions	- Safety issues from IVIS	- Testers' responses are integrated in the evaluation process	- Virtual interface; physical attributes within the vehicle environment
Vashitz et al. 2008	- Simulation of IVIS effects on driving safety in road tunnels	- IVIS	Safety	Society, Drivers, Road Participants	- IVIS supplier; OEMs; highway traffic safety administration	- OEM; highway authority staff; road infrastructure; IVIS	- Effect of IVIs on vehicle safety	- Drivers as testers of the distraction level of IVISs	- Virtual interface of the IVIS
Wan et al. 2014	- Development of an architecture for the integration of MCC[18] in VCPS[19]	- Safety hazard prediction; entertainment; traffic-aware mobile GIS[20]; Safety information and entertainment resources sharing; car-pool services; maintenance; emergency road services; real-time traffic information; cloud-supported dynamic routing; reservation services	Enhance service integration	Society, Incumbents, End Customer	- Driver or passenger; VCPS infrastructure provider; service providers; OEM; Suppliers – sensor providers; communication infrastructure providers (internet, access points); public cloud providers	- Vehicle; VCPS infrastructure; sensors; ICT infrastructure (internet, access points); public cloud	- The overall objective is to provide the necessary service infrastructure, where services fulfil different functions and applications	- Not mentioned, but drivers trigger data delivery to public clouds	- Virtual interfaces; road signs processing the data representing the physical environment

Authors	Goal of the Article	Service Systems	Service Value	Customer	Key stakeholders	Service network infrastructure	Service Objective	Customer Involvement	Points of Interaction
Yeh et al. 2007	- Software integration framework for the use of VIS	- Vehicle box that tracks the vehicle status and has a scene reconstruction function	Usability	Drivers, Information Service Consumer	- ICT suppliers; service providers; customers; OEMs	- Vehicle; service platform; GPS sensors; Geographic information; touch sensing software; V-box	- Overall safety and convenience related service applications	- Customers can interact via a touch-based GUI with the VIS	- Touchscreen based GUI; Vehicle

Note.

1. DAS – *Driver Assistance System*
2. RTIS – *Remote Traffic Information System*
3. RSU – *Road Side Unit*
4. IVS – *Intelligent Vehicle System*
5. OBD – *On-Board Diagnostic*
6. VIS – *Vehicle Information System*
7. ICT - *Information and Communication Technology*
8. IVIS – *In-Vehicle Information Systems*
9. TP - *Telematics Platform*
10. PSS – *Product Service Systems*
11. CAS – *Computer Aided System*
12. RTM - *Remote Technology Management*
13. ITS – *Intelligent Transport System*
14. ATIS - *Advanced Traveler Information System*
15. APTS - *Advanced Public Transportation System*
16. AVHS - *Advanced Vehicle and Highway System*
17. HMI – *Human Machine Interaction*
18. MCC - *Mobile Cloud Computing*
19. VCPS - *Vehicular Cyber-Physical Systems*
20. GIS – *Geographic Information System*
21. V2V – *Vehicle-to-Vehicle*

Appendix E: Literature categorization in accordance to the identified constructs

	Expression	Ordered Expression by Class	Category	Dimension
Service Value	Increased safety features; Transportation time and stress reduction; Driving experience enhancement; Navigation facilitation; Enhanced entertainment Cost reduction; Comfort; Service maintenance improvement; Optimized mobility experience; VIS usability improvement; Advanced service integration; Environmental impact reduction; Service individualization; Security improvement; IVIS safety improvement; IVIS experience enhancement; Object detection improvement; Infotainment improvement; IVIS usability enhancement; Mobility enhancement; Mobility accessibility improvement; Provision of health manager; Emergency support	Increased safety features; Emergency support; IVIS safety improvement; Improved testing conditions; Provision of health manager	Safety	**Safety & Security**
		Object detection improvement; Security improvement	Security	
		Cost reduction; Environmental impact reduction; Transportation time reduction	Resource efficiency	**Resource Optimization**
		Driving experience enhancement;	Driving experience	**Emotion & Experience**
		Enhanced entertainment; Service maintenance improvement; VIS usability improvement; Advanced service integration; Optimized mobility experience; Infotainment improvement; IVIS usability enhancement; IVIS experience enhancement	Service experience & Usability	
		Service individualization	Customization	
		Mobility enhancement; Mobility accessibility improvement	Accessibility	**Convenience**
		Traffic convenience improvement; Driving facilitation; Comfort; Transportation stress reduction; Navigation facilitation	Comfort & Convenience	
Service Objective	Carsharing; Intelligent transportation; Advanced driving assistance; Formation of VANETs; Maintenance reduction; Vehicle connectivity; Intelligent navigation provision; IVIS issue detection; IVIS driving effects recording; Routing time reduction; Reduced routing expenses; Driving decision support; Service integration; Vehicular sensing improvement; Vehicle diagnostics improvement; Maintenance instructions improvements; Enabling remote diagnostics; Visual vehicle detection techniques; RTM for testing services; Dynamic information delivery; Traffic awareness system; Connectivity enhancement; Safety software systems	Carsharing; Intelligent transportation; Intelligent navigation provision; Routing time reduction; Reduced routing expenses	Transportation & Navigation	**Intelligent Transportation**
		Formation of VANETs; Vehicle connectivity; Dynamic information delivery; Connectivity enhancement	Connectivity enhancement	**Connectivity**
		Advanced driving assistance; Traffic awareness system; Visual vehicle detection techniques; IVIS driving effects recording; IVIS issue detection; Safety software systems; Vehicular sensing improvement	Issue Detection & Driving support	**Driving Support & Assistance**
		Maintenance reduction; Vehicle diagnostics improvement; Provision of health manager; Maintenance instructions improvements; Enabling remote diagnostics; RTM for testing services; Service integration	Quality improvement	**Maintenance Assistance**
Service network infrastructure	Vehicle; Communication infrastructure; Stationary sensors; Geographic information; Environmental information; DAS; Battery; Virtual applications; Mobile communication devices; Electric grid; Application layer; Virtual applications; Network layer; MAC layer; RSU infrastructure; Data Center; Diagnostics and prognostics information; Spare Parts; Repair space; Public parking areas; Internet; Cloud infrastructure; Stores; ADAS technology; Electric Vehicle; Batteries; Charging station; Sensing platform; Emergency infrastructure; Insurance tarifs; Displays; Augmented technology; Software; Voice and gesture recognition technology; CAS; Tires; Test site facility; RMT platform; Road signs; Mobile sensors	Communication infrastr.; Stationary sensors; Electric grid; RSU; Signaling Devices; Road signs; Charging station; Emergency infrastr.	Stationary infrastructures	**Physical Stationary Infrastructure**
		Stores; Repair space; Public parking areas; Test site facility;	Areas	
		Vehicle; Mobile sensors; DAS; Electric Vehicle; Mobile communication devices; Spare Parts; Batteries; Tires; Displays	Mobile devices	**Physical Mobile Infrastructure**
		Geographic information; Environmental inf.; Diagnostics and prognostics inf.; Vehicular inf.; Insurance tarifs; Software; Voice and gesture recognition technology; CAS; Augmented technology	Information	**Digital Infrastructure**
		Data Center; Internet; Cloud infrastructure; Sensing platform; RMT platform; Application layer; Virtual applications; Network layer; MAC layer; ADAS technology	IT Infrastructure	

Appendix E: continued literature categorization in accordance to the identified constructs

	Expression	Ordered Expression by Class	Category	Dimension
Customer	Drivers; End customer; OEMs; Business customer; Incumbents; Information service consumer; Passenger; Car sharing consumers; OEM Business units; Users of IVIS; Automotive service providers; Electric vehicle manufacturers; OEM Suppliers; Automotive service consumers; Repair shops; Automotive service developers; OEM Units; Suppliers; Service providers; Public infrastructure managers; IVIS Suppliers; Mobile cloud computing users; Application providers; VIS Software development companies; VIS Software users	Driver; End customer; Information service consumer; Passenger; Car sharing consumers; Users of IVIS; Automotive service consumers; Mobile cloud computing users; VIS Software users	End Consumer	Extenal Service Recipient
		Automotive service providers; OEM suppliers; Repair shops; Suppliers; Service providers; Public infrastructure managers; IVIS suppliers; Application providers; VIS software development companies	Business Customers	
		Business customer; OEM business units; OEM units; Automotive service developers	Business Units	Internal Service Recipient
		OEMs; Electric vehicle manufacturers; Incumbents	OEM	
Key stakeholders	Spare parts supplier; 3rd-party beneficiaries; V2V communication providers; Traffic participants; Battery supplier; Financial service provider; Dealer; Battery charging station providers; Battery swapping service station operators; Charging grid operator; Communication infrastructure providers; Staff; RSU provider; Platform provider; Service technician; Engineer; Municipality; Backend provider; Software architect; Mobile device manufacturers; Mobile network operators; Governmental regulatory agency; Investors; Mechanic / technician; Staff for service design; Service development staff; Publishing staff; Test drivers; Service team; Highway authority agency; Sensor suppliers; Aftersales and sales staff; Terminologist; Insurances provider; Technical informant; Security and Privacy Provider; Translator; Time study technician; Service designer; Illustrator; Editor; Spare parts partner; Publicist; Test drivers; Road network providers; Usability experts; Human factor analysts; ICT supplier; Society; Highway traffic safety administration	Service technician; Technical informant; Time study technician; Human factor analysts; Dealer; Charging grid operator		Physical Service Provider
		Staff; Mechanic / technician; Staff for service design; Service development staff; Publishing staff; Test drivers; Service team; Highway authority agency	Service staff	
		Battery supplier; Battery charging station providers; RSU provider; Communication infrastructure providers; Mobile device manufacturer; OEM; Customer; Road network providers; Engineer; After Sales and sales staff; Terminologist; Spare parts partner; ICT supplier; Battery swapping service station operator; Spare parts supplier	Service Providers	
		Software architect; Usability expert; Service designer; Editor; Mobile network operator; Translator; Publicist; Service designer; Illustrator	Information service staff	Digital Service Provider
		Financial service provider; Insurance provider; V2V communication providers; Service Platform provider; Municipality; Backend provider; Governmental regulatory agency; Sensor suppliers; OEM; Security and Privacy Provider	Information service providers	
		3rd-party beneficiaries; Traffic participants; Investors; Municipality; Highway traffic safety administration; Society	Secondary beneficiaries	Secondary Service Beneficiary
Customer Involvement	Drivers as actuators of the DAS and IVS actions; Service usage; Service providers for grid balancing; Participation in a service network through vehicle movement; Active service participation; Feedback giver; Device carriers; Enablers for sensing platforms; Givers of sensory information; Direct/indirect engagement with service employees; Passively as service demanders; Information provision; Utilization feedback provider; Test persons; Active IVIS engagement; Collaboration with OEMs and suppliers as test service providers; Geographical information providers; IVIS distraction testers	Collaboration with OEMs and suppliers as test service providers; Test persons; IVIS distraction testers; Service providers for grid balancing	Developmental Collaborators	Active Participation
		Active service participation; Feedback giver; Direct/indirect engagement with service employees; Active IVIS engagement	Active Involvement	
		Service usage; Passively as service demanders	Service Users	Passive Participation
		Givers of sensory information; Information provision; Geographical information providers;	Information Provider	
		Device carriers; Drivers as actuators of the DAS and IVS actions; Participation in a service network through vehicle movement; Enablers for sensing platforms	Actuator / Enabler	
Points of Interaction	Sensor data infrastructure; Mobile applications; Infotainment system; Dealers; Battery swapping personnel; In-vehicle navigation system; Website; Customer service; Technicians; Virtual interface via mobile devices; Physical in-vehicle interfaces; Mechanics; Auditory interactions; Electric vehicle charging station; Digital interaction; Vehicle manual; Human Machine Interaction; Auto repair shop; Traffic information systems; Vehicle touchpoints	Dealers; Battery swapping personnel; Customer service; Technicians; Mechanics	Personnel	Human Interaction
		Vehicle touchpoints; Sensor data infrastructure; Infotainment system; Physical in-vehicle interfaces	Vehicle Composition	Physical Vehicle Attributes
		Electric vehicle charging station; Traffic information systems; Vehicle manual; Auto repair shop	Physical Environment	External Environment
		In-vehicle navigation system; Human Machine Interaction;	IVIS	Virtual Interfaces
		Mobile applications; Financial services; Virtual interface via mobile devices; Website; Auditory interactions; Digital interaction	Virtual interfaces	
Revenue Streams	Asset sales; Usage fees; Subscription fees; Lending/Renting/Leasing; Licensing; Brokerage Fees; Advertising			Transaction Revenues
				Recurring Revenues
Cost Struc-ture	Economies of scale;, Economies of scope; Fixed costs; Variable costs			Value-Driven
				Cost-Driven

Table 03: Literature categorization in accordance to the identified constructs

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Hiermit versichere ich, dass

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Leipzig, den 10. Oktober 2018

Marcus Grieger