Using Information Systems for the Realization of Service Operations Management in Industrial Equipment Enterprises

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The President:

Prof. Dr. Thomas Bieger
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Alexander A. Neff
# Table of Contents

**Part A  Synopsis** ............................................................................................................ 1

**1  Introduction** .............................................................................................................. 1

  1.1 Research motivation .......................................................................................... 1
  1.2 Research objective and research questions ....................................................... 4
  1.3 Research design ............................................................................................... 6
  1.4 Thesis structure ............................................................................................... 10

**2  Background** ............................................................................................................ 12

  2.1 Service science and service systems ............................................................... 12
  2.2 Service operations in the manufacturing industry .......................................... 13
  2.3 Information systems appropriation for service operations ............................. 14
  2.4 Governance mechanisms ................................................................................ 15

**3  Research Results** .................................................................................................... 17

  3.1 Theoretical background and research gap ...................................................... 18
  3.2 The implementation of service operation functions in the equipment manufacturing industry ................................................................................... 20
  3.3 Governance mechanisms for transforming the information systems support of service operations in equipment manufacturing enterprises .............. 21

**4  Summary of the Publications** ................................................................................ 25

  4.1 Article I: The Influence of Information Technology on Industrial Services in the Manufacturing Industry – A Literature Review and Future Research Directions ................................................................. 26
  4.2 Article II: Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry .................. 27
  4.3 Article III: Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis .................................................................. 28
  4.4 Article IV: Explicating Performance Impacts of IT Governance and Data Governance in Multi-Business Organisations ................................................ 29
  4.5 Article V: Fostering Efficiency in Information Systems Support for Product-Service Systems in the Manufacturing Industry ............................... 30
  4.6 Article VI: Developing a Maturity Model for Service Systems in Heavy Equipment Manufacturing Enterprises ............................................................ 31
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Discussion and Future Research</td>
<td>32</td>
</tr>
<tr>
<td>5.1 Implications for research</td>
<td>32</td>
</tr>
<tr>
<td>5.2 Implications for practice</td>
<td>35</td>
</tr>
<tr>
<td>5.3 Limitations</td>
<td>38</td>
</tr>
<tr>
<td>5.4 Future research</td>
<td>39</td>
</tr>
<tr>
<td>Literature</td>
<td>42</td>
</tr>
<tr>
<td>Appendix A Complete Publication List of the Author</td>
<td>55</td>
</tr>
<tr>
<td>Part B Imprint of the Articles</td>
<td>59</td>
</tr>
</tbody>
</table>
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMCIS</td>
<td>Americas Conference on Information Systems</td>
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<td>CAx</td>
<td>Computer-aided Technologies</td>
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<td>cf.</td>
<td>Confer</td>
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<td>CRM</td>
<td>Customer Relationship Management</td>
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<td>e.g.</td>
<td>exempli gratia</td>
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<tr>
<td>EMCIS</td>
<td>European, Mediterranean &amp; Middle Eastern Conference on Information Systems</td>
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<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<td>i.a.</td>
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<td>i.e.</td>
<td>id est</td>
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<td>IS</td>
<td>Information Systems</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>MES</td>
<td>Manufacturing Execution Systems</td>
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<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
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<tr>
<td>PACIS</td>
<td>Pacific Asia Conference on Information Systems</td>
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<tr>
<td>RQ</td>
<td>Research Question</td>
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<td>SSMED</td>
<td>Service Science, Management, Engineering, and Design</td>
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</tbody>
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Summary

For numerous equipment manufacturers, their service promise remains unfulfilled. Managers underestimate the effort required to implement service operation models in terms of physical resource limitations, knowledge deficits of the service workforce, information intensity, the variety of customers’ equipment and the production context. Information technology (IT) offers an established means to overcome the information-related issues by supplying service stakeholders with relevant information. Aiming to improve quality and effectiveness, IT can increase information speed, ensure universal access, diminish physical distance and reduce transaction costs. However, functional deficits in the existing information systems (IS) landscape prevent the rapid implementation of service planning and execution functions. Established IS fall short in terms of integrating service functionalities into product-centered IS, openness and flexibility toward legacy solutions, inter-organizational scalability and overcoming different abstraction layers (from shop floor to enterprise planning). Reaching a shared understanding on service operation functions and a clear demarcation from existing IS are essential for coordinating transformational change measures. Studying how industrial equipment manufacturers can implement those service functions can enlighten the integration needs of service-driven requirements in existing production-oriented IS. It is apparent that a broad set of resource-intensive organizational capabilities is required, while IT capabilities allow for more efficient service process redesign. This research presents instruments for analyzing the current situation and prioritizing change measures.

By following the design science research process and using select research methods for individual research projects, this cumulative dissertation investigates the IS implementation of equipment manufacturers’ service systems. After presenting the conceptual foundations, a functional reference model was developed that specifies and assigns service functions to the respective enterprise application layer. Based on these results, governance mechanisms are identified as a key to leverage synergy potential. A maturity model, as a concrete governance instrument, was constructed for the heavy equipment manufacturing industry. This model drafts an anticipated, evolutionary path to demonstrate service systems’ specific capabilities. The model reduces complexity as it renders a heterogeneous phenomenon into a homogenous model. This dissertation complements the extant service research by studying the neglected arena of back stage service systems. The designed reference model identifies and specifies application functions for service operations. Hence, this research contributes to the architecture debate on service systems, including connectedness and complementarity for value co-creation. The maturity model constitutes a refined version of the IS-enabled connection of front and back stage service systems tailored to the equipment manufacturer’s specifics. It complements research on business transformation by outlining the role of IS in implementing service models.
Zusammenfassung


Part A SYNOPSIS

1 Introduction

1.1 Research motivation

Manufacturing enterprises have discovered service offerings to be a source for continuous growth and enduring revenue streams. The economic statistics of international organizations and market analyses of leading consulting firms confirm this transformation from pure manufacturing to service organizations in the manufacturing industry. They report increasing numbers for the service workforce, sectorial turnover rates and revenue shares. All member states of the Organization for Economic Co-operation and Development (OECD) – save for Luxembourg – have experienced a steadily growing proportion of industrial services offered by manufacturing firms [OECD 2011]. Consultancy firm Bain & Company states that services account for about 20% of revenues for European equipment\(^1\) manufacturers. The profit margin for services is considerably higher than that of manufactured products. The 20% of revenue generated by services amounts to virtually half of the sector’s profit [Strähle et al. 2012]. In a recent study, the Boston Consulting Group compares (new) equipment and service sales. Beyond profitability, gross margin and predictability, they also consider service business to have a greater resilience to economic cycles. The average revenue drop due to the economic crisis has been 23% for equipment, while service sales only suffered a 9.8% decrease [Du et al. 2014]. Scholars have identified several drivers including decreasing market shares, increased international competition and solution-demanding customer organizations [Oliva/Kallenberg 2003].

Although service opportunities are widely accepted as offering the potential for outperforming one’s peers, numerous equipment manufacturers have been unable to transform their previous service business investments into additional revenue streams [Gebauer et al. 2005, Ulaga/Reinartz 2011]. Research identifies this phenomenon\(^2\) as the “service paradox” [Gebauer et al. 2005, p. 14 f.]. With the addition of novel services to the corporate product portfolio, the manufacturer faces the necessity of adapting strategy, structure and business processes [Johnson et al. 2008, Ulaga/Reinartz 2011]. This transformation implies that the previous, engineering-driven business focus needs to be supplemented with distinct service capabilities\(^3\) [Gebauer et al. 2005, Kindström 2010]. However, the current service operations staff is often insufficiently

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\(^1\) Equipment, machine and product are treated synonymously in this dissertation.
\(^2\) Neely [2008] explores the service paradox phenomenon and offers an explanation for the challenges of service transformation in manufacturing enterprises.
\(^3\) The literature explicitly outlines the need for a manufacturer to develop “the capability to design and deliver services rather than products” [Neely 2008, p. 114].
equipped to perform this organizational change. Common challenges involve not only the limited resources, but also knowledge deficits on the part of the employees and deficient equipment specifications.

In order to respond to varying and customer-specific service requests, both a contextualization to local circumstances and cooperation are of major significance [Tuli et al. 2007, Biege et al. 2012, Matijacic et al. 2013]. Customer manufacturing\(^4\) engenders versatile production, short delivery times and declining lifecycles [Schmidt et al. 2011]. Thus, the basis of high quality service deliveries is accurate, precise and timely information on the client’s equipment. Due to the high complexity and variety of the installed base, this information needs to cover both customer-related data (e.g. service level agreements) as well as technical objects (e.g. bill of materials or computer aided technology (CAx) structures).

One way to overcome these information-related difficulties is the use of information technology (IT). IT can increase the efficiency and quality of service processes by making information visible to all the involved stakeholders in the service operation departments [Becker et al. 2011]. Further benefits of the implementation of IT include increased speed of information, guaranteed universal access, diminished physical distance, and reduced cost of communications [Jonsson et al. 2009]. However, these advantages can only be realized when service operation activities are fully integrated into the already existing production-oriented information systems [Dietrich 2006, Becker et al. 2011].

There are four reasons why realizing this integration and fulfilling the information needs of the service workforce are challenging. First, the information systems, in place, have not been designed in accordance with service specific requirements [Davenport 1998, Dietrich 2006]. While CRM (customer relationship management) solutions cover service planning and execution in local sales and service entities, ERP (enterprise resource planning) applications entail technical descriptions of installed equipment. Second, in order to balance the insufficient functionality of standard applications (e.g. no remote access to sensor data from the customer installed base), industrial equipment manufacturers have projected proprietary software that collects and processes equipment statuses and field service data [Tuli et al. 2007, Jonsson et al. 2008, Biege et al. 2012, Matijacic et al. 2013]. Standard and proprietary application systems overlap in functionality and, thus, foster redundancy. Third, performing services on the customer’s production facilities requires a cross-organizational IS appropriation (i.e. several organizational boundaries must be spanned) [Jonsson et al. 2009, Becker et al. 2013b]. Fourth, information convergence can only be achieved by inte-

\(^4\) While some scholars refer to this collaboration type as customer co-creation, others tend to stipulate a contextualization on the individual level.
Part A: Introduction

grating distinct abstraction layers. Enterprise planning, manufacturing execution\(^5\) and shop floor process control vary, not only in terms of data types and scope [Schmidt et al. 2011] but also in their level of abstraction. The time factor demonstrates this distinction. While process control on the shop floor level happens in real-time, transactions on the enterprise planning level are processed on a periodic basis.

The resulting information systems’ landscape is considerably heterogeneous, partially redundant, and costly in terms of operation and maintenance. This situation might result in a “dead end” that hinders organizational flexibility and wastes numerous resources that would be highly necessary to work on value adding activities. The readiness to develop and operate new services that harness the digitalization of physical equipment is not given. The combination of digital components with the physical artifact alters the basic properties of the industrial equipment [Yoo et al. 2010]. “Due to the rapid spread of sensor technology in mobile devices and other machines, and through their networking capabilities, the pool of available data continues to grow quickly” [Brenner et al. 2014, p. 58]. Information that has previously not been available can now be accessed. The newly gained addressability, sensibility and communicability of the equipment and its environment [Yoo 2010] create significant potential\(^6\) for the service business [Jonsson et al. 2008].

Previous service research is characterized by a distinct lack of interest in the back stage part of service systems [Glushko/Tabas 2009, Becker et al. 2011]. Glushko and Tabas [2009] argue that the emphasis on the front stage, “discounts the contribution of the activities in the ‘back stage’ of the service value chain where materials or information needed by the front stage are processed” [2009, p. 407]. The causality between the operational service capabilities and the IT capabilities is identified. Neely [2008] states that, for novel service models for manufacturers “the operational capability delivered is underpinned by data collection and information processing capabilities” [2008, p. 105]. Further, he argues that this service transformation changes the notions of ownership and asset management and has “massive implications for many of the traditional operations management frameworks and philosophies” [2008, p. 105]. According to Becker et al. [2013a], manufacturing companies undergo a transformation process and have to meet client-specific information needs. They state that “manufacturing and service companies increasingly engage in networks to provide their customers with integrated solutions. In order to leverage complementary resources and capabilities fully, the network actors must span traditional boundaries between communities of practice in manufacturing and service” [Becker et al. 2013b, p. 468]. IT artifacts, such as enterprise information systems, business processes and data objects can eliminate the boundaries between product and service divisions since they “reside at

\(^5\) The manufacturing execution functionality usually resides in the plant layer. Please find more details in Schmidt et al. [2011] and Neff et al. [2014b].

\(^6\) For instance, Bax and Jonsson [2009] refer to field service automation (i.e. the replacement of field service with remote service).
the interfaces between fields or communities and that facilitate the transfer of cross-boundary information and knowledge” [Becker et al. 2013b, p. 469].

The extant body of literature has not performed a thorough investigation of business processes [Glushko/Tabas 2009] and the enterprise information systems that make allowance for integrating service and manufacturing processes. Although there have been attempts at outlining the convergence of IS capabilities in service systems, a comprehensive view of the IS capabilities in service operations is still only a vision. Along this line, Matijacic et al. [2013] note a lack of studies investigating the requirements for IT-based field service, since most research on mobile service assistance is focused on healthcare and education. Jonsson et al. [2009] give the first indication of the information needs and interdependencies of remote service to other service processes. They study remote diagnosis systems as inter-organizational information systems. Taking all the aforementioned aspects into consideration, the research field on the IS-based service systems from the manufacturer’s point of view calls for further investigation. With previous standardization efforts being insufficient, a shared understanding of service systems and requirements for the appropriation of information systems needs to be developed.

1.2 Research objective and research questions

Based on the apparent research gap concerning service operations in the manufacturing sector and the respective IS support, the research priorities and objectives are deduced. This research endeavor is led by an overarching, guiding question that frames the dissertation project:

*How can information systems foster efficiency in service operations for the manufacturing industry?*

Subsequent to the guiding question, three more detailed research questions (RQ) have been derived. Each RQ presents a manageable contribution to the guiding question and serves to individually guide the research projects.

Following the notion that scientific debate is characterized by rigor and relevance [Österle/Otto 2010], the first research question is primarily addressed for the purposes of establishing rigor. The debate is concerned with the sharpening of the research gap, the demarcation of the phenomenon and the derivation of a research agenda. To achieve a shared understanding of the investigated phenomenon, literature scholars suggest the derivation of a comprehensive conception [Zorn/Campbell 2006] of what the current state of knowledge on the topic is [Torraco 2005, vom Brocke et al. 2009].

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7 Most of the requirements discussed by Matijatic et al. [2013] for IS-based field services have resulted from interviews, such as “decision support for customer service operations”, “electronic checklist for customer service operations” or “interactive assistance for customer service operations” [2013, p. 12].
Drawing on the existing theoretical foundations, Hevner et al. [2004] describe this as a “knowledge base” that helps to inform the research endeavor [2004, p. 80 f.].

The existing literature reviews investigate service science [Spohrer/Kwan 2009, Beverungen 2011] and IT service management [Demirkan et al. 2009, Bardhan et al. 2010], but disregard the notion of using information systems for the implementation of service systems in the manufacturing industry. The literature synthesis suggests that equipment manufacturing firms are undergoing a massive business transformation, which makes them interesting research objects. Hence, the following research question has been derived:

**RQ.1:** What is the current state of knowledge regarding the service systems of manufacturing enterprises in information systems research?

After meeting the rigor requirements through sharpening the research gap and getting a shared understanding of the phenomena in the first place, the second research question targets the relevance dimension. The motivation behind the question lies in understanding the service operation functions relevant in the equipment manufacturing industry. Further, it questions how industrial equipment manufacturers can implement those service operation functions. This is particularly incisive as it becomes very challenging to integrate service-driven requirements into existing production-centered information systems. So far, service operation functionality has not been clearly defined and demarcated in the existing information systems landscape. Hence, the following research question has been constructed:

**RQ.2:** Which service operation functions are relevant to industrial equipment manufacturers and how can those enterprises implement service operation functions based on their existing IS landscape?

Current studies in IS and Operations Management explicitly refer to a transformation process. The implementation of extended service offering requires different organizational capabilities. This transformation process can be facilitated by IT artifacts as technological capabilities allow for a more efficient redesign of the service processes [Becker et al. 2013b]. However, in order to realize these technical capabilities, substantial resources are needed. Thus, managing and coordinating the broad business-to-IT scope of this transformation is especially challenging for organizations.

Being confronted with this wide array of heterogeneous business and technology issues, the equipment manufacturer’s management team has a crucial need to prioritize and control individual measures. Strategic IS planning and IT management scholars suggest a variety of governance mechanisms, for example maturity models, to tackle such a holistic transformation (cf. [Becker et al. 2009]). However, it remains unclear what the capabilities for transforming the information systems of service systems to offer service-oriented business are and how they can be coordinated and controlled.
Managerial practitioners with service and IT backgrounds postulate the need for designing respective instruments. In accordance with this notion, the third research question has been derived:

**RQ.3: What are the key requirements for transforming information systems support of service systems in order to offer service-oriented business in the equipment manufacturing industry, and how can the transformation be coordinated?**

Since this research endeavor follows the design science research paradigm of IS research [Hevner et al. 2004, Peffers et al. 2007, Winter 2008], it addresses real-world problems while targeting a duality in the audience structure [Hevner 2007]. This research is, therefore, dedicated to both research scholars and managerial practitioners.

For research, this thesis provides research results concerning the structuration, demarcation, design and application of information systems support for service systems in the equipment manufacturing industry. Studying the analyses of current implementations allows researchers to achieve specific business-to-IT insights into the service transformation state of the manufacturing industry. Accordingly, this thesis addresses the scientific communities on service science, IS and operations management.

For practice, this plurality of interdisciplinary stakeholders is also considered. This dissertation focuses on the managers responsible for (or involved in) service transformation, line managers from the service business, IT executives managing IT projects for industrial service initiatives (such as the Chief Information Officer) and enterprise architects responsible for the application landscape. Beyond these equipment manufacturing roles, there are stakeholders from software and IT vendors. Product management, solution management, development units and IT consultants can learn from industry experience with custom-built proprietary systems. Developed models and findings provide guidance and structuration for the design, the implementation and the control of the IS support for service operation functions.

### 1.3 Research design

The dissertation was developed at the Institute of Information Management at the University of St. Gallen and in collaboration with several industry and software vendor partners. Research has been conducted as part of the work in the Competence Center Industrial Services and Enterprise Systems at the chair of Prof. Walter Brenner. There has been a continuous exchange between research and practice institutionalized in the organizational body of the Competence Center. Moreover, data has been collected through a variety of methods (inter alia case study, expert interviews and focus group workshops) from industrial equipment manufacturers, software vendors and consulting firms in Germany and Switzerland. With continuous access to practitioners’
knowledge in the context of the investigated phenomenon [Hevner 2007]⁸, this approach should ensure the relevance of the research endeavor [Österle/Otto 2010]. Gaining access to the research environment is vitally important, since “research and innovation in the IS domain largely take place in the practitioner community [Starkey/Madan 2001]” [Österle/Otto 2010, p. 283].

Research in the IS discipline can be structured as both behavioral and design research [Wilde/Hess 2007]. As summarized by Winter [2008], “while behavioral IS research aims at ‘truth’, i.e., at the exploration and validation of generic cause–effect relations, IS design science research aims at ‘utility’, i.e., at the construction and evaluation of generic means-ends relations” [2008, p. 470]. This dissertation is subject to both the design-oriented and construction-oriented research approaches and, hence, follows the principles of design science research [Hevner et al. 2004]. The outcomes of the design science research process [Peffers et al. 2007] (i.e. the artifacts and their evaluation results) always take rigor and relevance criteria into consideration. Such research methods should yield applicable and useable solutions for corporate or business-driven problems [Denyer et al. 2008], while at the same time contributing to the extant body of knowledge [March/Storey 2008, Winter 2008, Hevner/Chatterjee 2010]. To differentiate the artifacts, March and Smith [1995] have identified four types that are well-accepted in the scholarly IS literature [Vahidov 2006, vom Brocke/Buddendick 2006, Winter 2008]. They state that “design science products are of four types: constructs, models, methods, and implementations” [March/Smith 1995, p. 253].

As a twofold research approach for this cumulative dissertation has been chosen, it is possible to distinguish between the dissertation program and individual research projects. The overarching dissertation program covers the frame of the cumulative dissertation and consists of several individual research projects. The overarching dissertation project is guided by design science research principles and inspired by the consortium research approach [Österle/Otto 2010]. The construction- and design-oriented research approach is applied and supplemented by knowledge-oriented elements [Iivari/Venable 2009]. The individual research projects can be clearly demarcated from each other and present a study that is concerned with one facet of the dissertation’s guiding question. The facets are organized into distinct research questions [RQ.1 - 3] (cf. Part A Chapter 1.2). Inspired by Hevner et al [2004], design science scholars suggest that researchers diffuse [Österle/Otto 2010] or “communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practicing professionals, when appropriate” [Peffers et al. 2007, p. 56]. This notion has been guaranteed in the dissertation project with fitting outlets to the stakeholder groups. While the research audience is addressed with publications in journals, conference proceedings and

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⁸ Hevner [2007] refers to the access practitioner’s knowledge as input values from “the contextual environment into the research” [2007, p. 87].
presentations on conferences, the practitioners’ community has been reached through workshops. Moreover, papers dedicated to managerial practitioners have been tailored.9

One or more sound research methods were selected in accordance with the research questions of the individual research projects. This approach is quite typical for IS design research involving a plurality of research methods [Wilde/Hess 2007, Österle/Otto 2010]. Subsequently, the main research methods applied in this dissertation are introduced. More detail on the research methods and their application in the concrete context can be found in the publications (Part B).

Following Baker’s [2000] notion that “the evolution and creation of new knowledge proceeds generally by a process of accumulation” [2000, p. 219], this dissertation program is initiated with a literature review. Such a review presents a solid foundation when undertaking a research endeavor [Baker 2000]. The underlying idea of a thorough review is to provide the sources relevant to a dedicated topic [vom Brocke et al. 2009]. Reviewing the literature makes a useful contribution to both the rigor and relevance of this dissertation. While relevance can be improved by sharpening the research questions that address novel facets and not reinvestigating already known facets [Baker 2000], rigor is fostered through critiquing the existing “knowledge base” [Hevner et al. 2004, p. 80]. The literature review has been continuously extended alongside the progress of the research process involved in the dissertation program.10 Moreover, each research project includes at least one structured literature review that is inspired by the methodical approach of vom Brocke et al. [2009]. Structured approaches are preferable [Webster/Watson 2002, Fettke 2006] as they make the review “as transparent as possible in order for the review to proof credibility” [vom Brocke et al. 2009, p. 3]. A rigor documentation, in particular of the literature search, puts scholar readers in a position to assess the exhaustiveness of the review conducted and this, in turn, promotes the usage of the review’s results by other researchers [vom Brocke et al. 2009].

Embedded into a qualitative research design, case study research serves as one of the primary methods of inquiry for this dissertation. This method has been well-accepted within the IS discipline [Benbasat et al. 1987, Dubé/Paré 2003] as it can lead to a better understanding of complex phenomena [Eisenhardt 1989] that is likely to be guided by “how” and “why” research questions11 [Yin 1981b, p. 100]. In the search for an appropriate research strategy, Yin [1981a, 1981b] suggests the usage of case study research when an inquiry wants to examine a “contemporary phenomenon in its real-life context”, particularly when “the boundaries between the phenomena and its con-

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9 There are many measures by which to tailor contributions to the practitioners’ needs. Inter alia those working papers are translated to the practitioners’ language.

10 Please find the initial literature review in chapter 4.1 (Part A).

11 In his seminal work, Yin [2003] even proposes the usage of a dedicated decision support framework [2003, p. 5] that takes the relevant situations into consideration.
text are not clearly evident” [1981b, p. 98]. More recently, he adds the need for “control over behavioral elements” as a relevant situational element to determine the appropriate research strategy [Yin 2003, p. 5].

This dissertation aims to explore how information systems might foster efficiency in the service operations of the manufacturing industry. Accordingly, case study research fits the purpose, since the question “how” is applied. Further, the boundaries between the service and manufacturing processes (i.e. the poorly researched relation between enterprise applications, product business processes and service business processes) and their contexts (i.e. the service systems in which they are embedded) have evidently not been explored. There are no suitable a priori variables available, giving this research an exploratory character while erasing the need for the controlled manipulation of variables. The service transformation of manufacturing firms and its implications for IS highlights the contemporary focus. In comparison to the single case study approach, the access to multiple manufacturing enterprises allows more significance in terms of a richer data base (i.e. enhanced validity) [Eisenhardt/Graebner 2007]. Further, by comparing several cases, the research results can be extended as well as evaluated and applied. Design science research relies strongly on the iterative notion of constructing artifacts [Hevner et al. 2004, Peffers et al. 2007], e.g. in the case of reference model development [Becker et al. 2009]. Data collection in case study research supports this notion by providing the flexibility to “cycle back and forth between thinking about existing data and generating strategies for collecting new” [Dubé/Paré 2003, p. 599]. Case study research typically exploits a combination of “data collection methods such as archives, interviews, questionnaires, and observations” [Eisenhardt 1989, p. 534]. More details on the sampling, data collection, data analysis and triangulation can be found in the individual publications (Part B).

The expert interview is a valid technique for evaluating artifacts [Österle/Otto 2010, Sonnenberg/vom Brocke 2012]. “An artifact’s idea could be further validated by means of descriptive justificatory knowledge in the form of results from surveys or interviews” [Sonnenberg/vom Brocke 2012, p. 394]. Becker et al. [2009, p. 217 f.] outline the usage of expert interviews in the iterative model construction stage. Also, there is a pattern in the IS literature of triangulating expert interviews and literature reviews in order to capture the current state of affairs, e.g. to refine the research questions [Mulligan 2002, Schultz et al. 2012]. The individual research projects use this method inter alia for problem analysis, model construction and model evaluation.

Being a well-accepted tool in social science, the focus group method refers to a specific form of group interview that capitalizes on communication among the participants and that is moderated by a researcher [Kitzinger 1994]. The most distinctive feature, compared to a group interview, is the interaction [Kitzinger 1994]. The aim is to capture differences based on the individual experiences and views of all participants, while at the same time to leverage interaction to achieve a shared understanding about
the issue under discussion (i.e. referring to a strengthened validity) [Krueger 2009]. While the moderating role is important for conducting the focus group workshop, an observer is responsible for data collection. The observer does not participate in the focus group, but has to carefully document the content as well as any kind of contextual information such as gestures, mimicry, behavior and the connotations of any exchange among the roles [Stewart et al. 2007]. IS scholars have introduced the focus group methodology for different purposes, e.g. for “seeking current practitioners issues” to “formally derive an industry-driven research agenda” during the identification of the research problem [Rosemann/Vessey 2008, p. 7]. In design science research, the scholarly literature has identified focus groups as an evaluative method. Two forms can, in fact, be differentiated. While exploratory focus groups are used to iteratively refine the artifact design (in the design or build/evaluate cycle [Hevner 2007]), confirmatory focus groups aim at the evaluation of artifacts in environmental use (field testing in the relevance cycle [Hevner 2007]) [Tremblay et al. 2010]. The individual research projects apply focus groups for capturing requirements and evaluating artifacts. Focus groups are embedded into workshops with managerial practitioners. More detailed information regarding the described methods as well as additional research methods and insights into the concrete actions within the individual research projects can be found in the published articles (Part B).

1.4 Thesis structure

This doctoral thesis is organized in accordance with the guidelines for cumulative dissertations at the University of St. Gallen. This dissertation consists of two building blocks. The first part (Part A: Synopsis) presents an overview of the research endeavor and the research results in the form of short descriptions of the publications and their contribution to the dissertation project. The second part (Part B: Imprint of Articles) replicates the complete versions of the published articles.

Part A of this dissertation is defined as the synopsis and characterized by a holistic perspective on the research endeavor. It sets the stage for the dissertation and comprises five chapters. First, it discusses the motivation for this research and states the research objectives, questions and design. Then, in chapter two, the background knowledge of the thesis is briefly described including short introductions to service systems, service operations in the manufacturing industry, information systems for service operations and governance mechanisms. The results of this doctoral thesis are set out in chapter three. Further, the contributions to both scientists’ and practitioners’ knowledge bases are presented. In chapter four, the published articles, which are the centerpiece of the cumulative dissertation, are summarized and their individual contributions to the dissertation project are emphasized. Finally, the results of the dissertation are discussed in chapter five concerning their implications for research and practice followed by the limitations of the study and suggestions for further research.
Part B includes the imprints of the author’s six publications, which constitute highly relevant contributions to this dissertation. The original publications remain untouched except for minor corrections.
2 Background

The dissertation project builds upon the existing theoretical foundations that Hevner et al. [2004] describe as a knowledge base. The effective inclusion of the knowledge base into all of the research projects ensures the scientific rigor of this dissertation.

2.1 Service science and service systems

While services have been dominating the economic activities in developed economies for half a century, the development of a service science discipline integrating academic fields lags behind [Chesbrough/Spohrer 2006]. However, with the recent emergence of the discipline of Service Science, Management, Engineering, and Design (SSMED), approaches aiming at understanding and innovating service systems are now highly debated in literature [Spohrer/Kwan 2009]. Further, the transformation challenge of manufacturing enterprises and, accordingly, the planning, operation and disposal of services are covered in various additional research fields such as information systems, marketing and operations management [Rai/Sambamurthy 2006, Bardhan et al. 2010].

In accordance with the idea that service provision rather than manufactured goods is integral to economic exchange [Vargo/Lusch 2004], a service can be defined as the “application of competences (knowledge and skills) by one entity for the benefit of another” [Vargo et al. 2008, p. 4]. These forms of value creation can be referred to as service systems. A service system represents “a value-coproduction configuration of people, technology, other internal and external service systems, and shared information (such as language, processes, metrics, prices, policies, and laws)” [Spohrer et al. 2007, p. 72]. At the heart of service systems is the understanding that value is created in cooperation. Providers and service clients (e.g. customers) are cooperating within complex value chains or networks with the goal of coproducing value [Spohrer et al. 2007]. The modes of interaction between service providers and service consumers cover all the participants, processes and resources involved in value creation [Vargo et al. 2008]. Service providers and service consumers might be either internal (intra-organizational) or external (inter-organizational) [Vargo/Lusch 2008] and might include individuals, firms, government agencies, or any organization of people and technologies [Spohrer et al. 2007]. Böhmann et al. [2014] summarize the fundamental aspects of service systems – value creation and cooperation – in their definition as they conceptualize “a service system as a socio-technical system that enables value co-creation guided by a value proposition” [2014, p. 74].

Service systems derive their theoretical origin from the usage of manufacturing system theory on services [Levitt 1972, Mills/Moberg 1982]. In this light, service systems can be separated into a front stage with customer interaction and a back stage with IS support [Glushko/Tabas 2009]. While the marketing and service science literature covers the front stage of service systems – that is, the customer’s perspective and the connec-
tion of the customer and the service and product processes – operations management and service process management literature classifies service and product business processes as essential parts of the back stage service systems [Glushko/Tabas 2009, Becker et al. 2011].

2.2 Service operations in the manufacturing industry

A considerable body of literature intends to specify the broad view of a product-service system by combining products and industrial services in terms of bundles [Oliva/Kallenberg 2003], solutions [Davies et al. 2006, Tuli et al. 2007] and systems [Goh/McMahon 2009]. In order to supply service systems, manufacturing firms need to expand their primary organizational focus to include this distinctly different service concept [Gebauer et al. 2005, Kindström 2010]. The service systems literature differentiates between three essential aspects of service systems: a general understanding of services and service systems, service innovation and engineering (also referred to as service design or service development), and service (operations) management [Fitzsimmons/Fitzsimmons 2005, Spohrer et al. 2007, Maglio et al. 2010]. With few exceptions, both service innovation and service operations are sparsely covered in the innovation and operations literature, respectively [Metters 2010, Ettlie/Rosenthal 2012]. While service design and engineering mean the development of new services by applying techniques such as service blueprinting [Fitzsimmons/Fitzsimmons 2005], service operations management deals with the question of how to provide services and value to customers [Johnston/Clark 2012]. Böhmann [2014] conceptualizes service system engineering as “the systematic design and development of service systems” [2014, p. 74]. According to Maglio et al. [2010], “service operations are processes involving input components that come from each individual customer. Service operations management is largely about managing customer influences on the ability to produce” [2010, p. 117].

For manufacturers, the key challenge in terms of offering service systems lies in service operations management, since service engineering is organized around the goal of managing the services that are related to a product’s installed base [Oliva/Kallenberg 2003]. Thus, the service offering of a manufacturer includes a “range of product- or process-related services required by an end-user over the useful life of a product in order to run it effectively in the context of its operating process” [Oliva/Kallenberg 2003, p. 163]. In order to achieve and sustain high profit margins, maintenance, repair and change operations on the installed based are included in this service portfolio [Oliva/Kallenberg 2003, Strähle et al. 2012]. Efficient service operations are compromised by unfulfilled information needs such as a coherent view on customer equipment [Becker et al. 2011]. The novel business model of manufacturers using service systems is based on an operational capability that is “underpinned by data collection and information processing capabilities” [Neely 2008, p. 105]. “In order to efficiently
execute service operations (i.e. quickly respond to service events in the customer production process), it is crucial to have access to high quality (accurate, precise and timeliness) information on the installed customer equipment” [Neff et al. 2014b, p. 3]. Manufacturing firms need more detailed insights into the installed base and the client’s production context [Neff et al. 2014b].

2.3 Information systems appropriation for service operations

Traditionally, manufacturing firms geared their value creation toward engineering and manufacturing physical products, while servicing these products remained on the sideline [Isaksson et al. 2009]. In the context of the transformation challenge from pure manufacturing to service systems, a key difficulty is the implementation of appropriate IT artifacts to utilize opportunities related to this shift [Becker et al. 2011]. The service systems in place at manufacturing firms have been implemented based on the requirements of the production business processes and are, thus, ill-suited to support the newly added service business [Becker et al. 2011]. The information systems supporting customer service processes are manifold and heterogeneous [Fellmann et al. 2011]. In general, the literature differentiates between two types\(^\text{12}\) of information systems that enable operative service processes. The first type refers to intra-organizational information systems – enterprise applications that are used for enterprise-wide but primarily internal service planning and executing. Typical applications of this type are ERP and CRM, which, however, do not fit the service specific requirements of industrial equipment manufacturers. While ERP is designed for production planning and lacks customer-orientation, CRM strongly features sales force planning and campaign management but shows functional deficits in the technical appropriateness of equipment specifications. In order to compensate for the functional shortcomings of standard applications, manufacturers began to develop and implement proprietary solutions [Tuli et al. 2007, Biege et al. 2012, Matijacic et al. 2013]. These applications are able to collect and analyze the status of the installed base and field workforce data as they incorporate remote technology and sensor information [Neff et al. 2014a]. With the aim of fulfilling the information needs of usage-based service models, proprietary application systems add inter-organizational capabilities to the existing and most likely template-based intra-organizational information systems.

The core benefit of inter-organizational systems (the second type of information systems supporting service operations) is the simplification of inter-firm collaboration as they are designed to link business processes [Robey et al. 2008, Legner 2009]. Services operated in collaboration with geographically separated stakeholders are built on a solid information infrastructure [Muller et al. 2008]. IT enables the distribution of

\(^{12}\) Other types, e.g. mobile IS, are not considered due to their lying beyond the scope of this dissertation. Nevertheless, field service is analyzed as a service operation function in chapter four (Part A), but only on the organizational macro level.
data across organizations and locations [McLeod Jr et al. 2008]. Shared IT functionalities such as database access or common communications support allow for faster and more efficient communication, coordination and value co-creation [Kumar/Van Dissel 1996, Robey et al. 2008]. Thus, IT artifacts used in inter-organizational service operations facilitate intense and broad boundary-spanning [Kumar/Van Dissel 1996]. With the digitalization of the industry, sharing digital forms of service process information at organizations’ new digital boundaries is an essential benefit of IT functionalities [Jonsson et al. 2009]. One instance of inter-organizational information systems is a remote diagnosis system. Remote technology allows for the performance of services on the products at the customer’s site and, thus, spans the organizational boundary between equipment manufacturer and serviced customer [Jonsson et al. 2009]. The installed base at the client’s site is equipped with sensors that facilitate automatic data exchange, condition monitoring from a distance, and analyses of changes over time [Jonsson et al. 2008]. With the application of remote diagnosis systems, manufacturing firms can gain a competitive advantage over their peers. Through the (partial) automation of field service routines and the associated higher efficiency, manufacturers can afford more competitive prices. In addition, variances in the monitored equipment can be detected early on and trigger necessary service interventions accordingly [Jonsson et al. 2008]. Thus, machine breakdowns and unplanned downtime can be minimized [Jonsson et al. 2008].

The resulting information systems landscape – standard and proprietary internal applications as well as inter-organizational information systems coexist – is highly heterogeneous [Fellmann et al. 2011, Neff et al. 2014a], partially redundant, and costly in terms of operation and maintenance [Neff et al. 2014b]. This situation might result in a “dead end” that hinders organizational flexibility and wastes numerous resources that would be vital for work on value adding activities.

### 2.4 Governance mechanisms

In view of the issues associated with the IS support for service systems (cf. Part A Chapter 2.3) and the need to take advantage of IT resources as a key lever for service operations (cf. Part A Chapter 2.2), the IT governance concept, aiming at establishing and sustaining an efficient and effective usage of those resources [Weill 2004], features promising management instruments. This is particularly incisive since service divisions in equipment manufacturers suffer resource scarcity when conducting their

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13 For example, a key lever might be the integration and support of organizational resources for service systems [Thomas et al. 2007], the (partial) replacement of field service with remote service [Jonsson et al. 2009] and the fulfillment of the information needs of all relevant service process stakeholders [Becker et al. 2011].

14 Considering the large scope of service operation functions (e.g. from field service and remote service, over data management to analytics and knowledge management) [Neff et al. 2014b], equipment manufacturers cannot develop all the capabilities necessary to provide those functions at the same time.
IS-driven service transformation in their engineering and production-dominated environment [Neff et al. 2014a].

The scholarly literature on strategic IS planning and IT management refers to IT governance as “specifying the framework for decision rights and accountabilities to encourage desirable behavior in the use of IT” [Weill 2004, p. 3]. Rather than studying contingency analyses [Sambamurthy/Zmud 1999] or structural issues of IT governance forms [Schwarz/Hirschheim 2003], this dissertation follows the approach of De Haes and Van Grembergen [2009] in investigating IT governance implementations through a more granular view of concrete practices. For usage and implementation in daily business, IT governance is operationalized as governance mechanisms in organizations [De Haes/Van Grembergen 2004, Ross/Weill 2005]. One can differentiate between three types of governance mechanisms: structures, processes and relational mechanisms [De Haes/Van Grembergen 2009]. While IT governance structures constitute “structural (formal) devices and mechanisms for connecting and enabling horizontal, or liaison, contacts between business and IT management (decision-making) functions” [Peterson 2004, p. 12], IT governance processes are regarded as “formalization and institutionalization of strategic IT decision making or IT monitoring procedures” [Peterson 2004, p. 13]. The third type of IT governance mechanisms, relational mechanisms, is understood as “the active participation of, and collaborative relationship among, corporate executives, IT management, and business management” [Peterson 2004, p. 14]. The governance mechanisms that are especially relevant for this doctoral thesis are project governance and management methods (e.g. in the form of a maturity model [Becker et al. 2009]) as well as performance measurement based on De Haes and Van Grembergen [2009] as well as Van Grembergen [2004].

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15 Literature reviews on IT governance and its origin in the corporate governance and strategic IS planning disciplines can be found in Brown and Grant [2005] and Webb et al. [2006].
3 Research Results

Figure A3-1 provides an outline of the research results of this dissertation. There are three research questions that are addressed within three research projects: (1) the theoretical background and research gap, (2) the implementation of service operation functions in the equipment manufacturing industry and (3) governance mechanisms for transforming the information systems support of service operations in equipment manufacturing enterprises.

Following the incremental structure of this thesis, the individual research projects feature an increase in detail. In line with this notion, the theoretical background and the research agenda are sharpened (Part A Chapter 3.1). Subsequently, the information systems implementations of service systems in the equipment manufacturing industry are studied. Using a multiple case study approach as well as standardization literature, relevant service functions can be identified and demarcated within the existing information systems landscape. The findings of this study (i.e. the developed reference
model and the service functions) are then reflected in the results of a structured literature review performed for each function (Part A Chapter 3.2). It turns out that the transformation from traditional manufacturing to firms encompassing service systems drives the service divisions beyond their resource constraints (i.e. they cannot develop capabilities for all service operation functions in parallel). Being an all-embracing, multifarious and complicated task with a comprehensive cluster of business and technology-related issues, this transformation calls for prioritization and a control instrument for the individual change measures. Managerial practitioners outline the need to achieve a broad view of service-related design and transformation projects. Governance mechanisms are derived as valid instruments that stipulate the effective management of this complex and heterogeneous transformation process. After this analysis, a maturity model has been developed that demonstrates the application of an instrument to govern and control (Part A Chapter 3.3).

### 3.1 Theoretical background and research gap

Article I and chapter 2 (Part A) form the theoretical background of this dissertation and establish the research gap. In accordance with Hevner [2007], the first research project provides “past knowledge to the research project to ensure its innovation” [2007, p. 90].

Chapter 2 introduces the central definitions and concepts in order to achieve a shared understanding [Zorn/Campbell 2006] for the entire dissertation. This becomes necessary to demarcate the field of interest from related research and to confirm the validity through contextualization. First, the notion of a service system in manufacturing is sharpened by the existing interdisciplinary body of literature and differentiated from the traditional service science discipline. Then, the service operation focus from a manufacturer’s viewpoint is explored and demarcated from service strategy, design and controlling activities. After that, the IS appropriation employed by manufacturing firms for service operation activities is described. This dissertation obtains an IS perspective on back stage service systems. Based on the complex and heterogeneous transformation tasks the equipment manufacturer is undergoing [Neff et al. 2014a], the relevance of governance mechanisms is derived (cf. Part A Chapter 1.1, Chapter 2.4, Article IV [Neff et al. 2013a]). In the context of building capabilities for implementing service operations models, governance mechanisms are derived as a means to control and manage individual change measures under conditions of resource scarcity (cf. Article VI [Neff et al. 2014a]).

Article I presents a literature review that is conducted according to the structured process suggested by vom Brocke et al. [2009]. This literature review comprises a conception, an analysis, a synthesis and a research agenda. The beginning features a presentation of the relevant definitions in the product-related service context. The concepts service system and product-service system achieve the most hits in the literature
search and fit appropriately with the manufacturing-related transformation challenge. The former refers to the value co-creation through the configuration of actors (e.g. people and their knowledge) and resources (e.g. information and technology) [Vargo/Lusch 2004] that connect internal and external service systems [Maglio/Spohrer 2008]. Böhmann et al. [2014] conceptualize the service system as a “socio-technical system that enables value co-creation guided by a value proposition” [2014, p. 74]. The latter term, product-service system, features the integration of product and service, while IS scholars focus on the architecture and interactions of service systems [Böhmann et al. 2014]. Further, the lifecycle of product and service bundles has become an essential part of this notion [Aurich et al. 2006, Becker et al. 2010]. In order to derive a research agenda, the results of the literature search are analyzed and synthesized. The analysis is presented in a matrix that demonstrates several focal points. The objective of IT is half efficiency-driven and half value-oriented. The literature review confirms the essential role of customer interaction and co-creation. There is a strong focus on investigated business-to-business scenarios. Manufacturing is the dominant industry sector in the studied articles. Startup and operation are the lifecycle stages that achieved the most hits, while the disposal stage has been neglected. For the actual topic of interest, the articles relevant to the individual lifecycle stage are investigated regarding the employed IS support. The outcome is synthesized in a concept matrix [Neff et al. 2012, p. 9 f.] that takes the lifecycle stages (startup, operation and disposal) [Becker et al. 2010] and confronts those with the IS support, which refers to individual software and standard software. Accordingly, the need for research can be crafted. Article I reveals sparsely covered research on the IS support of service systems. The reason behind this lies in the clear focus of service science on studying the front stage of the service system involving value co-creation, marketing and customer interaction [Glushko/Tabas 2009]. On the contrary, there is a lack of studies focusing on the back stage of service systems. Only a few studies conducted on enterprise applications are situated in the startup stage, while for the operation stage proprietary software [Väyrynen 2010] is prevalent. The disposal stage is not a subject of interest. For the operation stage, scholarly research has identified the need to further investigate remote service [Paluch/Blut 2011] or field service [Thomas et al. 2007]. This notion is confirmed by Beverungen et al. [2008] who state that the standardization of services can leverage a coherent integration of products and services. The implementation of service operation functions based on their existing IS landscape is the least understood topic. Further, the startup stage is concerned with strategy and requirement engineering, but governance mechanisms for the effective control and management of the service transformation remain unaddressed.

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16 Becker et al. [2010] assign services to the lifecycle stage of the corresponding product.
3.2 The implementation of service operation functions in the equipment manufacturing industry

Article II and Article III investigate the service operation functions in the equipment manufacturing industry and the corresponding IS implementations in the context of the existing enterprise application landscape. The articles address the research gap concerning a clear definition and demarcation of service operations from a functional viewpoint. In the practice of equipment manufacturers, the shortcomings of enterprise applications lie in the omission of relevant service functions (e.g. remote service is not supported) and in the ambiguous assignment to enterprise layers (e.g. installed base management exists in CRM and ERP and sub-functions are assigned to different layers). Moreover, similar functions are supported by enterprise applications, which facilitates redundancy. As a consequence, difficult and expensive integration projects have to be conducted, while standardization is still far out of reach (cf. Article II [Neff et al. 2014b]).

Using a multiple case study approach, standardization literature and expert interviews, Article II builds and evaluates a functional reference model (cf. [Becker/Schütte 2004, Fettke/Loos 2007]) that renders relevant service functions within the existing information systems landscape. The study explores “which functionalities belong to service management and structures the service functionalities along the enterprise application layers” [Neff et al. 2014b, p. 2] (i.e. corporate, customer plant and customer shop floor layer) [Louis/Alpar 2007, Schmidt et al. 2011]. The research results outline the functional requirements for realizing those service functions in the modern IT architecture. Service management functionality is present in all three layers. Core planning functionality comprises, for instance, knowledge management or warranty claim management and is usually provided by enterprise applications such as ERP or CRM. Located between the internal corporate and the external (i.e. customer) plant layer, some functionalities (e.g. remote service) remove organizational boundaries. This assignment to multiple layers is associated with complex integration issues for the supporting application systems. Nevertheless, these cross-boundary functions are very important, since they can give corporate access to valuable customer knowledge on the equipment in use and on the customer production environment that is buried in the subsequent customer layers. Article III complements the findings concerning the model and its evaluation with a structured literature review [vom Brocke et al. 2009]. In order to critically reflect the research results of Article II, a structured literature review has been performed for 12 individual functions. The analysis of the search results suggests a differentiation between peripherally and thoroughly addressed service functions. There have been some surprising insights. For instance, service analytics has not received much attention in the scholarly literature and is featured in only two articles (cf. Article III [Neff 2015]). One article investigates the usage of analytical capabilities, such as data mining, for the management of customer intimacy [Habryn et al. 2012], while vom
Broke et al. [2014] study the optimization levers of in-memory technology for, inter alia, maintenance operations and design-to-service re-engineering in the manufacturing industry. In the synthesis, each service function is operationalized, which allows differentiation but also provides an indication of the interdependencies that are potential sources of redundancy. These interdependencies further outline the complementary as well as boundary-spanning characteristics [Leifer/Delbecq 1978] of clusters of service functions. The discussion elaborates how field service and remote service supply other service functions (e.g. installed base management or contract management) with customer information by bridging the organizational boundary between equipment manufacturer and client [Jonsson et al. 2009]. The underpinning function data management, thereby, plays a crucial role in the collection and diffusion of information [Becker et al. 2013b].

With the results of Article II and Article III, research question 2 has been addressed to derive an understanding of the challenges and objectives of the implementation of the service operation functions of equipment manufacturers. The resulting artifacts present a first appropriation of the functional building blocks for service operation management relevant to the equipment manufacturing industry.

3.3 Governance mechanisms for transforming the information systems support of service operations in equipment manufacturing enterprises

Following the notion that governance is relevant (cf. Article I [Neff et al. 2012], Article IV [Neff et al. 2013a] or respective Part A Chapter 3; Chapter 3.1; Chapter 3.2), the governance mechanisms for coordinating and controlling the IS support of service operations for equipment manufacturers are analyzed and built.

Article IV investigates the governance mechanisms in terms of their impact on business process performance in multi-business, primarily manufacturing-oriented enterprises. Based on the notion that IT resources can foster integration and support of corporate resources to provide valuable business processes, e.g. customer services [Ray et al. 2005, Thomas et al. 2007], and that IT governance is a commonly accepted tool in establishing and maintaining efficient and effective usage of IT resources [Weill 2004], an explanatory model has been developed to explore the relationship between IT and business process performance. With the digitalization of the industry, data assets have become crucial for making smarter, data-driven business decisions [McAfee/Brynjolfsson 2012]. Since data assets refer to the outcome of IT resources [Raghunathan 1999] and good data governance should be closely intertwined with IT governance practices [Khatri/Brown 2010], Article IV conceptualizes an integrated

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17 IT resources (as technical assets) drive the automation of specified tasks, whereas data resources represent the factual documentation [Khatri/Brown 2010].
approach to balance IT and data governance practices. Resource relatedness makes allowances for the derivation of synergy\textsuperscript{18} sources in the multi-business environment [Davis/Thomas 1993, Campbell 1998]. Since IT resources tend to add value indirectly, i.e. through the mediation of closely linked and complementary resources [Mata et al. 1995, Melville et al. 2004], resource relatedness has been positioned as a mediating construct between IT and data governance as well as business process performance. The construct covers both the common usage of IT management processes and resources (IT relatedness) [Tanriverdi 2006] as well as data relatedness (i.e. the usage of common data resources and management processes such as data architecture capabilities, data analytics capabilities and data quality management) [Goodhue et al. 1992, Wang/Strong 1996, Raghunathan 1999] across different business units. The case study insights are analyzed alongside the model and the proposed relations (i.e. five propositions). The outcomes suggest that a higher maturity of IT and data governance (structures, processes and relational mechanisms) [De Haes/Van Grembergen 2009] positively influences the use of common IT resources and data resources across business units which, in turn, has a positive impact on business process performance. The data analysis reveals that operational service processes and product design benefited most from IT and data-driven harmonization and consolidation initiatives that are coordinated by governance practices. For instance, a “360 degree view on the business customer’s installed equipment” supports field service processes [Neff et al. 2013a, p. 7], while the data cleansing of “digital failure protocols and sensor data” contributes to the product and service design [Neff et al. 2013a, p. 6]. Further, Article IV provides an indication of the levers that increase process performance. A pattern is observable for firms that are successful in managing their cross-divisional resources. The smart combination of IT and data resources can lead to super-additive value synergies. Installed base management and condition monitoring as well as mobile computing and field service can constitute two promising pairs, so long as the required data quality and data integration can be ensured.

The findings of Article IV represent a strategic, analytical frame based on the resource based view, but remain limited in their level of detail. Nevertheless, the levers outline how some organizations have succeeded in managing service functions and technological capabilities. Considering the number of service functions and operationalized categories described in Article II and Article III, equipment manufacturers, being limited in their resources, are not capable of pursuing all functions at the same time. Building this broad scope of technological and service-related capabilities refers to a transformation process. Being confronted with such a complex, organizational challenge, the equipment manufacturer’s management has to derive and prioritize concrete transformation measures. A maturity model is considered as an established instrument for

\textsuperscript{18} In this case, synergies refer to economies of scope [Robins/Wiersema 1995, Tanriverdi/Venkatraman 2005]. Further, the outcomes of synergies are defined as sub-additive cost synergies and super-additive value synergies [Tanriverdi/Venkatraman 2005].
“supporting” the “effective management” of this “complex and heterogeneous” phenomenon [Neff et al. 2014a, p. 896]. Scholars suggest maturity models to be important instruments for developing and deploying IT effectively and efficiently [Becker et al. 2009]. In this light, Article V and Article VI are concerned with the construction and evaluation of the maturity model. The model’s development follows the procedure model of Becker et al. [2009] and is in line with the design science research approach [March/Smith 1995, Peffers et al. 2007]. This governance mechanism represents a conceptual model that outlines a typical, expected and evolutionary path in the application of a particular ability or in the achievement of a targeted end stage [Becker et al. 2009]. Further, maturity models are used to assess and benchmark the current situation. Drawing on this analysis, corporate capabilities can be developed and improved on a continuous basis [Paulk et al. 1993]. While maturity models make allowances for controlling the actual progress, they serve as management instruments that help to make the investment decisions necessary to advance the entire process of connected and complementary capabilities. Article VI is a significantly revised version of Article V, which is limited to early iterations of the model’s construction (cf. Part A Chapter 4.5 and Chapter 4.6).

The maturity model aims at facilitating the implementation of information systems support for service operations in equipment manufacturing enterprises as well as at increasing transparency by allowing a continuous measurement of the implementation. The problem identification yields requirements in the fields of “integration of service offering into the business model”, “service quality”, “installed base management”, “integration of product and service data” and “data quality assurance” [Neff et al. 2014a, p. 900 f.]. Using case study reports, standard specification literature, a literature review of existing maturity models and focus group analysis, the individual cells for each sub-dimension (informed by the requirements) are elaborated iteratively. Given the importance of the transformational aspect, the model is organized around the integration of the service offering into the business model (i.e. “the level descriptions should indicate how the transformation evolves along the cells”) [Neff et al. 2014a, p. 903]. For the ordinate, the sub-dimensions are classified and structured according to theoretically well-accepted dimensions. The underlying maturity concept serves as a theoretical lens for the model and is aligned with the notion of IS as a technological promotor of the service transformation (i.e. the IT artifact) [Benbasat/Zmud 2003] and the transformational impact of IT (i.e. strategy, organization and environment) [Agarwal/Lucas Jr 2005]. While the sub-dimensions of a particular service model remain distinct, the capabilities show interdependent and complementary characteristics at the same time. This becomes obvious when equipment manufacturers shift from reactive service models to a performance contracting-based mode. Internal efficiency and effectiveness goals, which accompany the maximization of customer interactions, are replaced by the customer’s output generation of the deployed equipment (equipment reliability or equipment’s output quality). The changed performance indicators can make the de-
ployment of sophisticated technical capabilities necessary and rentable. Continuous access to equipment’s sensing capabilities from a centralized remote service center becomes crucial for ensuring the agreed volume of output. Since customer operations are reduced, spotting, preventing or predicting machinery incidents is primarily conducted by off-site service technicians from the equipment manufacturer. Mobile solutions help the field service to prepare customer on-site activities with the right tools and spare parts as well as the accurate knowledge base. The fast-paced, almost real-time reactions that are necessary for performance-based models require a shared, unified view of customer equipment with high data quality (e.g. in terms of accuracy by means of serialized data structures) and automated data integration capabilities.

Article IV, Article V and Article VI address research question 3.
4 Summary of the Publications

The following subchapters provide the complete bibliographical details of the individual dissertation contributions and give a short summary of the content. Table A4-1 serves as an overview and assigns the contributions to the relevant research questions. The order of the contributions in Table A4-1 is, thus, based on the sequence of the research questions. The Articles I-VI are imprinted in Part B and combined with Part A to form the cumulative dissertation at hand. The contributions printed in Part B explicitly answer the research questions RQ.1, RQ.2 and RQ.3, which have been outlined in chapter 1.2.

In the context of this dissertation and related research projects, elaborated findings have been continuously published in the form of scientific papers. In total, 16 papers\(^\text{19}\) have been written with the participation of the author (this comprises research in progress work or further work closely related to the research projects), while 12 papers have been created in primary authorship. A complete overview of publications can be found in Appendix A.

<table>
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<tr>
<th>Article</th>
<th>Chapter</th>
<th>Title</th>
<th>Publication Outlet</th>
<th>Research Question</th>
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<tbody>
<tr>
<td>I</td>
<td>4.1</td>
<td>The Influence of Information Technology on Industrial Services in the Manufacturing Industry – A Literature Review and Future Research Directions</td>
<td>Pacific Asia Conference on Information Systems, 2012</td>
<td>RQ.1</td>
</tr>
<tr>
<td>II</td>
<td>4.2</td>
<td>Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry</td>
<td>European, Mediterranean &amp; Middle Eastern Conference on Information Systems, 2014</td>
<td>RQ.2</td>
</tr>
<tr>
<td>III</td>
<td>4.3</td>
<td>Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis</td>
<td>Institute of Information Management, University of St. Gallen, 2015</td>
<td>RQ.2</td>
</tr>
<tr>
<td>IV</td>
<td>4.4</td>
<td>Explicating Performance Impacts of IT Governance and Data Governance in Multi-Business Organisations</td>
<td>Australasian Conference on Information Systems, 2013</td>
<td>RQ.3</td>
</tr>
<tr>
<td>VI(^\text{20})</td>
<td>4.6</td>
<td>Developing a Maturity Model for Service Systems in Heavy Equipment Manufacturing Enterprises</td>
<td>Information &amp; Management, 2014</td>
<td>RQ.3</td>
</tr>
</tbody>
</table>

\(^{19}\) Of these, 13 papers are subject to a double-blind review process and three papers represent working papers that have been published by the Institute of Information Management at the University of St. Gallen.

\(^{20}\) Article VI is a substantially revised version of the work published in Article V. Article V features early iterations of the model development and remains very limited in terms of the design science process steps, e.g. evaluation.

Table A4-1: Categorization of central contributions and research questions addressed
4.1 Article I: The Influence of Information Technology on Industrial Services in the Manufacturing Industry – A Literature Review and Future Research Directions

<table>
<thead>
<tr>
<th>Title</th>
<th>The Influence of Information Technology on Industrial Services in the Manufacturing Industry – A Literature Review and Future Research Directions</th>
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<tbody>
<tr>
<td>Author(s)</td>
<td>Alexander A. Neff, Thomas Ph. Herz, Falk Uebernickel, Walter Brenner</td>
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<tr>
<td>State</td>
<td>Published</td>
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Table A4-3: Bibliographical Details of Article I (“The Influence of Information Technology on Industrial Services in the Manufacturing Industry – A Literature Review and Future Research Directions”)

Summary

In order to respond to shrinking margins, heated competition and to meet new customer requirements, manufacturing firms have recently started to include service offerings in their business portfolio. Based on the fact that firms’ information systems are built and optimized for production planning, IT support for the new service business is lacking in terms of both efficiency and functionality. In order to obtain a better understanding of the “information systems for service operations” field of research and the respective research gaps, the paper conceptualizes all relevant terms of the topic such as service, service system and product-service system. Next, an extensive literature review guided by an established literature review framework [vom Brocke et al. 2009] has been conducted. This review reveals the status quo of product-service systems and the corresponding IS support in the literature. The current literature insufficiently covers the specificity of industrial services in IT solutions supporting lifecycle management. The IS support for product-service systems is sparsely covered along all three lifecycle stages of product-related services based on Becker et al. [2010]: the start-up stage, the operation stage, and the disposal stage. Both the start-up stage and the disposal stage do not enjoy much scientific attention, while the IS support for product-related services at the operation stage is most likely developed in-house or proprietary. Thus, we propose further research on requirements engineering, IT architecture, IT infrastructure, IT governance, and sourcing.
4.2 Article II: Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry

<table>
<thead>
<tr>
<th>Title</th>
<th>Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry</th>
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<tbody>
<tr>
<td>Author(s)</td>
<td>Alexander A. Neff, Falk Uebernickel, Stephanie Lingemann, Walter Brenner, Matthias Herterich</td>
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<td>State</td>
<td>Published</td>
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Table A4-4: Bibliographical Details of Article II (“Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry”)

Summary

One of the key challenges that heavy equipment manufacturing firms have to meet is the integration of service planning and execution in their established product-centered IS environment. The difficulty of finding an appropriate IS solution for their service offerings is aggravated by the strategic need to lower operating costs and to meet the ever growing industrial service demands of their customers. Existing applications fail to adequately execute the service specific requirements. The extant literature lacks a clear perspective on the IS appropriation for service management in heavy equipment companies as well as a clear functional design. The present paper provides a distinct understanding of which functionalities belong to service management and structures the service functionalities along the enterprise application layers by developing a functional reference model. The model design follows the design science approach as the reference model combines a number of functionalities that were derived from a structured literature review with insights from focus group and case study research involving eleven heavy equipment manufacturing firms and two software companies. The reference model is evaluated based on four perspectives and the evaluation demonstrates its relevance. The model not only closes the theoretical knowledge gap regarding service functions and demarcation in existing enterprise application landscapes, but also serves as a management tool in order to analyze and improve service management.
4.3 Article III: Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis

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<th>Title</th>
<th>Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis</th>
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<tr>
<td>Author(s)</td>
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<td>State</td>
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Table A4-5: Bibliographical Details of Article III (“Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis”)

Summary

For manufacturing firms, the offering of industrial services is a valuable source of revenue and growth. However, adding services to the product portfolio is associated with a challenging transformation of strategy, structure and business process levels. One key challenge is the integration of service planning and execution into the established production-centered information systems. The existing enterprise information systems are not designed for service business specifics. In the existing enterprise application landscape, it is unclear how service functionality can be defined and delimited along with enterprise application layers. In Article II [Neff et al. 2014b], a functional reference model is developed that identifies the key functions that belong to service management functionality. This model serves as the basis for the paper at hand, which presents a structured literature review for each of the 12 service functions. In total, 91 articles were analyzed and synthesized in two comprehensive matrices. Thereby, the paper allows for a structuration and conception of service functions and, additionally, identifies interdependencies among the 12 service functions. Further, the idea of the service functions being complementary to one another and their ability to span organizational boundaries are discussed.
4.4 Article IV: Explicating Performance Impacts of IT Governance and Data Governance in Multi-Business Organisations

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<tr>
<th>Title</th>
<th>Explicating Performance Impacts of IT Governance and Data Governance in Multi-Business Organisations21</th>
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</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Alexander A. Neff, Maximilian Schosser, Saskia Zelt, Falk Uebernickel, Walter Brenner</td>
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<td>State</td>
<td>Published</td>
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Table A4-6: Bibliographical Details of Article IV (“Explicating Performance Impacts of IT Governance and Data Governance in Multi-Business Organisations”)

Summary

Data-driven decision-making in multi-business enterprises, e.g. between product and service division, can lead to sustained competitive advantages [McAfee/Brynjolfsson 2012]. By combining data and IT assets on an enterprise-wide level, a 360 degree view of customer equipment can be used for integrating and supporting valuable IT-based business processes such as field service planning and product design. While IT resources facilitate the automation of structured tasks, data assets present the accurate documentation [Khatri/Brown 2010]. Since ensuring above-average returns on technology investments has remained a challenging task and governance mechanisms represent an accepted strategic tool to establish and maintain effectiveness and efficiency in the usage of both complementary assets in multi-business firms, a combined approach of data and IT governance is postulated. The paper analyses how IT and data governance increases process performance via the mediators of IT relatedness and data relatedness. To explain the positive impact of IT and data governance on business process performance, the authors apply the resource-based perspective, the economic theory of complementarities and the concept of relatedness. The results of the conducted multiple case study suggest that a higher maturity in terms of IT and data governance processes, structures, and relational mechanisms has a positive impact on both IT relatedness – the use of common IT resources across business units [Tanriverdi 2006] – and data relatedness – the usage of common data resources and data management processes across business units [Campbell 1998]. The use of common IT and data resources, in turn, positively affects business process performance. Processes in service operations and product development are most likely to benefit from IT and data-driven harmonization and consolidation initiatives that are coordinated by governance practices.

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21 This article is part of a publication path that includes a set of articles with research in progress work on this issue. Please find more information and an overview of all publications in the appendix (Appendix A).
4.5 Article V: Fostering Efficiency in Information Systems Support for Product-Service Systems in the Manufacturing Industry

<table>
<thead>
<tr>
<th>Title</th>
<th>Fostering Efficiency in Information Systems Support for Product-Service Systems in the Manufacturing Industry22</th>
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<tbody>
<tr>
<td>Author(s)</td>
<td>Alexander A. Neff, Florian Hamel, Thomas Ph. Herz, Falk Uebernickel, Walter Brenner</td>
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*Table A4-7: Bibliographical Details of Article V (“Fostering Efficiency in Information Systems Support for Product-Service Systems in the Manufacturing Industry”)*

**Summary**

In order to adapt to the changing market environment and increasing service demands of customers, manufacturing firms shifted towards a stronger service orientation. While the paradigm change from a product-dominant to a service-dominant logic in the manufacturing industry has been widely accepted in both theory and practice, enterprise information systems are ill-suited for planning and executing industrial services. In the context of ever-increasing service and the need to reduce operating costs, several key requirements for the information systems supporting product-service systems have been identified based on a multiple case study. As a literature review reveals, the six requirements (business model, controlling objects, installed base management, mobile solution, enterprise integration, and data quality) are insufficiently covered in the existing maturity models and, thus, the development of a new maturity model is necessary. To build such a model, the design science research approach [Hevner et al. 2004, Peffers et al. 2007] has been utilized. The authors propose a novel maturity model for the IS support of industrial product-related services and, thus, address a real-world problem while simultaneously contributing to the scientific and practitioners’ body of knowledge. To critically review the maturity model, a multiperspective approach has been followed “organized in accordance with approved evaluation perspectives” [Neff et al. 2013b, p. 1].

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22 This article is part of a publication path that includes a set of articles with research in progress work on this issue. Please find more information and an overview of all publications in the appendix (Appendix A).
4.6 Article VI: Developing a Maturity Model for Service Systems in Heavy Equipment Manufacturing Enterprises

<table>
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<tr>
<th>Title</th>
<th>Developing a Maturity Model for Service Systems in Heavy Equipment Manufacturing Enterprises</th>
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<tbody>
<tr>
<td>Author(s)</td>
<td>Alexander A. Neff, Florian Hamel, Thomas Ph. Herz, Falk Uebernickel, Walter Brenner, Jan vom Brocke</td>
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Table A4-8: Bibliographical Details of Article VI (“Developing a Maturity Model for Service Systems in Heavy Equipment Manufacturing Enterprises”)

Summary

Following the paradigm shift from a product-dominant logic to a service-dominant logic, heavy equipment manufacturing firms aim at exploiting the full-service potential of their products. However, finding an appropriate information systems solution supporting service-systems and integrating the service planning and execution in their established product-centered information systems environment remains a challenge for the manufacturers. In the extant literature, there is neither a common understanding of service systems in industry goods companies nor of the corresponding requirements for the appropriation of information systems. The present paper addresses this knowledge gap by developing a maturity model based on a multiple case study and two focus group workshops with leading manufacturing firms from the heavy equipment goods industry. The maturity model is structured according to the “integration of service offering into the business model” [Neff et al. 2014a, p. 903 f.] and contains the following elements: performance measurement of industrial services, installed base management, mobile support for the service workforce, integration of service and product data, and data quality assurance. As evaluation is a substantial element of design-oriented research, the “utility, quality, and efficacy” have been verified [Hevner et al. 2004, p. 83 f.]. It has been confirmed that the maturity model makes a novel and useful contribution not only through its thorough coverage of the relevant requirements, but also through its exclusive focus on the back stage IS in the service system domain.

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23 This article is part of a publication path that includes a set of articles with research in progress work on this issue. Please find more information and an overview of all publications in the appendix (Appendix A).
5 Discussion and Future Research

Part A concludes with a critical reflection, supplemented with the limitations and a suggestion regarding future research for the entire dissertation. Further, each singular article comprises an individual discussion tailored to its specific scope (Part B).

5.1 Implications for research

The presented dissertation seeks to investigate the information systems realization of service operations in the industrial equipment manufacturing industry. This notion is expressed by means of the overarching guiding question (How can information systems foster efficiency in service operations for the manufacturing industry?). The guiding question has been substantiated into three research questions. In the following, the research results are discussed in relation to the specific research questions.

RQ.1 seeks to shed light on the current state of service research in the context of manufacturing-related transformation challenges from an IS viewpoint (What is the current state of knowledge regarding the service systems of manufacturing enterprises in information systems research?). Service science prefers to study front stage phenomena such as service innovation, customer co-creation and service marketing issues [Glushko/Tabas 2009]. Hence, Article I concludes that the IS support for service systems remains sparsely covered in the extant literature. This dissertation confirms the suggestion of Becker et al. [2011] to study the back stage aspects of the service system. Beyond their suggestion to investigate the business process layer, this research complements service research through the identification of the disregarded layers of enterprise systems and data management. The importance of the lifecycle is covered in operations management literature and confirmed by IS scholars [Becker et al. 2010]. Following the increase in usage or output based offerings, equipment is handled as a platform for the service. Since the startup, operations and disposal stages remain key activities that now fall within the responsibility of the manufacturers, the lifecycle becomes an essential component in the service business. This work highlights the importance of information systems (i.e. both transactional and analytical) that fulfill the information needs of the equipment in distinct lifecycle stages. Although there are several articles addressing the lifecycle issue, the confrontation of the lifecycle stages with the IS support outlines the under-researched dimension in terms of standard and proprietary software. The startup and disposal stages can be neglected, while the operation stage enjoys considerable discussion in the IS literature, particularly the challenges associated with the integration of service requirements into product-centered information systems. There is a strong indication for extensive use of individual, highly customized and proprietary software to support and process information for service operations processes, e.g. remote service, field service and maintenance. Tying up in this line of argument, IS scholars postulate the need for designing a service platform [Böhmann et al. 2014] that aims for a more suitable architecture and for the interaction...
of service systems. However, the service requirements in this field are parsimoniously explored, while current IS implementations remain the least understood aspect alongside the integration of product and service.

In view of the identified research gap concerning the back stage service systems of manufacturing enterprises, RQ.2 addresses the relevance of the need to understand which service operation functions are used by equipment manufacturers to run their service systems. Further, RQ.2 seeks to explore how these equipment manufacturers implement the service operation functions based on their existing IS landscape. Article II constructs and evaluates a reference model that explores and conceptualizes application functions for service operations from a functional viewpoint. Thereby, this research endeavor contributes to the knowledge base in “architecture of service systems by recognizing the connectedness and complementarity of these elements in enabling value co-creation” [Böhmann et al. 2014, p. 74]. Bearing in mind the long-term goal of a service platform, this reference model presents an early appropriation of the building blocks that can be used later as an input factor in the design of an IS architecture for service systems. The reference model renders the integration challenge of product and service on the architectural level. The research gap on service functions and demarcation in present enterprise application systems is addressed, which provides insights into the ERP and CRM literature. With the addition of customer production, the reference model facilitates the extension of architectural research on service systems. Beyond enterprise resource planning, the applications in the plant and shop-floor layers, e.g. MES and automation systems, become relevant to service research. Since the reference model connects a view of internal IS applications with the external customer production and its components as serviced installed base, this research endeavor is related to the research body of inter-organizational systems. The results of the literature search in Article III substantiate this relation as a category in the service collaboration function. Moreover, Jonsson et al. [2009] even classify a remote diagnosis system as an inter-organizational system. The boundary-spanning practices and boundary object literature provides a theoretical lens through which to analyze value co-creation in service systems. Following the notion of considering field service and remote service as boundary-spanning practices, the fit of this theoretical lens has been demonstrated in Article III. This lens includes not only the organizational boundaries between equipment manufacturer and customer, but can also be applied to departmental boundaries within the manufacturer or between individuals (e.g. service technician or operator). Beyond the structuration and demarcation of service functionality along the enterprise application layers, this research endeavors to identify complementary clusters. The boundary-spanning lens has been applied in this context to identify the entry points that leverage the acquisition of customer insights. Field service and remote service have been identified. Each of them is a boundary-spanning practice that eliminates the organizational boundary between the manufacturer and customer to gain customer information. The inclusion of external information sources, such as equipment in use
information and contextual information on customer production processes, allows a
digital refinement of existing internal planning information into valuable customer
knowledge. Data management issues are crucial for making information flow to enable
an enterprise-wide distribution for the processing of other service functions. This dis-
sertation extends the narrow view of data management (e.g. as track pattern recogni-
tion) toward an enabling role for customer knowledge (i.e. data objects as units of ex-
change) in service operations. The supplied service operation functions apply customer
equipment and contextual information for creating valuable customer knowledge.

RQ.3 aims at the identification of the requirements relevant for the transformation of
the IS support for service systems (What are the key requirements for transforming
information systems support of service systems in order to offer service-oriented busi-
ness in the equipment manufacturing industry, and how can the transformation be co-
ordinated?). In order to make the equipment manufacturer ready for offering service-
oriented business with efficient means, management is challenged by a broad business-
to-IT related scope under resource limitations. Governance mechanisms are considered
an appropriate means to coordinate and control this transformation. Article IV analyz-
es governance mechanisms regarding their influence on business process performance
with a focus on equipment manufacturers. Governance mechanisms (operationalized
as structures, processes and relational mechanisms) are included in the service systems
research. Mature governance practices drive the consolidation and harmonization
throughout the business units responsible for service and production. The complemen-
tary bundle of common IT resources and common data resources, in turn, positively
influences process performance in terms of synergies. Data relatedness, thereby, ob-
tains the role of a mediating construct, which is in line with previous IT business value
studies stating the non-direct value creation of IT resources. Complementary resource
pairings refer to installed base management and condition monitoring or mobile com-
puting and field service. This research extends service science by applying the multi-
business characteristics to manufacturing enterprises. This fits with the manufacturing
firms, since they are structured in a few centralized business units responsible for pro-
duction and numerous business units responsible for sales and service. Moreover, the
sales and service entities are subsidiaries located in countries with rentable markets.
The use of common data and IT resources across the business units (i.e. resource relat-
edness) has been identified as a potential source for the desired synergy effects. Fur-
ther, Article IV presents an important step in merging governance practices for the
regulation of decision rights and accountabilities of IT and data resources into a com-
bined approach, since IT and data resources are usually studied separately within
scholarly literature [Khatri/Brown 2010].

Articles V and VI design and evaluate a maturity model that is an accepted means by
which to approach complex and heterogeneous phenomena (e.g. coordinating and con-
trolling the transformation the IS support of service systems). The research endeavor
adds enterprise application and data management as relevant components to the integration layer between the front stage and back stage of the service system. Previous studies address enterprise application systems when defining the service system’s requirements and specifications, but are limited in terms of connectedness and contextualization. The maturity model refines the IS-based linkage between front and back stage service systems with the specifics of the equipment manufacturer that adopts service systems as part of a modified business model. While production system-orientation is deeply rooted in the ERP research [Jacobs/Weston 2007] and manufacturing processes neglect a service dimension, the maturity model proposes an integrated view of business process research in manufacturing and service systems research.

There is an established field in business process research that addresses the organizational modifications of manufacturers relevant for including services into the corporate portfolio. The maturity model complements this research by emphasizing the IS role in making the organizational service models work. For a particular service model, the capabilities in the model feature a minimum baseline for the implementation. Tailored to the manufacturer’s specifics and his role as service provider, the model introduces a heterogeneous set of required capabilities (from performance measurement over installed base management to data quality assurance). The model complements research on inter-organizational systems by outlining the data management requirements needed for information convergence. Various data sources with varying data quality are collected and merged with views that allow for the interpretation, for instance, of the installed base. These data sources comprise digitalized equipment [Candell et al. 2009, vom Brocke et al. 2014], mobile computing [Matijacic et al. 2013], analytical and transactional application systems [Li et al. 2012, Peltier et al. 2013] as well as proprietary solutions [Jonsson et al. 2008, Neff et al. 2014a]. Relevant structures refer to technical drawings, bills of material, service orders, service contracts, spatial data, functional locations and sensor data, amongst others. Although the model’s elements cover a broad scope of business to technology-related topics, each of them is explicitly linked to the IS concept that it is a key enabler of transformation. The model extends current research by applying the dimensions of the IS concept as a sensitizing device for structuration. The service transformation is drafted along the maturity levels for service systems and, hence, clearly refers to the macro aspect of IS. In fact, this illustrates the human, task and technology characteristics and, thus, is in line with the social technical system notion.

5.2 Implications for practice

Equipment manufacturers are challenged in manifold ways when using information systems to realize service operations. This section outlines the managerial practitioners’ lessons learned and critically discusses them.
The constructed reference model (Article II or respective [Neff et al. 2014b]) is a management instrument for coordinating the development of service capabilities in equipment manufacturing firms. It provides a holistic view of service operation functionalities and the functions’ affiliations with enterprise application layers. This implies best practices in the form of a suggested blueprint of how to affiliate service function with the appropriate enterprise application layers. The usage of common terms from the model improves both internal (e.g. with subsidiaries and cross-divisional) and external communication (e.g. with software vendors and IT consultancy firms). Therefore, this shared understanding allows the identification of redundant software support for a dedicated functionality. The reference model is not restricted to a deployment in equipment manufacturing, as the model’s flexibility allows the addition and removal of individual service functions to make it fit for other business contexts. By clearly structuring service functions along the enterprise application layers, this model presents a first, conceptual appropriation toward a standardized enterprise platform for the service operations of equipment manufacturers. Although the model is not complete and comes with certain restrictions, it features essential, industry-relevant terms and functionalities that facilitate a dialogue with industry partners, software vendors and IT consulting firms. Using the model allows the identification of redundancies in the application landscape and in the grounding databases. This is particularly incisive due to the organizational structure involving numerous country-specific service subsidiaries that are managed de-centrally, while some service functions are executed centrally (e.g. remote service). Consequently, complex, heterogeneous IS landscapes can be ascertained in the service business.

A standardized, integrated, flexible and scalable enterprise platform that is designed according to the service business needs of an equipment manufacturer is still only a vision. Since most manufacturing enterprises are subject to lock-in effects in terms of their enterprise software contractual agreements, those firms expect and hope that software vendors will combine legacy applications and transaction systems (large investment for rollout and migration) with a novel enterprise platform. Market leaders have developed costly proprietary applications to implement end-to-end service offerings, e.g. remote diagnosis systems to enable remote service. This includes not only the bypassing of functional deficits in the enterprise planning layer, but also the access to production monitoring and shop floor execution at the customer site. In comparison with internal production optimization, there are inter-organizational boundaries between the planning and execution layers that require a service view of the shop floor. To withdraw this data and interpret it from a service viewpoint, an inter-organizational system relies on extensive collaboration that is capable of bridging the abstraction level across the layers. Data structures have to be integrated at the appropriate quality level from shop floor to enterprise planning so that, for example, abstractions in time units can be overcome from day over hour to second basis. Successful service players foster the development of proprietary solutions that entail the use of remote technology.
and sensor monitoring to offer valuable services. The system design is closed to ensure the manufacturer’s competitive advantage over its peers. Early adopters (i.e. manufacturers) of such IT-enabled service offerings claim ownership of any customer and installed base-related data. To a certain extent, this contradicts the collaborative notion in service research. However, it is observable that customer organizations, suppliers and service providers have already noticed that data ownership is crucial for their businesses, while in some industries those groups have captured the rights and accountabilities for the operational, service-related data. The digitalization of equipment can be used during the product development stage to make a design-to-service optimization for the equipment. Equipment’s altered features such as addressability, sensibility and communicability will be optimized for service purposes by means of tweaking measurement points, operating systems and interfaces.

Transformation in this industry is taking place in a dynamic environment and requires a continuous reassessment of the current circumstances. A suitable service operation mode depends heavily on the integration of the service offering into the business model (cf. Article VI [Neff et al. 2014a]). In a more output-driven service mode, the installed base, for instance, might not be the equipment anymore, but the usage which is a combination of serviced equipment and the operations crew. For that reason, the constructed maturity model is structured along the service transformation. The maturity model presents a coordination instrument analyzing the current situation to determine the key levers for improvement in order to unleash the full potential of the IS support for the service system (cf. Article VI [Neff et al. 2014a]).

With the introduction of output-driven service models, operational objectives have shifted from the financial consideration of individual service transactions to a more relationship-based interaction with the customer and his installed base. That means, the interests between equipment manufacturer and customer are aligned in terms of production up-times and output generation of the installed base. In other words, the minimization of total costs has replaced the previous notion of maximizing billable customer transactions. Technical capabilities such as remote diagnosis and the monitoring of digitalized equipment are introduced to reduce or even replace costly, human-intensive field service activities (cf. Article VI [Neff et al. 2014a]). When field service cannot be avoided, the service workforce is appropriately prepared with tools, spare parts and context-dependent information on the installed base and is further supported by remote service center during on-site operations. It is ensured that the service technician has the required skill set, while he also has access to an internal knowledge base, tutorials, service job and installed base information. Equipment-related data represents the focal point as it is processed by all service processes. Hence, a holistic data quality concept becomes inevitable to ensure precise and accurate data. Precision refers to electronic machine records that feature a history of past service events, while
accurate equipment data is reflected in converging serialized description on sold equipment with structural production information (cf. Article II [Neff et al. 2014b]).

The sub-dimensions of the maturity model are also interdependent. A service manager can treat this model practically to identify and structure capabilities that mutually reinforce each other. Of course, this model is not able to comprehensively describe all heterogeneous service-related issues. Instead, the underlying idea is to support managerial investment decisions through providing the minimum baseline for the equipment manufacturer’s implementation ability regarding a concrete service operation model. For each service model, the maturity model reveals which fundamental prerequisites need to be fulfilled. The model outlines which adaptations on the strategic, organization, customer interaction, and IT levels become necessary to master the integration of services into the equipment manufacturer’s business model. On the one hand, the maturity model supports the self-assessment of performance in the service business. Additionally, it serves as an investment decision framework for expanding the service offering. Further, the model allows a critical reflection on the controlling instrument of previous transformation steps.

The complementary capabilities in such a holistic transformation process are valuable levers with which to achieve cross-divisional synergy potentials. By definition, complementary effects suppose that the realization of the sum of combined value is higher than the sum of the individual values (cf. [Davis/Thomas 1993]). Data quality assurance initiatives allow more value creation in the integration of product and service data objects. Data management capabilities can ensure high data quality (cf. [Otto 2011]) with fully automated data integration. This, in turn, drives a single version of truth view concerning customer equipment and contextualization. Taking advantage of this merged and consolidated equipment information, a mature installed base management enables the efficient processing of service jobs. In particular, the usage of remote service and the condition monitoring of digitalized equipment puts the manufacturer in the position to expand his service offering through efficient means. Once a physical customer visit becomes necessary, the field service can rely on mobile computing technology for job preparation, processing and documentation. If the field technician requires on-site assistance, a remote service engineer will give guidance e.g. for knowledge access or facility access. The mobile device allows for appropriate preparation as it presents the access point to client’s installed base and contextual information. Equipped with this information, a data-driven performance measurement can be established to determine profitability in the service offerings.

5.3 Limitations

The research results presented in this dissertation are intended to answer the research questions, but are also subject to various limitations.
The qualitative research design imposes methodological restrictions in terms of validity. The usage of qualitative research methods as part of the design science research process is an accepted means for investigating complex phenomena in the IS discipline. Further, the careful selection of case study companies and managerial representatives with lengthy industry experience should improve the generalizability of the research results. However, a quantitative evaluation would have significantly increased the validity. The results of Articles II, V and VI are evaluated inter alia by expert interviews, focus group workshops and case study research. Data sampling is restricted in terms of a certain number of case companies and interview partners from a specific industry sector (i.e. the equipment manufacturing industry). Data collection for case study research requires different information sources. By capturing three sources, Articles II, V and VI have to be positioned at the minimum level. Quantitative ratios, such as inter-coder reliability for coding procedure, could help to substantiate the findings of the data analysis.

The industry focus on equipment manufacturers that offer services for their produced equipment to business customers limits the generalizability of the research results. Equipment manufacturing enterprises have been selected as the object of interest since those companies encounter a particularly intensive service transformation (i.e. the transition is exceptionally long). They are challenged by the balancing of the main business focuses on engineering and production with distinct service capabilities. In comparison to the consumer manufacturing industry, the installed base of equipment manufacturers is characterized as being long-living, expensive, complex and highly valuable for customers (i.e. as part of the production process). This makes the service more equipment-centered, more service-intensive and the knowledge of the manufacturer more valuable.

5.4 Future research

This dissertation aims to provide inspiration for future research to shape the notion of IT as a valuable partner on the road to a digitalized service business. However, the path to a modular, scalable and customizable service platform is rocky.

There is a gap between knowledge in theory and practice that results in the need to study manufacturing enterprises that are actually undergoing the service transformation. Those firms have developed customized and proprietary IT appropriations that keep up with customer needs and technological shifts to realize sophisticated service models. By studying the organizational structures, processes and data structures of these ongoing service initiatives, scholarly research can contribute reference models, reference processes, design principles and architectures to the standardization of enterprise planning and execution software.
Heterogeneous firm-specific requirements and the highly individualized assignment of service functions to the enterprise layers drive the understanding of contextual parameters influencing the reference model’s application. Article II reveals the first indication of the parameters (i.e. number of product variants and production quantity). While the investigation of additional findings can provide more solid findings, changing the studied object to a single plant level presents a practicable approach to increase the validity. Contextualization and connectedness refer to key sources for value-oriented scenarios in the service systems engineering field [Böhmann et al. 2014]. To study these, Article III suggests the usage of boundary spanning literature and boundary objects. This dissertation promotes further research on complementary service clusters. For instance, the combination of field service, remote service and data management constitutes an interesting area of investigation. Beyond remote technology, mobile computing and big data management, the digitalization of industrial equipment posits further research [Yoo et al. 2010, Brenner et al. 2014]. The digitally refined properties (e.g. sensibility of a machine’s health state) allow for the realization of innovative and more efficient service offerings [Yoo 2010]. The replacement of field service routines with remote service activities improves process efficiency [Jonsson et al. 2008] and gives allowance for a more competitive pricing strategy. Remote workers can sense variances in the usage data of the monitored equipment. With the collection and refinement of in-use data of the serialized equipment, there is significant potential for optimizing effectiveness in the service interaction (cf. remote and field service events) in terms of preparation and execution. Sophisticated and highly automated service interaction relies on ubiquitous computing technology.

According to the findings of Articles IV to VI that outline governance mechanisms and an instantiated governance practice for project coordination (i.e. the maturity model), there is a clear need for research to further study governance structures, processes and relational mechanisms. Another interesting study subject might be the portfolio management process that is concerned with the investment decisions for novel technologies and enterprise applications (including the information systems for the service business). The propositions as formulated in Article IV suggest a large-scale empirical testing (cross-industry), which is a well-recognized means to substantiate and give weight to findings. A further literature exploration as well as the novel items of the maturity model (Article V and Article VI) can be used to inform a quantitative-based model that would overcome the criticism of being developed through a top-down approach. Instead, the levels and maturity dimensions should be derived before an assignment to the respective level. Using a quantitative bottom-up approach (cf. [Cleven et al. 2012, Raber et al. 2013]), future work should apply an explicit maturity concept and questionnaire items. The data analysis translates the results of the questionnaire into maturity levels by means of the Rasch algorithm24 and rating scales. The resulting model would be more comprehensive and allow for a more accurate under-

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24 This method is accepted for the construction of maturity models (cf. [Cleven et al. 2012, Raber et al. 2013]).
standing of the underlying relationships among the different elements in the model. As a governance mechanism in the transformation process, the know-how to advance from one maturity level to another requires more exploration. Article VI concludes that numerous factors influence this transformation step, such as regulatory compliance or the industry sector of the investigated firm. Hence, a contingency model\textsuperscript{25} seems to be a promising means by which to study the advancement of the integration of service offerings into the business model.

\textsuperscript{25} The usage of contingency theory in IS research is very common and well-accepted (cf. [Weill/Olson 1989, Teo/King 1997, Weber et al. 2009]).
Literature

[Agarwal/Lucas Jr 2005]

[Aurich et al. 2006]

[Baker 2000]

[Bardhan et al. 2010]

[Becker et al. 2013a]

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Beverungen, D., Mapping the Emerging Field of Service Science: Insights from a Citation Network and Cocitation Network Analysis, Proceedings of the 32nd International Conference on Information Systems (ICIS), Shanghai, China, 2011.

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[Cleven et al. 2012]

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[De Haes/Van Grembergen 2004]

[De Haes/Van Grembergen 2009]

[Demirkan et al. 2009]

[Denyer et al. 2008]

[Dietrich 2006]

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[Dubé/Paré 2003]

[Eisenhardt 1989]
[Eisenhardt/Graebner 2007]

[Ettlie/Rosenthal 2012]

[Fellmann et al. 2011]

[Fettke 2006]

[Fettke/Loos 2007]

[Fitzsimmons/Fitzsimmons 2005]

[Gebauer et al. 2005]

[Glushko/Tabas 2009]

[Goh/McMahon 2009]

[Goodhue et al. 1992]

[Habryn et al. 2012]

[Hevner/Chatterjee 2010]

[Hevner et al. 2004]

[Hevner 2007]

[Iivari/Venable 2009]

[Isaksson et al. 2009]

[Jacobs/Weston 2007]

[Johnson et al. 2008]

[Johnston/Clark 2012]

[Jonsson et al. 2009]

[Jonsson et al. 2008]

[Kindström 2010]

[Kitzinger 1994]

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[Krueger 2009]

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[Legner 2009]

[Leifer/Delbecq 1978]

[Levitt 1972]

[Li et al. 2012]

[Louis/Alpar 2007]

[Maglio et al. 2010]

[Maglio/Spohrer 2008]

[March/Smith 1995]

[March/Storey 2008]

[Mata et al. 1995]

[Matijacic et al. 2013]

[McAfee/Brynjolfsson 2012]

[McLeod Jr et al. 2008]

[Melville et al. 2004]

[Metters 2010]

[Mills/Moberg 1982]

[Muller et al. 2008]

[Mulligan 2002]

[Neely 2008]

[Neff 2015]

[Neff et al. 2013b]

[Neff et al. 2014a]

[Neff et al. 2012]
[Neff et al. 2013a]

[Neff et al. 2014b]

[OECD 2011]

[Oliva/Kallenberg 2003]

[Otto 2011]

[Österle/Otto 2010]

[Paluch/Blut 2011]

[Paulk et al. 1993]

[Peffers et al. 2007]

[Peltier et al. 2013]

[Peterson 2004]

[Raber et al. 2013]

[Raghunathan 1999]

[Rai/Sambamurthy 2006]

[Ray et al. 2005]

[Robey et al. 2008]

[Robins/Wiersema 1995]

[Rosemann/Vessey 2008]

[Ross/Weill 2005]

[Sambamurthy/Zmud 1999]

[Schmidt et al. 2011]

[Schultz et al. 2012]

[Schwarz/Hirschheim 2003]

[Sonnenberg/vom Brocke 2012]

[Spohrer/Kwan 2009]

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Strähle, O., Füllermann, M., Bendig, O., Service Now! Time to Wake up the Sleeping Giant, Bain & Company, 2012, pp. 1-35.

[Tanriverdi 2006]

[Tanriverdi/Venkatraman 2005]

[Teo/King 1997]

[Thomas et al. 2007]

[Torraco 2005]

[Tremblay et al. 2010]

[Tuli et al. 2007]


# Appendix A  Complete Publication List of the Author

The following table includes all articles by the author that have been written during the entire research process of this dissertation. Besides the core set of articles that are contained in this dissertation, this table also includes research in progress work (i.e. publication paths) or further work closely related to the research projects.

<table>
<thead>
<tr>
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<td>W</td>
<td>Multivendor Installed Base Service Management in the Heavy Equipment Industry – A Value Proposition</td>
<td>Neff, Alexander A.; Uebernickel, Falk; Zencke, Peter; Brenner, Walter</td>
<td>Institute of Information Management, University of St. Gallen</td>
<td>Published</td>
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</tbody>
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26 P.5 draws from P.2.
27 P.6 draws from P.3.
28 P.7 revises and extends P.6. Also P.7 draws from P.3.
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<td>P.8</td>
<td>Explicating Performance Impacts of IT Governance and Data Governance in Multi-Business Organisations</td>
<td>Neff, Alexander A.; Schosser, Maximilian; Zelt, Saskia; Uebernickel, Falk; Brenner, Walter</td>
<td>Australasian Conference on Information Systems, 2013</td>
<td>Published</td>
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<tr>
<td>P.9</td>
<td>The Role of Application Portfolio Management in Application Services Outsourcing: Explicating Variations in Application Portfolio Management among Outsourcing Gestalts</td>
<td>Zelt, Saskia; Neff, Alexander A.; Wulf, Jochen; Uebernickel, Falk; Brenner, Walter</td>
<td>Australasian Conference on Information Systems, 2013</td>
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<tr>
<td>P.10</td>
<td>Towards an Application Lifecycle Approach for Selective Outsourcing</td>
<td>Zelt, Saskia; Neff, Alexander A.; Wulf, Jochen; Uebernickel, Falk; Brenner, Walter</td>
<td>Hawaii International Conference on System Sciences, 2014</td>
<td>Published</td>
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<td>P.12</td>
<td>Succeeding in Application Services Outsourcing Strategies – A Contingency Perspective</td>
<td>Zelt, Saskia; Wulf, Jochen; Neff, Alexander A.; Uebernickel, Falk; Brenner, Walter</td>
<td>European Conference on Information Systems, 2014</td>
<td>Published</td>
</tr>
<tr>
<td>P.13</td>
<td>Service Operation Models of Manufacturers – Minimum Baseline for Process and Information Systems Capabilities</td>
<td>Neff, Alexander A.; Uebernickel, Falk; Brenner, Walter</td>
<td>Institute of Information Management, University of St. Gallen, 2014</td>
<td>Published</td>
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<td>P.14</td>
<td>Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry</td>
<td>Neff, Alexander A.; Lingemann, Stephanie; Uebernickel, Falk; Brenner, Walter; Herterich, Matthias</td>
<td>European, Mediterranean &amp; Middle Eastern Conference on Information Systems, 2014</td>
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<tr>
<td>P.15</td>
<td>Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis</td>
<td>Neff, Alexander A.</td>
<td>Institute of Information Management, University of St. Gallen, 2015</td>
<td>Published</td>
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</tbody>
</table>

29 P.8 draws from P.2 and P.5.
30 P.11 revises and extends P.7. P.11 draws from P.3 and P.6
31 P.13 has been tailored for managerial practitioners. This paper is primary based on P.11, but also drawing from P.3, P.6 and P.7.
<table>
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<td>Mobile Work Support for Field Service: A Literature Review and Suggestions for Future Research</td>
<td>Herterich, Matthias; Söllner, Matthias; Uebernickel, Falk; Brenner, Walter; Neff, Alexander A.</td>
<td>International Conference on Wirtschaftsinformatik, 2015</td>
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# Part B  IMPRINT OF THE ARTICLES

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<td>II</td>
<td>Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry</td>
<td>Neff, Alexander A.; Lingemann, Stephanie; Uebernickel, Falk; Brenner, Walter; Herterich, Matthias</td>
<td>European, Mediterranean &amp; Middle Eastern Conference on Information Systems, 2014</td>
<td>Published</td>
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<td>III</td>
<td>Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis</td>
<td>Neff, Alexander A.</td>
<td>Institute of Information Management, University of St. Gallen, 2015</td>
<td>Published</td>
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<tr>
<td>IV</td>
<td>Explicating Performance Impacts of IT Governance and Data Governance in Multi-Business Organisations</td>
<td>Neff, Alexander A.; Schosser, Maximilian; Zelt, Saskia; Uebernickel, Falk; Brenner, Walter</td>
<td>Australasian Conference on Information Systems, 2013</td>
<td>Published</td>
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<td>VI&lt;sup&gt;32&lt;/sup&gt;</td>
<td>Developing a Maturity Model for Service Systems in Heavy Equipment Manufacturing Enterprises</td>
<td>Neff, Alexander A.; Herz, Thomas Ph.; Hamel, Florian; Uebernickel, Falk; Brenner, Walter; vom Brocke, Jan</td>
<td>Information &amp; Management, 2014</td>
<td>Published</td>
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</table>

<sup>32</sup> Article VI revises and extends Article V.
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<td><strong>Author(s)</strong></td>
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<td><strong>State</strong></td>
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<td><strong>Abstract</strong></td>
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THE INFLUENCE OF INFORMATION TECHNOLOGY ON INDUSTRIAL SERVICES IN THE MANUFACTURING INDUSTRY – A LITERATURE REVIEW AND FUTURE RESEARCH DIRECTIONS

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Abstract

In the last 40 years, industrial organizations have optimised their production processes through information technology (IT). Nowadays, manufacturing firms are confronted with shrinking margins, service-demanding customers, and increased competition that are associated with the structural shift from a product-dominant to a service-dominant economy. In order to answer the changed market conditions, those firms started to offer industrial product-service systems that refer to customer life cycle oriented combinations of products and services realised in an extended value-creation network. Since enterprise information systems (IS) are designed and optimised for production planning, a clear lack in functionality and integration for industrial services can be ascertained. In particular, the life cycle management for product-service systems is not adequately covered in current standard software solutions. Firms heavily rely on individual software instead. Due to the cross-disciplinary field of research, it is important to have an overview of the extant literature. Therefore, we present a structured literature review grounded in an established literature review framework. The results suggest that extant literature lacks depth in covering the specificity of industrial services in IT solutions supporting life cycle management. We propose further research in requirements engineering, IT architecture, IT infrastructure, IT governance, and sourcing.

Keywords: service science management and engineering, service science, information systems, literature review
1 INTRODUCTION

The service sector is on the rise; employees working in business services in Germany account for 42% of the total workforce compared with 27% in the 1970s (Wölfl 2005). Furthermore, the fraction of industrial product-related services is increasing for all Organisation for Economic Co-operation and Development (OECD) countries except Luxembourg (OECD 2011). In 2000, product-related services accounted for 22.5% of the sales volume in the German electronic engineering industry (Stille 2003). The paradigm shift from a product-dominant to a service-dominant logic (SDL) can hardly be refuted (Vargo & Lusch 2008). Economic exchange is not based on products anymore but on services (Vargo & Lusch 2004). Over the last thirty years, academics as well as practitioners have begun to investigate services as a distinct phenomenon with its own body of knowledge and rules of practice (Spohrer & Kwan 2009). Their approaches are revitalised under the emergent discipline of service science, management, and engineering (SSME).

Traditional manufacturing firms have recognised the structural change in the industry and the shift towards the service-based economy. In response to the attendant challenges in terms of shrinking margins, service-demanding customers, and increased competition, numerous customer solutions now include service components (Oliva & Kallenberg 2003). Accordingly, firms strive to professionalise their portfolios with the aim of providing integrated customer solutions (Tuli et al. 2007). Nonetheless, organisations struggle to implement business services that are complementary to their existing product portfolios (Oliva & Kallenberg 2003). This phenomenon is known in literature as “service paradox” (Gebauer et al. 2005), i.e., it appears more difficult than expected to make incremental profits by adding services (Neely 2008). The reasons are complex and manifold; however, two of them are especially conspicuous. First, the current implementation of standardised enterprise systems fails to adequately cover the required functionality of industrial services (Dietrich 2006), since the enterprise application software is designed for production (Campbell-Kelly 1995; Light et al. 2001) and retail planning (Teo & Wong 1998). Second, the resources necessary to form product-services bundles are distributed cross-departmentally in the enterprise. As a consequence, services require inter- and cross-organisational collaboration to achieve the desired service orientation. In view of the implementation issues of business services, IT can help to support and integrate resources in order to create valuable business services with customer involvement (Thomas et al. 2007). However, the resulting solutions are associated with in-house software development that requires valuable, and therefore expensive capabilities (Väyrynen 2010). Combining products and services in so called product-service systems involves specific requirements for the life cycle management (Berkovich et al. 2011). For that reason, Becker et al. (2010) posit a framework (figure 1) that assigns services to the corresponding life cycle of the product. Services in the initial start-up stage refer to pre-sales activities such as problem analysis, consultant services (Menschner et al. 2011), and financial offerings (Becker et al. 2010). Literature dedicated to the operation stage is primarily concerned with services that uphold the operability of the physical component (Becker et al. 2010). During the disposal stage, service activities include replacement, recycling, and disassembling (Becker et al. 2010).

![Figure 1. Life cycle of product-related services based on Becker et al. (2010)](image-url)
Despite the IT support for the service industry (Bitner et al. 2000; Saloner & Shepard 2004; Teo & Wong 1998) the impact of IT on product-service systems is only sparsely addressed in extant literature (Becker et al. 2010; Berkovich et al. 2011). Prior literature reviews target SSME (Beverungen 2011; Spohrer & Kwan 2009), conceptual modeling of product-related services (Becker et al. 2010), interdisciplinary perspectives on IT and service science (Bardhan et al. 2010) as well as IT services (Demirkan et al. 2009) but neglect the IT support of product-related services in the manufacturing industry. Hence, we propose a literature review to investigate the potential of IT to facilitate SSME, which is structured according to the following research questions:

(1) What are the relevant definitions for product-service systems?
(2) What is the current state of knowledge on product-service systems in IS research?
(3) How is the IS support of life cycle management addressed in extant literature?
(4) What are potential fields for future research endeavours?

Such a review represents an “essential first step and foundation when undertaking a research project” (Baker, 2000) and aims to “uncover the sources relevant to a topic under study” contributing to the relevance and rigour of research (vom Brocke et al. 2009). While relevance refers to the avoidance of investigating what is already known (Baker 2000), rigour is concerned with the effective use of the existing knowledge base (Hevner et al. 2004). This literature review aims to provide an overview of relevant definitions, clarify the role of IT, point out the current state of knowledge by classifying the literature from an IS perspective, and deduce a detailed agenda for future research endeavours.

2 LITERATURE REVIEW

According to vom Brocke et al. (2009), rigour is essential when initiating research; on that basis they suggest a documented five-step literature review process. This literature review is conducted and structured in line with this framework. The scope is clearly defined, followed by a conceptualisation of the research topic. After presenting the process of literature search, a detailed literature analysis is accomplished. Synthesising the major results, a matrix and a table are used to classify the academic work in the field. Taking into account the aforementioned aspects, a research agenda is proposed.

2.1 Definition of Review Scope

The literature review is based on a taxonomy for literature reviews (vom Brocke et al. 2009) such as that proposed by Cooper (1988), which recommends six characteristics, each of which contains certain categories. Some of these characteristics are mutually exclusive (4 and 6), while others (1, 2, 3, and 5) can be combined independently (vom Brocke et al. 2009). The grey shaded categories in table 1 represent focal points of this literature review.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Categories</th>
</tr>
</thead>
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<tr>
<td>(1) Focus</td>
<td>Research outcomes</td>
</tr>
<tr>
<td>(2) Goal</td>
<td>Integration</td>
</tr>
<tr>
<td>(3) Organisation</td>
<td>Historical</td>
</tr>
<tr>
<td>(4) Perspective</td>
<td>Neutral representation</td>
</tr>
<tr>
<td>(5) Audience</td>
<td>Specialised scholars</td>
</tr>
<tr>
<td>(6) Coverage</td>
<td>Exhaustive</td>
</tr>
</tbody>
</table>

Table 1. Taxonomy of literature reviews based on Cooper (1988)
2.2 Conceptualisation and Terminology

According to vom Brocke et al. (2009), a review must begin with “a broad conception of what is known about the topic” (Torraco 2005). In this light, it seems reasonable to develop a common understanding of the definitions. Definitions on services, service systems and product-service systems are deduced from the aforementioned literature reviews. Additionally, operations management (OM) researchers and practitioners suggest taking product-service solutions and bundles into consideration. Answering research question 1 (what are the relevant definitions for product-service systems?), the working definitions and paraphrases of the key terms are provided in table 2.

<table>
<thead>
<tr>
<th>Focus</th>
<th>Definition</th>
<th>Author(s)</th>
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<tr>
<td>Service</td>
<td>[…] is a time-perishable, intangible experience performed for a customer acting in the role of a co-producer […]</td>
<td>Fitzsimmons &amp; Fitzsimmons (2005) MKTG (Textbook)</td>
</tr>
<tr>
<td></td>
<td>[…] as production processes wherein each customer supplies one or more input components for that customer’s unit of production […]</td>
<td>Sampson &amp; Froehle (2006) OM (Journal)</td>
</tr>
<tr>
<td></td>
<td>[…] as the application of competence (e.g., knowledge, resources, etc.) for the benefit of another entity […]</td>
<td>Vargo &amp; Lusch (2004) MKTG (Journal)</td>
</tr>
<tr>
<td>Service system</td>
<td>[…] a work system is a system in which human participants or machines perform work using information, technology to produce products and services for internal and external customers […]</td>
<td>Alter (2010) IS (Journal)</td>
</tr>
<tr>
<td></td>
<td>[…] represents any value co-creation configuration of people, technology, value propositions connecting internal and external service systems […]</td>
<td>Maglio &amp; Spohrer (2008) MKTG (Journal)</td>
</tr>
<tr>
<td>Product-service solution</td>
<td>[…] customer-supplier relational processes comprising customer requirements definition, customization and integration […] and their deployment and post-deployment […]</td>
<td>Tuli et al. (2007) MKTG (Journal)</td>
</tr>
<tr>
<td></td>
<td>[…] involves the provision of tailored combinations of products and services as high-value integrated solutions that address the specific needs of large business and government customers […]</td>
<td>Davies et al. (2006) OM (Journal)</td>
</tr>
<tr>
<td></td>
<td>[…] solutions create integrated and customized offerings that solve […] customer problems […]</td>
<td>Sawhney et al. (2006) MGT (Journal)</td>
</tr>
<tr>
<td>Product-service bundle</td>
<td>[…] along a continuum from pure product to pure service providers and thought of manufacturing firms moving along that axis […]</td>
<td>Oliva &amp; Kallenberg (2003) based on (Chase 1981) OM (Journal)</td>
</tr>
<tr>
<td>Product-service systems</td>
<td>[…] is an integrated solution […] and provides services to […] users without necessarily transferring the ownership of the product […]</td>
<td>Goh &amp; McMahon (2009) based on (Alonso-Rasgado et al. 2004) OM (Journal)</td>
</tr>
<tr>
<td></td>
<td>[…] industrial PSS [product-service systems] are defined as customer life cycle oriented combinations of products and services, realized in an extended value creation network […] suppliers &amp; partners […]</td>
<td>Aurich et al. (2006) based on (Mont 2002) OM (Journal)</td>
</tr>
</tbody>
</table>

Table 2. Overview of selected product-related service definitions

There is an ongoing academic as well as practitioner debate about services and related products. Research scholars consider service science from distinct perspectives, such as OM, management (MGT), marketing (MKTG), and IS (Bardhan et al. 2010; Beverungen 2011; Maglio & Spohrer 2008; Rai & Sambamurthy 2006; Spohrer & Kwan 2009). The conceptualisation of services thus heavily depends on the academic imprint of the researchers. Consistent to the SDL, MKTG scholars consider services as the application of competence (Vargo & Lusch 2004). The traditional view of services, however, seems restricted since it treats services as residual, i.e. as value-added services offered to
enhance goods or products (Bardhan et al. 2010). Organisations engage in exchange to access the benefits of operant resources such as competencies, skills, and knowledge. Goods can act as a transmitter of operant resources, or they might be intermediate products. While the former refers to embedded knowledge, the latter are used by other operant resources as appliances in the value-creation process, which implies that customers are co-producers of services for themselves (Spohrer & Maglio 2008). Grounded in the SDL, IS scholars define services as the application of competence and knowledge with the aim of creating value between providers and receivers (Spohrer et al. 2007). However, this value can arise from the interaction of service systems that comprise people, organisations, technology, and shared information. The ultimate goal of service science is to lay the groundwork to advance the ability to design, refine, and scale service systems on behalf of business organisations and society (Bardhan et al. 2010).

Extant literature on OM and MGT tends to combine products and industrial services in terms of bundles, solutions and systems. Scholars fostering the term product-service bundle structure their consideration along the continuum from pure products to pure services (Oliva & Kallenberg 2003), while Davies et al. (2006) refer to product-service solutions that involve “the provision of tailored combinations of products and services as high-value integrated solutions that address the specific needs of large business”. A similar definition is applied by Sawhney et al. (2006), while Tuli et al. (2007) prompt a broader approach in terms of customer-supplier relational processes such as requirements definition and deployment phases. The definition of product-service systems contributes to the debate by adding the life cycle aspect. Aurich et al. (2006) refer to “customer life cycle oriented combinations of products and services, realized in an extended value creation network”. Although Sampson and Froehle (2006) try to consolidate the theoretical views on services, no consensus has been reached on a general definition of services (Metters 2010). Sampson and Froehle (2006) conclude that customer involvement is the only element of the definition taken into consideration by all relevant theoretical approaches. Intangibility, heterogeneity, inseparability, and perishability (Lovelock & Gummesson 2004) are representative characteristics (Sampson & Froehle 2006).

2.3 Literature Search

In view of the notion that the process of literature search plays a fundamental role in crafting a thorough review on a topic (Zorn & Campbell 2006), this paper follows the four-phase approach proposed by vom Brocke et al. (2009) and depicted in figure 2. Each phase is incrementally organised as it involves both search and evaluation tasks (Levy & Ellis 2006). The corresponding documentation ensures reliability and repeatability of the search process (vom Brocke et al. 2009). The consequent evaluation is then accountable for the selection of articles relevant to the research topic.

![Figure 2: Literature search process based on vom Brocke et al. (2009)](image-url)
The journal search is the first step in the literature search process. It is commonly recommended to focus on journal articles and high-ranked conference proceedings, based on the fact that they have been peer-refereed before publication (Rowley & Slack 2004; Webster & Watson 2002). Since the comprehensiveness of the top-tier journals is crucial for the quality of the literature search, primarily those scholarly databases that provide access to the top journals are queried (Webster & Watson 2002). Consistent with vom Brocke et al. (2009), we chose relevant journals proposed by Willcocks et al. (2008), the Association for Information Systems (AIS) World MIS Journal Ranking for IS and Management literature, and Olson (2005) for OM, and we chose Baumgartner & Pieters (2003) for MKTG literature. The selection of relevant conferences is supported by the AIS World database (AISeL) and comprises the International Conference on Information Systems (ICIS), the European Conference on Information Systems (ECIS), the Hawaii International Conference on System Sciences (HICSS), the American Conference on Information Systems (AMCIS), and the Pacific Asia Conference on Information Systems (PACIS).

Equipped with the relevant journals, it is now possible to select and evaluate proper databases. The database search ensures exhaustiveness in coverage since all relevant top journals are taken into consideration. Accordingly, the following databases have been selected: EBSCOhost, ProQuest (ABI/INFORM), Emerald, ScienceDirect, and Web of Science.

The third step is a keyword search, in which the databases identified are queried using relevant keywords (Xiao & Benbasat 2007). Researchers recommend the use of precise search phrases (Rowley & Slack 2004) in addition to a precise documentation of the applied keywords (vom Brocke et al. 2009). The keywords are derived from the relevant definitions as outlined in the foregoing section.

<table>
<thead>
<tr>
<th>Database</th>
<th>Service science (IT OR IS)</th>
<th>Product service bundle (IT OR IS)</th>
<th>Product service system (IT OR IS)</th>
<th>Product service solution (IT OR IS)</th>
<th>Net hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBSCOhost</td>
<td>4 (94)</td>
<td>0 (5)</td>
<td>7 (35)</td>
<td>1 (8)</td>
<td>5</td>
</tr>
<tr>
<td>ProQuest</td>
<td>8 (96)</td>
<td>0 (5)</td>
<td>1 (55)</td>
<td>0 (5)</td>
<td>9</td>
</tr>
<tr>
<td>Emerald</td>
<td>0 (75)</td>
<td>0 (16)</td>
<td>0 (15)</td>
<td>0 (3)</td>
<td>0</td>
</tr>
<tr>
<td>ScienceDirect</td>
<td>3 (189)</td>
<td>0 (2)</td>
<td>4 (441)</td>
<td>0 (46)</td>
<td>7</td>
</tr>
<tr>
<td>AISeL</td>
<td>20 (145)</td>
<td>0 (1)</td>
<td>3 (3)</td>
<td>3 (7)</td>
<td>22</td>
</tr>
<tr>
<td>Web of Science</td>
<td>10 (589)</td>
<td>3 (21)</td>
<td>7 (506)</td>
<td>2 (471)</td>
<td>17</td>
</tr>
<tr>
<td><strong>Net hits</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>47 (60)</strong></td>
</tr>
</tbody>
</table>

Table 3. Results of the keyword search

Bearing in mind these requirements, we present the results of the keyword search in table 3, which maps the search phrases with the corresponding source database and the number of hits for the time period from 1990 to 2011. In order to select the relevant articles (in bold) the total number of hits (in brackets) were derived through individual evaluation of the titles and abstracts. However, neither the database nor the search phrases are mutually exclusive and consequently double counts had to be removed manually to achieve the net hits.

The applied framework suggests proceeding with a forward and backward search as the final step of the search process. Since no consensus has been reached on the terminology, forward and backward searches are particularly important in identifying relevant literature sources that are well recognised across disciplinary borders. Further textbooks are taken into consideration. As a result, this search yields 34 relevant articles deriving a sum of 81 scholarly articles.
3 LITERATURE ANALYSIS AND SYNTHESIS

With the aim of deriving a research agenda, the most difficult part of conducting a literature review lies in synthesesing the information selected and critiqued (Parker et al. 1998). The reader should be informed about what has been learnt and what patterns can be identified (Webster & Watson 2002).

For classification purposes, we employed a two-dimensional matrix as depicted in table 4. While the first dimension addresses research question 2 (what is the current state of knowledge on product-service systems in IS research?), the second dimension targets formal meta-information about the articles in line with the applied taxonomy of Cooper (1988). It is not within the scope of this paper to outline all possible categories; instead, the focus lies on those that are relevant. The categories are mutually exclusive.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Service science &amp; IS</td>
<td></td>
</tr>
<tr>
<td>Applied term</td>
<td>Service system (30)</td>
</tr>
<tr>
<td>IT objective</td>
<td>Efficiency (26)</td>
</tr>
<tr>
<td>Customer role</td>
<td>Non-customer involvement (18)</td>
</tr>
<tr>
<td>Industry</td>
<td>Manufacturing (30)</td>
</tr>
<tr>
<td>Life cycle stage</td>
<td>Start-up (21)</td>
</tr>
<tr>
<td>Standardisation of applied IS</td>
<td>Individual (8)</td>
</tr>
<tr>
<td>(2) Meta-information</td>
<td></td>
</tr>
<tr>
<td>Focus</td>
<td>Research outcomes (31)</td>
</tr>
<tr>
<td>Goal</td>
<td>Integration (19)</td>
</tr>
<tr>
<td>Audience</td>
<td>Specialised scholars (47)</td>
</tr>
<tr>
<td>Theoretical lens</td>
<td>System theory (9)</td>
</tr>
<tr>
<td>Literature domain</td>
<td>IS (52)</td>
</tr>
<tr>
<td>Literature type</td>
<td>Journal article (47)</td>
</tr>
<tr>
<td>Research method</td>
<td>Literature review (7)</td>
</tr>
</tbody>
</table>

Table 4. Matrix for literature analysis

The characteristics and categories of the service science and IS dimension (1) are deduced from three sources: literature in OM, MGT, IS, and MKTG, interviews with senior managers from the enterprise application software industry and interviews with service science researchers. In total, seven characteristics can be identified. The applied term indicates which of the derived keywords is applied in the article. We consider the IT objective category since IT usually targets efficiency or value-adding goals in the IT business-value discussion (Melville et al. 2004). Also, the role of the customer is addressed due to its crucial meaning reflected in its appearance in several service definitions (Sampson & Froehle 2006; Sawhney et al. 2006; Spohrer & Maglio 2008). The creation of value can only take place interactively with customers (Vargo & Lusch 2008) in terms of consumers (B2B) or companies (B2C) (Becker et al. 2010). The characteristic industry specifies the primary industry sector in which
the investigated firm is operating. To analyse the life cycle aspect of product-related services, we draw on a framework (Becker et al. 2010) that assigns services to the corresponding life cycle stage of the product. The concrete IS support of product-related services is addressed in terms of standard or individual software and was in particular suggested by the practitioners from the software industry.

The second dimension contains the meta-information (2) and adopts the first three characteristics as proposed by Cooper (1988): focus, goal, and audience. In order to understand research outcomes, the applied theoretical lens is listed. In line with Alavi & Carlson (1992), we included three dimensions to provide further insights about the literature domain, the type of literature, and the research method. With the aim of classifying extant literature, the authors have counted articles containing particular phrases. However, an interpretation has not been conducted.

The results of the literature analysis are presented in a framework as depicted in table 4. In total, 81 relevant articles were found and classified according to the particular categories. Amongst them, 40 articles cover at least one stage of the product life cycle and the accompanying services. The majority of the articles are focused on outcomes. While 53 articles aim to address central issues, only four articles posit criticisms. Most research contributions (47) target specialised scholars. Extant literature prefers the SDL (23) as theoretical lens, whereas the unified service theory (2) and the system theory (9) are negligible. 52 articles are IS publications, while OM (10), MKTG (8), and MGT (6) account for a small number of results. Numerous articles are from journals (47) and conference proceedings (26), whereas textbooks (5) and other forms (2) represent just a small portion. In relation to the research method, there are 7 literature reviews, 19 case studies, 8 surveys, 8 illustrative and 29 conceptual articles. Only one article applies mathematical modeling. Conspicuous aspects of the results are presented in subsequent sections and are structured according to general findings and findings on the life cycle management of industrial services.

3.1 General findings

The cross-disciplinary character of service science prompts a differentiated view on the definitions. The term service is subject to considerable change and has a long tradition in MKTG and OM (Chase 1981; Hill 1977). The service debate has been revitalised by the seminal work of Vargo and Lusch (2004), fostering a paradigmatic shift as they propose that services and not products are the basic unit of economic exchange. 23 articles build on their work applying the SDL as theoretical lens.

However, the combination of products and industrial services leads to another direction. Oliva and Kallenberg (2003) even see a paradigm change from transaction-based services to relationship-based services. They claim that manufacturing firms begin their service endeavours with the installed base and then extend their portfolio through professional services such as training, consulting, and spare parts management. After dealing with these aforementioned transaction-based services, manufacturing organisations shift their focus to relationship-based activities such as sophisticated maintenance and operational services (Oliva & Kallenberg 2003). Tuli et al. (2007) posit a process-centric view considering customer solutions as relational processes comprising requirements definition, customisation and integration, deployment, and post-deployment stages. Based on these results, Neely (2008) derives empirically a classification of product-service systems. Each form of product-service systems possesses a different focus, i.e. integration, product, use, service, and result orientation.

A common pattern is observable in numerous articles. OM literature specifies a problem in the product-service domain in a concrete instance (e.g. bullwhip effect, synchronised supply chain or integrated life cycle management). The application of IT moderates the association between that challenge and the business performance while MKTG provides the theoretical lens.

The level of abstraction of the articles is structured in line with Österle (2010) (strategy, process and system). It ranges from product-service strategies (Gebauer et al. 2005; Neely 2008) over business processes (Göh & McMahon 2009; Paluch & Blut 2011) to dedicated IT systems (Günther et al. 2009). Most articles (30) reside on a procedural level that, for example, analyses a remote maintenance
process and the appropriate IT support (Zolnowski et al. 2011). Twenty eight articles discuss the topic on a strategic level, whereas only 17 articles can be positioned on a system level.

### 3.2 Findings on the life cycle management of industrial services

<table>
<thead>
<tr>
<th>Stage</th>
<th>Sub stage</th>
<th>Article</th>
<th>Individual Software</th>
<th>Standard Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up stage</td>
<td>Service strategy</td>
<td>Alter (2011)</td>
<td></td>
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<td></td>
<td></td>
<td>Bensch et al. (2011)</td>
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<td>Brohman et al. (2009)</td>
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<td>Davies et al. (2006)</td>
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<td></td>
<td></td>
<td>Gebauer et al. (2005)</td>
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<td>Grace et al. (2008)</td>
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<td>Holmström et al. (2010)</td>
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<td>Karimi et al. (2001)</td>
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<td></td>
<td></td>
<td>Menschner et al. (2011)</td>
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<tr>
<td></td>
<td></td>
<td>Schmidt-Rauch and Nussbaumer (2011)</td>
<td>x</td>
<td></td>
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<td></td>
<td></td>
<td>Schrödl and Turowski (2011)</td>
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<td></td>
<td></td>
<td>Schweitzer et al. (2010)</td>
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<td></td>
<td></td>
<td>Spohrer and Maglio (2008)</td>
<td></td>
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<tr>
<td></td>
<td>Service innovation</td>
<td>Chae &amp; Olson (2011)</td>
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<td></td>
<td></td>
<td>Dominguez-Péry et al. (2011)</td>
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<td></td>
<td></td>
<td>Sawhney et al. (2006)</td>
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<td></td>
<td></td>
<td>Ye et al. (2011)</td>
<td></td>
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<tr>
<td></td>
<td>Requirements engineering</td>
<td>Amberg et al. (2008)</td>
<td></td>
<td>x</td>
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<tr>
<td></td>
<td></td>
<td>Becker et al. (2010)</td>
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<td>Becker et al. (2011)</td>
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<td></td>
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<td>Berkovich et al. (2011)</td>
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<td></td>
<td>Maintenance</td>
<td>Bitner et al. (2000)</td>
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<td></td>
<td></td>
<td>Günther et al. (2009)</td>
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<td>x</td>
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<td>Nyman et al. (2008)</td>
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<td></td>
<td>Paluch and Blut (2011)</td>
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<td>x</td>
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<td>Thomas et al. (2007)</td>
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<td>x</td>
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<td>Thomas et al. (2008)</td>
<td></td>
<td>x</td>
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<td></td>
<td></td>
<td>Väyrynen (2010)</td>
<td></td>
<td>x</td>
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<tr>
<td></td>
<td></td>
<td>Westergren (2010)</td>
<td></td>
<td>x</td>
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<tr>
<td></td>
<td></td>
<td>Zolnowski et al. (2011)</td>
<td></td>
<td>x</td>
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<tr>
<td></td>
<td>System Integration</td>
<td>Erl (2005)</td>
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<td>Galup et al. (2009)</td>
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<td>Lee (2005)</td>
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<td>Lim and Palvia (2001)</td>
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<td>Marks and Bell (2006)</td>
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<td>Mueller et al. (2010)</td>
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<td>vom Brocke (2007)</td>
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<td>Wang et al. (2010)</td>
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<tr>
<td></td>
<td>Disposal stage</td>
<td>Recycle</td>
<td>Beverungen et al. (2008)</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 5. Concept matrix

We draw on the framework developed by Becker et al. (2010) (depicted in figure 1) that assigns services to the corresponding life cycle stage of the product. Three stages and six sub stages have been selected to answer the third research question (how is the IS support of life cycle management
addressed in extant literature?). Forty articles cover at least one particular phase of the life cycle. Each stage is explained below including research tendencies. Table 5 maps the articles to the life cycle stages and the sub stages to the IS support referred to as individual and standard software.

Services in the initial start-up stage refer to pre-sales activities such as problem analysis, consultant services (Menschner et al. 2011), and financial offerings (Becker et al. 2010). Design, engineering, and innovation processes also play a major role during this stage (Bullinger et al. 2003). Twenty one of the life cycle oriented articles account for the start-up stage. Service innovation and its potential is an emerging research topic (Rai & Sambamurthy 2006), for which 10 articles can be positioned on a strategic planning layer (service strategy), where scholars consider innovation as a holistic approach with the aim of planning and optimising service processes, e.g. by employing sourcing activities in service networks (Brohman et al. 2009; Schrödl & Turowski 2011). Another stream is centred around requirements engineering (Amberg et al. 2008; Becker et al. 2011; Becker et al. 2010; Berkovich et al. 2011) creating more attention in literature than customer feedback processes (Barnes et al. 2005).

In the start-up stage typical business processes include financial services for capital-intensive production of goods as well as the development and application of service-level agreements (Dietrich et al. 2008). However, software support for these processes is sparsely addressed. 21 articles can be assigned to the initial stage and thereof only 2 articles address the IS support. Individually developed software is the dominant approach during the start-up stage. In this light Schmidt-Rauch and Nussbaumer (2011) study IT-enabled co-creation at the service encounter in the travelling and finance industry by developing prototypes to support the advisory function. Amberg et al. (2008) report a gap between the challenges posed by the industrial service business and the actual implemented requirements. They continue that diversity in the application landscape can be reasoned with the knowledge specificity of the processes along the life cycle.

Literature dedicated to the operation stage is primarily concerned with services that uphold the operability of the physical component (Becker et al. 2010). 10 articles deal with maintenance activities comprising preventive maintenance, maintenance and repair, line operation, logistics, documentation, and training. Call centre and help desk activities in service encounters (Bitner et al. 2000) take a backseat to the utilisation of modern state-of-the-art monitoring (Paluch & Blut 2011) and maintenance services (Günther et al. 2009; Thomas et al. 2007). For this reason, extensive in-house software solutions (Väyrynen 2010) are applied to control and integrate smart devices (Westergren 2010) into the corporate IT architecture. IS scholars postulate a system-centric integration (Davies et al. 2006) perspective to analyse and solve problems articulated by practitioners and researchers from the OM field. 8 articles consider the IT architecture that provides the necessary systems integration, but neglect the software and infrastructure implementation. For example, scholarly literature investigates the relationship between SOA and business performance (Mueller et al. 2010) or proposes that SOA is a suitable approach to support service processes (Bardhan et al. 2010).

The IS support of operation processes is primarily provided through custom-build software. In particular, 6 maintenance processes are enabled by individual software solutions, whereas one singular article reports on a standard software solution. Custom-build interfaces allow communication between installed base, manufacturing execution systems and standard software modules such as ERP (enterprise resource planning) and CRM (customer relationship management). Further sophisticated remote services enable service delivery regardless the geographical location (Zolnowski et al. 2011) or mobile devices support the service staff to maintain the installed base (Thomas et al. 2008; Thomas et al. 2007). Both can contribute to co-creation with customer involvement. Individual software requires specific capabilities. Väyrynen (2010) identified 20 capabilities related to software development as well as to software business that are also valid for manufacturing firms. She concludes that requirement engineering and cost control capabilities are essential for the software service business. Standard software solutions can be partly ascertained by Günther et al. (2009). In their study they investigate IT infrastructure solutions in the manufacturing industry. Further they have analyzed the IT architectures of seven case companies in order to understand the positive effects of tight shop-floor integration. The architectural IT solutions comprise standard software modules such as ERP and data
warehouse as well as highly customized components, e.g. manufacturing execution systems and control systems. Given standardised IT components, Günther et al. (2009) conclude that tailoring the IT to firm-specific requirements is still a need for each manufacturer.

During the disposal stage, service activities include replacement, recycling, and disassembling (Becker et al. 2010). Research contributions for this stage are scarce. A single article addresses this stage and takes part in the sustainability discussion. Beverungen et al. (2008) have designed a SOA for the recycling of electronic equipment based on standardised IT systems. They conclude that SOA can provide the flexibility required by product-service systems.

4 RESEARCH AGENDA

After exploring the definitions and discovering the current state of knowledge from an IS perspective, it seems reasonable to target the final research question (what are potential fields for future research endeavours?). The results of the literature synthesis confirm the lack of enterprise application standards for the service business as proposed by Dietrich (2006). The enterprise software support of product-service systems is sparsely covered in the start-up stage, while the disposal stage does not enjoy much attention at all. For the operation stage, extant literature outlines that in-house developed software (Väyrynen 2010) is prevalent. Standard software solutions can rather be part of a mid-term perspective. We propose research in the following 6 fields derived from scholarly literature and specified in concrete research questions. Each research field correspond to the sub stages of the life cycle (Becker et al. 2010).

1) Analyzing existing requirements engineering approaches, Becker et al. (2010) conclude that conceptual modeling should combine event-driven process chain and service blueprinting. Berkovich et al. (2011), instead, focus on the integration of requirements engineering into the development process and the handling across different life cycle stages of product-service systems. They posit that an extension of the life cycle management is required to efficiently support the service part in product-service systems, leading to research issues: What are the specific needs associated with industrial product-related services? What are the IT requirements for manufacturing firms entering the service business?

2) After analysing the IT requirements of manufacturing firms further investigation is necessary on the design of analytical models that help to plan and execute standardized business services (Dietrich et al. 2008). Then reference models can be developed serving as a basis for concrete software prototypes. Beverungen et al. (2008) suggest that “standardising services” allows “a sound integration of products and services”. Hence, we propose further research in the IS domain to adequately support business services through standardised enterprise application software: What are reference models for the IT architecture of standardised business services?

3) Regarding the operation stage literature scholars suggest additional research on the design and adaption of an IT architecture that supports maintenance activities. An initial approach to classify monitoring services has been conducted by Palut and Blut (2011). They investigate determinants of remote service satisfaction. Thomas et al. (2007) analyse a maintenance service by implementing a mobile solution for the plant and construction industry. They posit further research on the design of IS to improve customer quality despite technological complexity. Rather than focusing on the process level, the authors also facilitate research on the system level. Thus we propose more research to provide additional insights into the IT architecture and IT infrastructure that enable the communication and business execution between the installed base and the manufacturer’s system (Günther et al. 2009): What are best practices for product-service systems? Which is the appropriate IT architecture to support product-service systems?

4) Zolnowski et al. (2011) outlines the need for a coordinated installed base management. They stress the importance of machine data. In order to take advantage of the machine data, they claim that
business analytics might give critical insights on customers and hence provide decision support. Further, those data can be applied to improve corporate production, while knowledge management systems give the customers guidance for the appropriate usage of the machines. However, the success of knowledge management initiatives heavily depends on the managerial ability to make customers and employees contribute (Kankanhalli et al. 2005): *What is the potential of business intelligence and mass data analysis to give decision support? How can knowledge management systems help to overcome information asymmetries?*

In order to facilitate the development of standards for the IS support of product-service systems, the authors primarily target requirements engineering, IT architecture, and IT infrastructure. However, literature scholars also propose research in terms of IT governance and sourcing.

5) Some researchers study the product-service systems on a rather strategic layer with the aim of end-to-end optimization of the service business. Gebauer et al. (2005) analyze service strategies to overcome the service paradox and stipulate further research in the positioning of a firm in terms of behavioral and organizational theories. Building on their work, Tuli et al. (2007) reveals research gaps on contractual relationships, while Neely (2008) concludes that organizational capabilities associated with product-service systems are under-researched. IT governance models are deemed promising for the management to control the relationship between suppliers and service providers. In this light, researchers might consider the question: *What are the differences between the extant vendor management and the management of service suppliers and providers? Which adoptions are necessary to achieve a similar maturity?*

6) The sourcing of services is sparsely covered. Oliva and Kallenberg (2003) implicitly refer to sourcing by describing the final stage of transition to a service provider as “taking over the operation of the customer”. Dietrich (2006) describes a “significant level of subcontracting” in the service context. In particular, the usage of sourcing reference models might provide useful insights to develop a better understanding about the factors influencing a sourcing decision. The management of a service network has created more attention in the community. Moreover, researchers address the network dimension in service science (Brohman et al. 2009). When services are orchestrated through a network, it is quite important to ensure quality, leading to the questions: *What are the key performance indicators needed to monitor supplier performance in a service network? Which is the suitable IT architecture to support service orchestration?*

### 5 CONCLUSION

This paper aims to analyze the body of knowledge of industrial product-related services and the management of their life cycle. Hence, we conducted a structured literature review in line with a literature review framework while providing the relevant definitions for conceptualization. Summing up, we analyzed 81 articles on industrial product-related services and structured our findings according to the life cycle. Research question 1 (what are the relevant research perspectives for product-service systems?) was answered by rendering the relevant definitions, while research question 2 (what is the current state of knowledge on product-service systems in IS research?) was approached through a deep analysis of the body of knowledge on the search as well as the classification. Research question 3 (how is the IS support of life cycle management addressed in extant literature?) strengthens the relevance of the life cycle management as proposed by experts from the enterprise application software industry. We conclude that extant literature lacks depth in the area of IS support for the life cycle management of industrial services. The enterprise software support of product-service systems is sparsely covered in the start-up stage. For the operation stage, extant literature outlines that in-house developed software (Väyrynen 2010) is prevalent. Standard software solutions can rather be part of a mid-term perspective. The disposal stage does not enjoy much attention. Subsequently, we outlined six potential research options structured along the life cycle with the aim of answering research question 4 (what are potential fields for future research endeavours?). Requirements engineering represents a...
promising field to start the research endeavour since it will provide additional insights about the how
and why manufacturing firms are applying individual software. After that we can continue research on
developing reference models that cover the explored needs. Reference models and best practice
analyses help to derive standardised building blocks which, in turn, serve as a basis for concrete
software prototypes. The economic value of standard enterprise software lies in the compensation of
knowledge asymmetries between manufacturing firms and customers on a reasonable cost level.
Machine data allow the manufacturing firm to optimise the production, while the customer gains
insights about the qualitative improvement of the installed base management. Additional research
fields might cover sourcing through the service network, governance models for coordination and
integration frameworks.

However, some restrictions are apparent when considering the results of this paper. Although the
relevant journals and conference proceedings are subject to the database search, there is no guarantee
that all relevant articles are taken into account. This holds particularly true since we emphasise the IS
perspective. Furthermore, the terms applied as well as the selection are subjective to the authors,
unless they are deduced from extant literature. Other keywords may lead to considerably different
results. It could be argued whether the life cycle stages as proposed by Becker et al. (2010), provide
the appropriate framework to classify and analyse industrial product-related services. Alternatively,
the conceptualisations of Neely (2008), Tuli et al. (2007), and Sawhney et al. (2006) appear to be quite
promising. Following vom Brocke et al. (2009) the applied literature review approach emphasises a
structured review process with a strong methodological focus.

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### Article II

<table>
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<tr>
<th><strong>Title</strong></th>
<th>Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry</th>
</tr>
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<tr>
<td><strong>Author(s)</strong></td>
<td>Alexander A. Neff, Falk Uebernickel, Stephanie Lingemann, Walter Brenner, Matthias Herterich</td>
</tr>
<tr>
<td><strong>State</strong></td>
<td>Published</td>
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<tr>
<td><strong>Abstract</strong></td>
<td>Heavy equipment manufacturing (HEM) firms are increasingly challenged by the inclusion of service planning and execution functions in their established information systems (IS) environment. Being confronted with the strategic challenge of reducing operating costs and being forced to meet the ever increasing industrial service demands, these firms have more and more problems to find the appropriate IS solution. Moreover, service functionality needs to be clearly defined and demarcated in the existing enterprise application landscape. Despite a few standardization efforts, the IS appropriation for service management in HEM companies lacks a common understanding so that a clear functional design is still a vision. We address this need by developing a functional reference model. The design of the model is grounded in standardization literature, focus group and case study research involving eleven HEM and two software companies.</td>
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</tbody>
</table>
Towards a Functional Reference Model for Service Planning and Execution in the Heavy Equipment Manufacturing Industry

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Abstract

Heavy equipment manufacturing (HEM) firms are increasingly challenged by the inclusion of service planning and execution functions in their established information systems (IS) environment. Being confronted with the strategic challenge of reducing operating costs and being forced to meet the ever increasing industrial service demands, these firms have more and more problems to find the appropriate IS solution. Moreover, service functionality needs to be clearly defined and demarcated in the existing enterprise application landscape. Despite a few standardization efforts, the IS appropriation for service management in HEM companies lacks a common understanding so that a clear functional design is still a vision. We address this need by developing a functional reference model. The design of the model is grounded in standardization literature, focus group and case study research involving eleven HEM and two software companies.

Keywords: Service Planning, Enterprise Systems, Functional Reference Model, Heavy Equipment Manufacturing Industry.

1 INTRODUCTION

1.1 Motivation and problem statement

The servitisation of the manufacturer’s product portfolio initiates a holistic transformation process addressing strategy, structure and business process level (Ulaga and Reinartz 2011). This trend holds particularly incisive for HEM companies, as the machinery equipment of this industry is known as long-living and highly productive at the customer site (Neff et al. 2014). As a consequence, service operation capabilities are particularly important for achieving and sustaining high profit margins (Oliva and Kallenberg 2003; Strähle et al. 2012). Specifically this means they have to supplement their predominant business focus on the design and manufacturing of products with the considerably different service component (Gebauer et al. 2005; Kindström 2010). HEMs face the challenge of integrating service planning and execution activities in their established production-focused IS environment (Becker et al. 2013; Dietrich 2006). Beyond the strategic IS challenges of reducing operating costs and implementing service functionality, HEMs’ service divisions require considerably
higher information quality (e.g. precision and accuracy) about the equipment to professionalise monitoring as well as prediction processes (Neff et al. 2014). Precision features serialized descriptions on sold equipment that is linked with technical structures, while accuracy refers to the provisioning of an aggregated view on past service activities (Becker et al. 2013; Neff et al. 2014).

Established enterprise applications fail in adequately executing the service specific requirements since they are designed for different purpose (Davenport 1998; Dietrich 2006). Enterprise resource planning (ERP) applications (Jacobs and Weston 2007; Park and Kusiak 2005) lack in the customer interaction processes, while customer relationship management (CRM) applications (Peltier et al. 2013) are limited in the required detail for technical descriptions on installed equipment. With the aim to compensate the functional deficits of standard applications (e.g. remote access to sensor data of the customer installed base), HEMs have projected proprietary solutions that collect and process machine statuses and mobile workforce information (Biege et al. 2012; Matijacic et al. 2013; Tuli et al. 2007). Applications on corporate, plant and shop floor layer (Schmidt et al. 2011) run in parallel and lack a clear demarcation. Service functionality is not clearly defined and demarcated in the existing enterprise application landscape. Application systems partly provide support for similar functions (e.g. installed base management), which leads to interconnection, but also fosters redundancy. On the one hand, this situation hinders standardization efforts. On the other hand, it results in difficult integration projects and increased costs.

1.2 Research goal and research question

This paper’s objective is to address several research goals. The demarcation of applications on all three layers is core of the research and is summarized in a functional reference model. The paper clearly defines which functionalities belong to service management and structures the service functionalities along the enterprise application layers. It also identifies potential sources for redundancies. Although standard specifications exist, the question of which functionality to implement by which enterprise application remains unanswered to the HEM industry. Hence, we operationalize the following research question (RQ):

RQ: What could a functional reference model that assigns and covers service planning and controlling functions to enterprise applications in the HEM industry look like?

2 BACKGROUND

2.1 Service requirements in HEM industry

HEM customers employ long-living HEM products in a highly productive environment, i.e. production facilities. Customer manufacturing is characterized by short delivery times, decreasing lifecycles and versatile production. For the HEM player, it hence becomes essential to have accurate, precise and timely information on the installed customer equipment when performing service operations. Due to the technical complexity of the equipment (in terms of quantity and quality), these information types include not only customer related data (such as contracts and entitlements), but also comprise technical information (bill of material). Expending the HEM portfolio with proactive and performance based services is one of the most important capabilities to outperform competing companies, while reliable margins are ensured. However, the realization of service offerings as part of the business model can drive service operation divisions beyond their physical resource limits; there is a lack of qualified technicians to provide the newly offered services (Neff et al. 2014). “Call centre employees, for example, are often neither trained to deliver technical remote services for the installed base nor do they have access to the necessary information to manage the service request” (Neff et al. 2014, p. 896). Service processes are highly diverging and have to be provided locally and in co-creation with the customer (Biege et al. 2012; Matijacic et al. 2013; Tuli et al. 2007). While HEM production locations primary use ERP applications, local sales and service entities decided for CRM solutions for service planning and execution. Proprietary implementations further contribute sophisticated service offerings (such as preventive maintenance and performance based contracting) that are based on remote technology and sensor data. The customer runs production monitoring and
detailed planning on manufacturing execution systems (MES). This heterogeneity in the service business is directly reflected in the enterprise applications (Schmidt et al. 2011). Numerous isolated applications have been deployed which result in substantial difficulties for ensuring horizontal and vertical reconciliation.

### 2.2 Demarcation of service management functionality in enterprise application layers

Service management functionalities are present on different layers on corporate, customer plant and customer shop floor level (Figure 1). On the corporate layer, enterprise applications such as ERP and CRM provide very broad service business functionality along the entire operational supply chain.

![Enterprise application layers](image)

**Figure 1.** Enterprise application layers (based on Louis and Alpar (2007) and Schmidt et al. (2011))

Between the corporate and the subsequent layer there is an organizational boundary. This customer plant layer constitutes applications e.g. MES that optimize and control the production process. In order to efficiently execute service operations (i.e. quickly respond to service events in the customer production process), it is crucial to have access to high quality (accurate, precise and timeliness) information on the installed customer equipment. The HEM requires a more granular view on customer equipment and production process. The data elements are buried in the customer’s MES and shop floor systems. Existing applications on corporate layer fall short in collecting and processing real-time information on the customer production data that are generated on the shop floor level. ERP systems show an inadequacy to respond to changing demands or deviations in the production process. This becomes evident when considering the time units on the different layers. ERP schedules events on daily basis, while MES performs events on one minute-by-minute basis. Moreover ERP cannot process shop floor based sensor data and lacks the sufficient level of detail. As service management is interpreted differently, standardization organizations such as International Standards Organization (ISO), German Standards Organization (DIN/VDI), National Institute of Standards and Technology (NIST) have put much effort into identifying a common definition and specifying generic functionalities. For model structuration we relied on the aforementioned three enterprise application layers (based on MES standards) (Louis and Alpar 2007; Schmidt et al. 2011).

Thus, on the one hand, existing functional references such as ERP, CRM and MES are limited to single enterprise layers and respectively to a limited number of service functions. For instance, ERP only focuses on internal service functions and CRM is limited to functions related to customer interaction. MES in turn only covers functions on the plant layer. Standards provided by the international standard organizations, on the other hand, identify a broad range of functions but do not
classify these functions according to the different enterprise application layers. Accordingly, the shortcomings of existing functional references lay both in the omission of relevant service functions and in the ambiguous assignment to enterprise layers.

2.3 Functional reference model

Reference models can be drawn back to the attributes universal applicability, reusability, and best practice recommendations (Fettke and Loos 2004) that are strongly intertwined. Universal applicability refers to the opportunity to roll out the model in more than a singular organization. This reinforces reusability effects (Fettke and Loos 2007), since conceptual patterns can be implemented with adaption mechanisms (Schlosser et al. 2014; Schmidt et al. 2011). Recommendations for best practice actions conclude the reference model attributes. For classifications purposes, scholarly literature (e.g. Becker and Schütte (2004)) suggests the usage of five views (function, organization, data, output, and control) and three levels (requirements definition, design specification, implementation description). Both classification elements are grounded in the Architecture of Integrated Information Systems (ARIS) that aims at the design for analysing and designing information systems (Scheer and Schneider 2005). In this study the reference model states requirements that are derived from service processes (requirements definition level) and that are implemented by application functions (functional view).

3 RESEARCH METHODOLOGY

3.1 Research approach

A qualitative and explorative research approach has been selected, since the literature analysed revealed a lack of suitable constructs for quantitative research. The desired outcome of this research endeavour should be a functional reference model that documents enterprise functions required for the design of service systems in HEM companies. To develop this type of ‘artefact’, we followed a design-oriented research approach (Hevner et al. 2004; Peffers et al. 2007). Design science research (DSR) extends the existing knowledge base by means of finding innovative solutions to a class of real-world problems (Baskerville and Myers 2009). This research aims to construct and evaluate artefacts that help to overcome existing capability limitations (Hevner et al. 2004).

In DSR reference models have a long tradition as an anticipated artefact class, particularly in Europe (Frank et al. 2008). Reference models can be derived either by generalizing findings from a number of investigated cases or by adapting an existing reference model to particular requirements (Becker et al. 2002). In this paper, we pursue a combined approach: The initial reference model consisted of a number of functional blocks that were derived from a structured literature review (vom Brocke et al. 2009) of scientific publications and specifications of standardization bodies. The standard specifications provide a functional reference for application across firms and industries. It lacks, however, consideration of HEM specific requirements and, consequently, prevents OEMs from applying these standards. As noted by a case study participant (ELECTRIC.1): “when you study the CRM specifications for manufacturing enterprises, you notice that you are deeply rooted in consumer product industry”.

3.2 Iterative model development

The research procedure for developing the functional reference model for service planning and execution in the HEM industry follows a DSR development process according to Hevner’s DSR guidelines (Hevner et al. 2004). Becker et al. (2009) suggest a seven-step construction process for reference models that is suitable for deriving the functional reference model. In order to limit the complexity of the model as well as of the research procedure to an appropriate level we consolidated three process steps (i.e. the conception of transfer and evaluation, the implementation of transfer media and the evaluation were merged into the evaluation step). Since the third step of the approach of Becker et al. (2009), the ‘determination of a development strategy’, is directly linked to the results of
the second step, the ‘comparison of existing models’, we included this step into the second process step. Thus, after adapting the 7-step-approach, our research procedure comprises five steps that are described in Figure 2 in relation to the performed activities, used techniques and the corresponding paper section. The research procedure begins with the problem identification (step 1). Our research is initiated by a ‘need and require’ intention that includes not only the scientific shortcoming but also justifies the relevance and necessity of the model development. The poorly researched field of IS appropriation for service businesses in HEM companies and respective functional design underlines the focus of the research project. In addition to an initial literature review, an exploratory case study approach substantiates the research need. An exploratory case study describes, analyses and explains phenomena in a given context and is hence the appropriate research format (Benbasat et al. 1987; Yin 2009). The second step, a comparison of existing models (step 2), builds on the problem identification (step 1) and on the identification of shortcomings of existing functional references such as provided by the MES standards. This step is based on an in-depth literature review and a review of relevant industrial standards as well as on the multiple case studies. The third step, the iterative model development, has been conducted in two iterations (see Figure 2) and led to the identification of 18 functions constituting the functional reference model. In the first iteration an in-depth analysis of the case study reports and of the industrial standards has been performed in order to operationalize the reference model functions. In the second iteration the model has been refined with expert interviews and with a refinement workshop with two software vendor practitioners and three IT consultants (Table 1, SOFTWARE.8-CONSULT.9). An evaluation (step 4) completes the procedure. Thereby a multi-perspective approach with practitioners has been conducted. The final step (step 5) sums up the findings and supplements its findings for research and practice.

<table>
<thead>
<tr>
<th>Step</th>
<th>Activities Performed</th>
<th>Techniques Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation &amp; Problem Statement</td>
<td>Problem Identification</td>
<td>• Identification of the scientific shortcoming</td>
</tr>
<tr>
<td></td>
<td>• No appropriate design of information systems for service operations in heavy equipment manufacturing firms</td>
<td>• Seven exploratory case studies</td>
</tr>
<tr>
<td></td>
<td>• Initial literature review</td>
<td>• Initial literature review</td>
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<td>Background</td>
<td>Comparison of existing models</td>
<td>• Identification of service requirements in the HEM industry</td>
</tr>
<tr>
<td></td>
<td>• Evaluation of existing enterprise applications for service planning and execution</td>
<td>• Seven exploratory case studies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• In-depth literature review</td>
</tr>
<tr>
<td>Reference Model Design</td>
<td>Iterative model development</td>
<td>• Iteration 1: Conceptualisation of service functions and definition of structural elements</td>
</tr>
<tr>
<td></td>
<td>• Iteration 2: Model refinement</td>
<td>• Iteration 1: In-depth analysis of case study reports and industrial standards</td>
</tr>
<tr>
<td>Model Evaluation</td>
<td>Evaluation</td>
<td>• Iteration 2: Expert interviews and refinement workshop</td>
</tr>
<tr>
<td></td>
<td>• Multi-perspective approach</td>
<td>• Focus group workshop with four additional HEM enterprises</td>
</tr>
<tr>
<td></td>
<td>• Multiple evaluation rounds</td>
<td>• Self-positioning of HEM enterprises</td>
</tr>
<tr>
<td></td>
<td>• Reflection on evaluation results</td>
<td></td>
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<tr>
<td>Discussion; Summary &amp; Outlook</td>
<td>End of Model development</td>
<td>• Reflection of study findings and extant body of literature</td>
</tr>
<tr>
<td></td>
<td>• Summary of findings</td>
<td>• Reflection of study findings and industry standards</td>
</tr>
<tr>
<td></td>
<td>• Discussion on implications for research and practice</td>
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<tr>
<td></td>
<td>• Limitations and future research</td>
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</tr>
</tbody>
</table>

Legend: Corresponding paper sections | Phase

![Figure 2. Procedure model for reference model development](image)

### 3.3 Research techniques overview

The study design is characterized by a multi-case study approach since a total of seven leading HEM firms are examined with regard to the same topic, namely service management. The selection of the case companies was subject to a theoretical sampling approach (Eisenhardt 1989) that uses ‘company size’ and ‘industry’ as criteria. In order to guarantee a representative sample of the of the HEM industry in Germany, Austria and Switzerland, companies with considerably different characteristics were included for each criterion (small, medium-sized and large companies as well as companies from different industries). The analytical unit refers to an individual case of this study. As this study consists of seven cases, an increased generalizability of the findings, as compared to single case studies, can be assured (profiles in Table 1, ELECTRIC.1-ISERVICE.7). All case studies were performed by a two over a period of three months in 2012. While a variety of methods for data collection has been applied, the main mode was semi-structured interviews. These interview partners have been chosen carefully based on both their business and IS knowledge to ensure an equal representation. In addition to the transcription of the interviews, we collected company documentation...
material for triangulation of sources in a case study report. Further, we conducted expert interviews with representatives of software vendors and IT consultants to refine the functional reference model. The focus group workshop served as evaluation technique with representatives of four distinct manufacturing companies (Table 1, MACHINERY.10-13) (Tremblay et al. 2010).

<table>
<thead>
<tr>
<th>FIRM. ID</th>
<th>Size</th>
<th>Interview partner</th>
<th>Number interviews</th>
<th>Research technique</th>
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<td>Case study</td>
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<tr>
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<td>CIO, Head of Processes</td>
<td>2</td>
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<td>MACHINERY.4</td>
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<td>Interview</td>
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<td>CONSULT.9</td>
<td>S</td>
<td>Principal Service, Senior Partner, Project Manager</td>
<td>3</td>
<td>Interview</td>
</tr>
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<td>M</td>
<td>Head of IT Services for Sales, Head of Customer Service</td>
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<td>Focus group</td>
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<tr>
<td>MACHINERY.13</td>
<td>M</td>
<td>Head of IT Strategy</td>
<td>1</td>
<td>Focus group</td>
</tr>
</tbody>
</table>

Legend:  
Large > 50k employees AND >20bn US$ revenue  
Medium 15k – 50k employees AND 5 – 20bn US$ revenue  
Small <15k employees AND <5bn US$ revenue

Table 1. Profiles of the participants

4 REFERENCE MODEL DESIGN

4.1 First design cycle

In the first design cycle the focus lies on the conceptualization of service functions and the definition of structural elements. Due to the exploratory character of this study, we coded the case study reports into enterprise functions. For each of the service functions we identified elements that serve as an operationalization. Workforce management e.g. is operationalized as access to customer data, to installed equipment data and to knowledge management database (blueprints, CAD drafts and best practices). Maintenance instructions and transactions of billing are provided (digital signature, confirmation of billing and service execution).

As a next step we carried out a structured literature review of existing standards, norms and specifications from well-known standardization organizations, i.e. ISO, DIN (or PAS as a preliminary stage), VDI, NIST. Our keyword search yielded 517 results. After scanning the titles, abstracts and keywords we selected 26 documents for in-depth analysis. Equipped with the operationalized service functions and the standard specifications, we conducted a fit assessment between both data sources to derive a synthesis of relevant enterprise functions in the service business (Table 2). To achieve our goal of developing a functional reference model for service systems in the HEM industry, we used the standard specifications and industry standards for the initial model construction and altered our definition of service functionality. The resulting model is structured in accordance with the aforementioned MES standards (Figure 1). We used the three layers, as specified in the previous section, comprising corporate, customer plant and customer shop floor layer. This initial model visualizes business, manufacturing and service functionality and assigns them to the appropriate layers, i.e. to the applications that are assigned to these layers.

Service planning functionality is primarily present on the corporate layer such as warranty claim management, contract management, customer communication and service collaboration. Warranty claim management has not been specified by the analysed standards. However, the case studies have
highlighted its importance as a core service management functionality. Warranty claim management comprises the configuration and management of warranties connected to the equipment and major subcomponents installed at the customer’s side. For service execution and controlling functionality the organizational boundary towards the customer must be passed. Workforce management, installed base management and analytics are located between corporate and customer plant layer. In order to acquire real-time data or process direct machine control, the customer shop floor layer becomes essential. This becomes particularly relevant for remote service management that has been integrated, although it is not part of the investigated standard specifications. Commercial software vendors have propagated this function as an innovation application that has been implemented by MACHINERY.2 and MACHINERY.4. Remote service management incorporates processes and routines that allow performing service activities on the installed customer equipment from centralized back office service centres. Among them remote diagnosis (read access for cryptic reports and run diagnosis software), remote call (bi-directional interaction between service staff and customer staff) and remote monitoring (condition based monitoring of installed base) are predominant forms.

<table>
<thead>
<tr>
<th>Source</th>
<th>Function</th>
<th>ISO</th>
<th>DIN</th>
<th>VDI</th>
<th>NIST</th>
<th>PAS</th>
</tr>
</thead>
</table>

Table 2. Service planning and controlling functions specified by different standards

As outlined by MACHINERY.2’s Vice President, “remote technology and our embedded machinery software allow us to fulfil full service contracts and performance based contracting with efficient means. 70% of all service incidents can be fixed via remote service without the involvement of costly on-site customer visits”. MACHINERY.4’s CIO ties up in this line of argumentation by referring to an
increased service quality in terms of reduced facility downtimes. The installed base at customer plant structures is continuously analysed. Sensor data are collected from metering points and then processed in the back office service centre. This ensures an immediate replacement of the correct defect equipment, while at the same time allows accurate predictions on the remaining lifetime. The service functions are complemented with supporting functions that are not directly associated with the service business, e.g. accounting, product life cycle management or quality management. The detailed specifications of each function and the corresponding sub functions ensure a common understanding and inform the expert interviews in the second model development iteration.

4.2 Second design cycle
In the second design cycle we conducted expert interviews and a workshop to refine our findings from the first iteration. It was the aim to deepen our understanding by exploring a more detailed specification for each service function and then to assign each sub-function to the enterprise application layers. For that reason, we took the operationalized service functions and enriched this list of sub-functions with software documentation. To assign the sub-function and then the functions to the enterprise application layers, we conducted expert interviews and then consolidated the results in a refinement workshop (Tremblay et al. 2010). The selection of the companies for this second iteration was based on logical reasoning. The case study participants in the first round stated that large proprietary software solutions were implemented to support the service business. Consequently we address the primary software vendors and IT consultancy firms that were involved in those projects. They helped us to bring in the solution and product perspective from the software vendors. By analysing the software documentation from standard software in comparison to proprietary implementations, we were able to specify the service functions on more granular level. The transcribed expert interviews allowed us to assign the sub-functions to the respective enterprise application layer and then to refine the functional reference model (extract of this analysis is shown in Table 3).

The function installed base management has been selected since it illustrates how certain sub tasks of the function are implemented by different application layers. This function is concerned with the different processes that reach from selling, delivery, installation, and maintenance over monitor to replacement. 19 sub tasks refer to internal planning activities that are processed on two different enterprise application layers (corporate vs. plant layer).

However, we constitute redundant application assignment between CRM and ERP. While CRM applications lack detailed technical specifications, ERP is accountable for the operational maintenance services performed on enterprise owned equipment that is used for production. More concretely, ERP allows different types of technical objects, object links for horizontal structures, and creates “built on-site” installed base: automatic creation of equipment master from sales order, internal refurbishment orders. CRM shows its strengths in customer interaction in call centres and web shops, but lacks technical structures and relies on replicated and redundant installed base data. Since several sub tasks of the installed base management are processed on the customer plant level, we have positioned this function between enterprise and customer plant layer. This holds particularly true for the unplanned maintenance, installed base information and machine records, as well as monitor installed base performance and utilization.

The resulting functional reference architectures shed light on the functional requirements that need to be fulfilled by the software vendors and IT consulting firms. The functional reference model aggregates the study results from all participating organizations (see Figure 3).
Considering the analysed instantiations (iteration 1) and the experience of the interviewed experts (iteration 2), it is difficult to achieve a common model for the entire industry. The requirements that are company-specific usually depend on the factors such as integration of service offering into the business model, production variants or position in the supply chain. This heterogeneity leads to the question of what relevant factors are that are observed in the assignment of functions to the applications. We decided to address this issue in the discussion section (Chapter 6). Nonetheless, some general trends on the functional reference model can be drawn. For instance, workforce management, knowledge management, service collaboration, customer communication, contract management and warranty claim management are mostly seen as core functionalities covered on the corporate layer. Other functionalities such as remote service management, installed base management, analytics and equipment master data management, service management applications need to provide support. Being assigned to multiple layers, integration issues become prevalent since single sub functions of the corresponding function are supported by different applications that can be assigned to more than one layer. This holds particularly true for applications that cross the organizational border from the internal corporate layer to the customer plant layer. The functional reference model depicted in Figure 3 summarizes the function assignments consolidated across all case studies and expert interviews and, thus, represents the revised functional reference model for integrated service management in the HEM industry.

### Table 3. Specifications of service-related tasks with assignment to the enterprise application layers (extract)

<table>
<thead>
<tr>
<th>General function</th>
<th>(Sub) Function</th>
<th>Corporate layer</th>
<th>Plant layer</th>
<th>Shop floor layer</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Offer and configuration</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Sales for technical products</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Service contract</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Solution selling</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintain individual installed base data and structure customer installations</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintain “as-built” status and configuration management</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Delivery and installation</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Integration with logistics execution</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintain “as-delivered” status</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Offer, plan and perform installation service</td>
<td></td>
<td>✓</td>
<td></td>
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<tr>
<td></td>
<td>Internet registration by customer</td>
<td></td>
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<tr>
<td></td>
<td>Maintenance</td>
<td></td>
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<tr>
<td></td>
<td>Planned maintenance</td>
<td>✓</td>
<td></td>
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<tr>
<td></td>
<td>Unplanned maintenance</td>
<td></td>
<td></td>
<td>✓</td>
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<tr>
<td></td>
<td>Installed base information</td>
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<td></td>
<td>✓</td>
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<tr>
<td></td>
<td>Parts planning</td>
<td>✓</td>
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<td></td>
<td>Change management</td>
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<td></td>
<td>Offer and perform modification services</td>
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<tr>
<td></td>
<td>Maintain “as-maintained” status</td>
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<tr>
<td></td>
<td>Change history / installed base lifecycle</td>
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<td></td>
<td>Machine record</td>
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<tr>
<td></td>
<td>Monitoring</td>
<td></td>
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<tr>
<td></td>
<td>Monitor installed base performance and utilization data</td>
<td>✓</td>
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<tr>
<td></td>
<td>Problem and damage documentation</td>
<td></td>
<td></td>
<td>✓</td>
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<td></td>
<td>Customer profitability information on installed base level</td>
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<td></td>
<td>Replace and resell</td>
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<td></td>
<td>Information for repair / replace decisions</td>
<td></td>
<td></td>
<td>✓</td>
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<td></td>
<td>Offer and deliver replacement products</td>
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<td>✓</td>
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<td></td>
<td>Offer and perform dismantling service</td>
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<td>Returns processing</td>
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<td>Repair / refurbishment processing</td>
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<td>Sales of used technical products</td>
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Legend: ✓ Involved applications with data exchange
5 \textbf{Evaluation}

The software vendor practitioners and three IT consultants in the second iteration helped identifying reference customers and success stories that are widely accepted as industry benchmark for the service business in the HEM industry. We invited nine representatives of eight companies and five managers from four additional HEM enterprises, who have not been part of the case study, attended the workshop (see Table 1, MACHINERY.10-13). In order to structure the evaluation section, we followed a multi-perspective approach (Frank 2006). This evaluation approach compiles and aggregates evaluation practices that have been identified in previous research such as Fettke and Loos (2004) and Schütte (1998). The chosen approach is beneficial for application in this context as it is specifically geared to reference models. Further, evaluating a concept from multiple perspectives is an approximation to objectivity by supporting a more nuanced and balanced judgment (Frank 2006). The four perspectives applied are economic – focussing on costs and benefits, deployment – focussing on applicability, engineering – focussing on the fulfilment of previously defined requirements – and epistemological – focuses on criteria for scientific research. By utilizing the four approved evaluation perspectives we arrive at the following results.

\textbf{Economic perspective}: As the complexity of the model is relatively low and its usage intuitively, there are no substantial costs to the potential user. During the practitioner’s workshop it has been observed that a basic presentation and explanation of the functional building blocks of the model is adequate to allow for model application in specific business contexts. Thus, costly, training in detail is not necessary. At the same time the functional reference model does not automatically generate quantifiable value. However, the model can be utilized to support standardization across companies with regards to service-related functions. As the model has been derived in line with well-known industry standards it further fosters an industry-wide common language for service planning and controlling functions. In addition, as the workshop has shown, the model is suitable to improve communication and knowledge exchange among the HEMs as well as between software vendors and the HEMs (i.e. the software vendors’ customer organizations) regarding appropriate IS support of service management.
Deployment perspective: The case study participants confirmed the applicability, comprehensibility and usability of the model. The reference model is an appropriate and useful tool for service management. Its deployment allows for finding common terms regarding functionalities that belong to service management. Thus, the model presents a comprehensive and integrated approach for classifying and documenting the IS appropriation for service systems in HEM companies. The indicated comprehensibility of the functional reference model is supported by the structure of the model and the clear graphical representation. It allows to intuitively grasp the different enterprise application layers and the respective functional building blocks.

Engineering perspective: The evaluation with the industry experts approved the reference model’s suitability towards its intended scope and goals. It can be applied to the intended domain of usage (HEM industry) and it also fulfils its purpose of defining functional requirements of service management. Further, it can be adjusted to specific contexts within the HEM industry (adaptability of reference models). It is further possible to add or remove functional building blocks (extensibility of the reference model).

Epistemological perspective: An in-depth literature review and a review of relevant industrial standards ensure a sound theoretical foundation. The model development is based on case study research, expert interviews and follows a multi-step procedure model. As a result, the model is embedded into the design science approach and critically evaluated in accordance with approved evaluation perspectives. The model is based on a solid representation of the object world and fulfils the criterion of critical distance and an appropriate level of abstraction.

6 DISCUSSION, SUMMARY AND OUTLOOK

With regards to the study’s contribution to research, we would especially like to highlight four aspects. First, the functional reference model identifies and specifies application functions for service systems in HEMs on a conceptual level. Thereby, the theoretical knowledge gap concerning service functions and demarcation in existing enterprise application landscapes has been approached. Second, the paper at hand provides a first indication for configuration parameters and contingency factors influencing the application of the reference model, i.e. integration of service offering into the business model, number of product variants, production quantity, vertical range of manufacturing and green vs. brown field. Third, this research endeavour expands the current state of research by applying the design approach to the HEM industry. At last, the study transfers practical knowledge to science by generating knowledge from seven HEM firms and two software companies. In addition, the research project contributes to practice in three ways. First, the model is an instrument for evaluating existing and identifying required service management functionality. By deploying the model, HEM firms would be able to find common terms regarding functionalities that belong to service management. This facilitates not only internal service management, but also communication with respective software vendors and IT consultancy firms. Second, the reference model comprises practicable best practices (i.e. blueprint) and recommendations for doing business as it clearly defines the affiliation of service functions to enterprise application layers. Third, based on the universal applicability of the reference model, it is not limited to one specific organization and can be utilized in multiple business contexts. Due to the model’s flexibility, an adaption to specific contextual circumstances by adding or removing functional building blocks is possible. The functional reference model for service systems in the HEM industry serves the goal of clearly assigning service functions along the enterprise application layers on a conceptual level. This model clarifies essential terms and helps to establish a common, industry-wide understanding. Thus, it allows an aligned expression of functional requirements when communicating with software vendors and IT consultancy firms. While standard organizations have defined service management and specified generic functionalities, a functional reference model considering HEM specific requirements has not been developed. Two design cycles, combining operationalized service functions derived from the case studies with standard specifications and findings from expert interviews, led to the model. Addressing real-world problems and simultaneously contributing to the scientific and practitioners’ body of knowledge, it was the researchers’ aim to produce consumable results. Moreover, the model benefited from a multi-perspective evaluation.
One possible limitation of this study might be the case selection. Adding additional cases and thus investigating more industries from other geographical regions could enhance the generalizability of the results. Since the service systems environment is characterized by continuous structural changes, an on-going re-evaluation of the functional reference model is recommended. Due to the heterogeneity of company-specific functional requirements and the individual assignment of functions to the different layers, we understand the contextual parameters influencing the model’s application as an important area of future research. Our data analysis revealed some first insights on parameters such as the number of product variants or production quantity. One way of pursuing more solid findings is by analysing additional cases of usage of further HEM companies. Another approach is to deepen the investigation by analysing single plants. Moreover, the functional reference model can be understood as an origin for designing IS appropriation for service systems, for industry-wide domain models that contain functional components, and for a consistent language on service-related entities.

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<table>
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<th>Article III</th>
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<td><strong>Title</strong></td>
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<tr>
<td>Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis</td>
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<td><strong>Author(s)</strong></td>
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<td>Alexander A. Neff</td>
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<tr>
<td><strong>Abstract</strong></td>
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<td>Manufacturing enterprises have boosted their service businesses to enable growth and stable revenue streams. For an efficient implementation of the different service operation functions, however, the service workforce shows information needs that require a comprehensive view on service planning and execution activities. Service functionality is not clearly defined and demarcated in the established production-centered enterprise application landscape. This means, application systems hold accountable for similar functions (e.g. installed base management or contract management) and hence foster redundancy. Moreover functional deficits of standard applications, inter alia remote service functionality, are reported. This situation results in relentlessly expensive integration projects while at the same time hindering any standardization efforts. In addressing this lack of understanding and demarcation, this paper builds on the functional reference model developed by Neff et al. [2014b] and critically evaluates the 12 major service functionalities with the extant body of literature. This study presents a structured literature review that is grounded on keyword searches performed for each of the 12 service functions. This research contributes a structuration and conception of service functions supplemented by a critical reflection on the literature search results. Within each service function the extant literature sets different foci that allow for differentiation and provide an indication of interdependencies among the service function. The discussion part of this paper investigates how service functions span organizational boundaries and complement one another.</td>
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Service Operation Functions in Industrial Equipment Enterprises: A Literature Analysis

Alexander A. Neff

Working Paper

Chair: Prof. Dr. Walter Brenner
Version: 1.0
Date: March 05, 2015

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Abstract

Manufacturing enterprises have boosted their service businesses to enable growth and stable revenue streams. For an efficient implementation of the different service operation functions, however, the service workforce shows information needs that require a comprehensive view on service planning and execution activities. Service functionality is not clearly defined and demarcated in the established production-centered enterprise application landscape. This means, application systems hold accountable for similar functions (e.g. installed base management or contract management) and hence foster redundancy. Moreover functional deficits of standard applications, inter alia remote service functionality, are reported. This situation results in relentlessly expensive integration projects while at the same time hindering any standardization efforts. In addressing this lack of understanding and demarcation, this paper builds on the functional reference model developed by Neff et al. [2014b] and critically evaluates the 12 major service functionalities with the extant body of literature. This study presents a structured literature review that is grounded on keyword searches performed for each of the 12 service functions. This research contributes a structuration and conception of service functions supplemented by a critical reflection on the literature search results. Within each service function the extant literature sets different foci that allow for differentiation and provide an indication of interdependencies among the service function. The discussion part of this paper investigates how service functions span organizational boundaries and complement one another.
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ARIS</td>
<td>Architecture of Integrated Information Systems</td>
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<tr>
<td>B2B</td>
<td>Business to Business</td>
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<tr>
<td>B2C</td>
<td>Business to Consumer</td>
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<tr>
<td>CIO</td>
<td>Chief Information Officer</td>
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<td>CRM</td>
<td>Customer Relationship Management</td>
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<td>DIN</td>
<td>German Industry Norms</td>
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<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<td>IS</td>
<td>Information Systems</td>
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<td>ISO</td>
<td>International Standards Organization</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>KPI</td>
<td>Key Performance Indicator</td>
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<td>M2M</td>
<td>Machine to Machine</td>
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<tr>
<td>MES</td>
<td>Manufacturing Execution System</td>
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<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>VDI</td>
<td>Association of German Engineers</td>
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</table>
1 Introduction

1.1 Motivation and problem statement

The service business has been widely accepted as a value generator, enabling growth and ensuring stable revenue streams for manufacturing enterprises [Strähle et al. 2012, Du et al. 2014]. By adding new services to the product portfolio, the manufacturer is subject to a challenging transformation on strategy, structure and business process levels [Johnson et al. 2008, Ulaga/Reinartz 2011]. Management needs to complement the primary engineering-driven paradigm with the culturally distinct service notion [Gebauer et al. 2005, Kindström 2010]. In place service operations often have insufficient physical resources to implement the industrial transformation; challenges include knowledge deficits on the part of the service workforce or inadequate technical installed base information [Neff et al. 2014a]. Since the requested services vary, a local contextualization and collaboration with the customer is of great importance [Tuli et al. 2007, Biege et al. 2012, Matijacic et al. 2013]. Customer co-creation or customer manufacturing features adaptable production, compressed delivery times and shortened lifecycles [Neff et al. 2014b]. Thus, to ensure satisfactory service delivery, the service operation division relies on high quality data (e.g. accuracy) about the installed base\(^1\). The technical complexity\(^2\) of the equipment makes it necessary to integrate customer-specific data (e.g. entitlement information) with structural information (e.g. computer-aided design structures) [Neff et al. 2014a].

Information technology (IT) shows potential to overcome these business challenges by providing information to the relevant process stakeholders in the service operation units and thereby making the service processes more efficient [Becker et al. 2011, Neff et al. 2014a]. IT is especially well-suited to increase the speed of information, enable universal access, overcome physical distance, and cut communication costs [Jonsson et al. 2009]. However, in order to realize these potential benefits and fulfill the information needs of the service workforce, service planning has to be incorporated into prevalent resource planning applications [Dietrich 2006, Becker et al. 2011]. This becomes difficult when the established enterprise applications are not intended for service process support [Davenport 1998, Dietrich 2006]. ERP (enterprise resource planning) applications are used within production locations, while service operation activities in local sales and service entities are based on CRM (customer relationship management) solutions. In order to address functional deficits of existing enterprise software equipment manufacturers have projected proprietary solutions that handle field and machine information [Tuli et al. 2007, Jonsson et al. 2008, Biege et al. 2012, Mati-

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1 The installed base is defined as “the total number of products [equipment] currently under use” [Oliva/Kallenberg 2003, p. 163] at the customer site.

2 This holds particularly true for heavy equipment or investment goods that are deployed in the customer’s production process. The equipment manufacturer customizes the machines to the individual needs of the production line. More information can be found in Neff et al. [2014a] or in Oliva/Kallenberg [2003].
Proprietary systems expedite the use of remote technology and sensor information for the realization of more usage-based service offerings. The production at the customer’s site is continuously monitored and the customer runs detailed planning on manufacturing execution systems (MES). Thus, the service business in the equipment manufacturing industry is highly heterogeneous and this variety is mirrored in the enterprise applications at the corporate, plant and shop floor layers [Schmidt et al. 2011]. Applications give allowance for very similar functions\(^3\), which leads to redundant configurations. While this situation impedes standardization efforts, it makes integration projects a bold venture.

1.2 Research question

This paper is geared toward addressing the theoretical knowledge gap on exploring and demarcating the service functions and the information systems (IS) appropriation in the manufacturing industry. The extant literature has developed a functional reference model [Neff et al. 2014b] based on standard literature, case study research and focus group analysis, but neglects the current state of knowledge in scholarly literature. Departing from this conceptual work, this paper conducts a structured literature review to add to the theoretical body of knowledge concerning service functions. The following research question (RQ) guides this paper:

RQ: *What is the current state of knowledge on service planning and execution functions and the corresponding information systems?*

1.3 Structure

The remainder of this paper is structured as follows. First, the central terms from function view over service management in enterprise application systems to the service function that serves as the cardinal point for this literature review are introduced. Second, the research methodology, including the conception used and literature search, is elaborated. Third, the results of the literature search are analyzed and synthesized. Fourth, the results are discussed with regards to their contribution to research. Fifth, the paper concludes with a summary and the main findings, supplemented with a critical view on the limitations.

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\(^3\) For instance, the installed base management is part of both the SAP enterprise applications CRM and ERP. The modules are called CRM Service and ERP Customer Service.
2 Background

2.1 The function view of ARIS

ARIS⁴ (Architecture of Integrated Information Systems) is a concept for enterprise modeling that provides a guideline for “developing, optimizing and implementing integrated application systems” [Scheer/Schneider 2005, p. 605]. The approach can be used to reduce the complexity of describing business processes by applying different views on an information system. This concept has been visualized in form of the ARIS house (Figure 1) [Scheer 2002]. The ARIS house of business process management shows the general architecture of business process management and is structured along the three levels of (1) strategy, (2) process-design, -optimization and -controlling, and (3) execution [Scheer/Schneider 2005]. One benefit of the ARIS house is its universal applicability for different types of business processes. It can be deployed in every sector, private and public, and in manufacturing as well as service businesses [Scheer/Schneider 2005].

![Figure 1. Views of the ARIS house based on Scheer [2002, p. 41]](image)

In order to represent processes clearly and systematically, the ARIS framework includes four static views (function, data, control, and output view) and one dynamic view (organization view) that are interrelated with one another [Scheer/Schneider 2005]. For the present paper, the function view can, in particular, inform IT support of service functions. The function view describes the functions of the information system and their relationships. These functions can be assigned to the units from which they

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⁴ ARIS was first developed by August-Wilhelm Scheer at Saarland University in the 1990s and since then it has been continuously improved [Scheer 1998].
are executed. On the concept level, function trees serve as descriptions of the individual functions and their interrelationships [Scheer 1998]. For their execution on the data processing concept level, depending on the programming paradigm used, for example flow charts, structure diagrams, unified modeling language state or activity diagrams are applied [Scheer 1998]. At the implementation level, the actual programming and provisioning of the function takes place. Application programs support the function view [Scheer/Schneider 2005]. “These programs can be described in more detail by module concepts, transactions or programming languages” [Scheer/Schneider 2005, p. 611]. In the ARIS concept, the functions are treated as an independent view on a business process [Scheer 1998].

Within the ARIS concept, the term “function” is defined as an operation performed on an object in order to support objectives [Scheer 1998, p. 22]. The name of a complex function such as “order processing” is also used for a business process. However, a business process also includes the description of the activity, the dynamic control of the function sequence from its beginning to its completion [Scheer 1998]. Yet in a purely functional description, the depiction of the static functional structure dominates. The basis of functional modeling for business process design is the data process-oriented strategic output concept [Scheer 1998]. In this concept, the objectives that will be supported by the functions are defined [Scheer 1998]. The objectives can be interrelated and one function can support multiple objectives [Scheer 1998]. Functions can be classified by their level of detail [Scheer 1998, p. 25 f.]:

- **Bundle of functions:**
  Complex function, which is composed of a plurality of activities

- **Function:**
  Complex activity that can be further subdivided and is part of a bundle of functions

- **Partial function:**
  Activity, which is decomposed into sub-functions or elementary functions and is part of higher-order functions

- **Elementary function:**
  Activity, which cannot be further subdivided in a useful way

In addition to defining the functional structure, this concept is also tasked with defining the sequence of functions [Scheer 1998]. Thereby, the transition to a process description can be achieved [Scheer 1998]. Compared to the later process descriptions of the control view, however, the trigger of a function is not defined but only the logical sequence of functions [Scheer 1998]. In the present paper, the functional view de-

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5 The terms “function”, “transaction” and “activity” are used synonymously [Scheer 1998].
6 The concept of critical success factors developed by Rockart [1978] can serve as the basis for defining these objectives.
scribes application functions that are derived from service processes (based on previous work, e.g. Neff et al. [2014b]) at the requirements definition level.

2.2 Demarcation of service management functionality in enterprise application layers

All the different layers on the corporate, customer plant and customer shop floor levels incorporate service management functionalities (Figure 2). Enterprise applications such as ERP and CRM, located in the corporate layer, support very general service business functionalities such as service planning along the entire operational supply chain [Neff et al. 2014b]. An organizational boundary separates the corporate layer from the two lower levels and the perspective changes from corporate to customer view [Neff et al. 2014b].

In the customer plant layer, applications that monitor and streamline the production process (e.g. MES) are deployed [Neff et al. 2014b]. In the third layer, the shop floor layer, production and automation systems entail real-time customer production data [Neff et al. 2014b]. To provide efficient, high quality services that are tailored to customer demands, the equipment manufacturer needs access to high quality (e.g. timely) information on the client’s assets [Neff et al. 2014a, Neff et al. 2014b]. This data remains hidden in the customer’s MES and in the shop floor systems [Neff et al. 2014b]. Although a more detailed view on the customer’s equipment is required for service management, existing systems in the corporate layer do not collect and process the real-time data from the subsequent layers [Neff et al. 2014b]. ERP systems in the corporate level are not suitable to meet variable requirements in the client’s manufacturing [Neff et al. 2014b]. The time unit varies for each layer. ERP schedules are set up on a daily basis while MES performs and responds to needs on a minute-by-minute basis [Neff et al. 2014b]. Further, the level of detail in an ERP system is low and it falls short of processing sensor data that has been generated in the shop floor layer [Neff et al. 2014b].
2.3 Modeling service planning and execution functions

Through the literature, Neff et al. [2014b] first made an attempt to define and demarcate service functionality in the existing enterprise application landscape. They developed a functional reference model that describes service functionalities on the application abstraction levels. Further it provides a first indication on redundant functionalities. The model development is based on standardization documents, focus group and case study research comprising eleven equipment manufacturers and two software firms [Neff et al. 2014b]. Drawing from standards and norms from popular standardization organizations they identified 26 standardization items that served as a basis for the functional reference model [Neff et al. 2014b]. The operationalized service functionalities in the model illustrate the current state of service business integration in the heavy equipment manufacturing industry [Neff et al. 2014b]. Accordingly, their research primarily contributes to practice. The model is a first attempt to identify, analyze and assess the required service management functionalities. Further, it eases communication with IT service providers and software vendors by establishing common terms [Neff et al. 2014b]. However, this exploratory model falls short of critically reflecting and synthesizing the study results with the scientific body of knowledge.

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7 Figure 2 is depicted as illustrated in Neff et al. [2014b, p. 3] and is based on Louis and Alpar [2007] as well as Schmidt et al. [2011].

8 Standardization organizations include the International Standards Organization (ISO), German Industry Norms (DIN), Association of German Engineers (VDI) and National Institute of Standards and Technology (NIST).
This research endeavor is geared toward addressing this shortcoming by taking these service functions and performing a structured literature review.

Nonetheless, there is one core contribution to the theoretical body of knowledge that serves as a profound base. From the conceptual standpoint, the application functions of service business in manufacturing firms are identified and specified by the model. Thus, the model\(^9\) aims at closing the research gap concerning the demarcation of service management functionality in enterprise applications [Neff et al. 2014b]. In their original model, Neff et al. [2014b] identified 14 functions that belong to the core or at least to a certain part of service management functionality. Key functionalities in the domain of service planning, which takes place in the corporate layer, are, inter alia, warranty claim management, contract management, customer communication and service collaboration [Neff et al. 2014b]. While warranty claim management is not mentioned in the standardization literature, the case studies performed have emphasized that it should be classified as a core service management functionality [Neff et al. 2014b]. The occurrence of warranty claims connected to the client’s equipment and their management are at the center of this functionality. The execution and monitoring of services take place at the plant and shop floor layers. At this stage in the service business, the organizational boundary between the equipment manufacturer and the customer needs to be overcome [Neff et al. 2014b]. Core service functionalities such as workforce management, installed base management and analytics are located at the interface of the corporate and the customer plant layers [Neff et al. 2014b]. The customer shop floor layer therefore becomes relevant for generating real-time data or performing direct machine control [Neff et al. 2014b]. Remote service management relies heavily on this information [Neff et al. 2014b]. Similarly to warranty claim management, remote service management has not been specified by the analyzed standardization literature [Neff et al. 2014b]. However, the case studies revealed its relevance [Neff et al. 2014b].

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\(^9\) Please find a more detailed view on the reference model and the 14 service functions in Neff et al. [2014b].
3 Research Methodology

3.1 Review scope and conceptualization

The service functions derived from Neff et al. [2014b] serve as the primary source for conceptualization. In their functional reference model, they identified 14 functions that belong to the core or, at least to a certain extent, to service management functionality. The function “machine control” was excluded, since the object of investigation in this paper is the manufacturing enterprise and not the customer. The remaining functions – all residing in the corporate layer – are used as the primary input values for the key-word search. The search paraphrases are completed with the two strings “information system OR information technology” and “service planning OR service execution”. “Master data management” and “equipment master data management” were simplified\(^\text{10}\) and merged into “data management”. Table 1 demonstrates the conceptualization applied for this search.

3.2 Literature search

The search process itself is conducted using a two-step approach. The first step constitutes a keyword search, in which the selected databases are queried [Xiao/Benbasat 2007]. Literature scholars endorse the application of proper search terms [Rowley/Slack 2004] in conjunction with a traceable keyword documentation [vom Brocke et al. 2009]. Precision is given by the use of the 12 service functions that are combined with the aforementioned strings. The queried databases\(^\text{11}\) guarantee exhaustive coverage since the important journals are considered. Table 1 shows the search results for every search phrase linked to the corresponding source database over a time frame from 1990 to October 2014. The numbers in brackets are the net hits, while the bold numbers refer to the number of relevant articles. The relevance has been judged in terms of an individual assessment of every article’s title and abstract. Multiple counts have been removed manually to arrive at the net hits\(^\text{12}\). In addition, as the applied literature review framework proposes, a forward and backward search has been performed. This second step of the search process is highly necessary in light of the interdisciplinary character of information systems. In total, this search generates additional 14 articles so that a sum of 91 scholarly articles can be ascertained.

\(^{10}\) During the literature search process, it turned out that “master data management” and “equipment master data management” result in very similar search results.

\(^{11}\) Accordingly, the following databases have been selected: EBSCOhost, ProQuest (ABI/INFORM), ScienceDirect, and Web of Science. The Association for Information Systems Electronic Library (AISeL) completes the database list by adding the current state of the major IS conferences.

\(^{12}\) Because the search phrases have been used to search all six databases independently and neither the database nor the search phrases are mutually exclusive, some articles have been included more than once.
<table>
<thead>
<tr>
<th>Database</th>
<th>AND</th>
<th>“Service planning” OR “service execution”</th>
<th>“Information technology” OR “information systems”</th>
<th>Aggregated 12 service functions</th>
<th>Net hits*</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBSCOhost</td>
<td>2 (43)</td>
<td>4 (13)</td>
<td>3 (95)</td>
<td>3 (77)</td>
<td>20 (1115)</td>
</tr>
<tr>
<td>ProQuest</td>
<td>1 (26)</td>
<td>7 (34)</td>
<td>4 (21)</td>
<td>2 (67)</td>
<td>15 (282)</td>
</tr>
<tr>
<td>Emerald</td>
<td>0 (14)</td>
<td>0 (1)</td>
<td>1 (6)</td>
<td>0 (0)</td>
<td>14 (164)</td>
</tr>
<tr>
<td>ScienceDirect</td>
<td>2 (34)</td>
<td>2 (54)</td>
<td>4 (64)</td>
<td>5 (39)</td>
<td>18 (680)</td>
</tr>
<tr>
<td>Web of Science</td>
<td>1 (449)</td>
<td>2 (20)</td>
<td>2 (365)</td>
<td>2 (431)</td>
<td>22 (2526)</td>
</tr>
<tr>
<td>AISeL</td>
<td>4 (12)</td>
<td>4 (5)</td>
<td>1 (10)</td>
<td>3 (18)</td>
<td>24 (140)</td>
</tr>
<tr>
<td><strong>Net hits</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>77</strong></td>
</tr>
</tbody>
</table>

Legend: *Double counts are removed manually

Table 1. Results of the keyword search and (exemplary) excerpt from four functions
4 Literature Analysis and Synthesis

The challenging aspect of a literature review is to synthesize the search results [Parker et al. 1998]. It is relevant for the reader to understand what have been the learnings as well as what commonalities and patterns can be filtered from the literature [Webster/Watson 2002]. In total, the literature search yielded 91 articles. Each selected article is classified into categories. First, a general view on the search results is presented. Then the findings on peripherally addressed service functions followed by thoroughly service functions are explained.

4.1 General findings

Table 2 shows a two-dimensional matrix that has been deployed to classify the general findings. The first group of characteristics targets some central service-related meta information, while the second group addresses the formal meta information, which is based on Cooper’s [1988] taxonomy [Webster/Watson 2002]. To expound all possible categories would go beyond the constraints of this paper. Instead, it focuses on those categories that are relevant in the context of this research endeavor. In total, 91 relevant articles were found and classified according to the particular categories (classification is mutually exclusive). Amongst them, 48 involve target efficiency and 20 concern value-adding. Some 8 articles aim at improving customer satisfaction, while another 8 target higher integration, alignment or standardization across companies, departments or IT systems. The majority of the articles analyzed (55) acknowledge the customer and its needs and requirements in the service provision. While only 12 articles do not include the customer as an element of value creation, 22 articles describe collaboration and co-creation models. Most of the articles cover business clients; private clients are only targeted in 12 articles. The predominant industry\(^1\) in the 91 analyzed articles is manufacturing (60), followed by healthcare (8). The service-dominant logic is applied in 24 articles\(^2\), while 12 articles use a system theory-oriented lens. The unified service theory serves as a theoretical basis for only 3 articles. Some 43 articles are IS publications, 24 articles are published in the operations management, while the management domain accounts for 18 articles. A total of 4 articles have been published in the domain of product development, design or innovation. Most articles are journal articles (72). Some 19 articles have been published in the respective conference proceedings\(^3\). The dominant research method is case study research (35), while 20 articles deploy mathematical modeling or conceptual modeling, respectively. Other methods of research such as surveys (8), literature reviews (3) and experiments (2) are less common.

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\(^{1}\) Others, e.g. banking, agriculture and the public sector, are rarely approached (by less than 3 articles).

\(^{2}\) Particularly in recently published articles, the service dominant logic is the predominant theoretical lens.

\(^{3}\) Proceedings are usually complemented by presentation and discussion at the appropriate conference track. The AISeL conferences are peer-reviewed in a double blind approach.


### Table 2. Meta-information of the search results

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(IT) objective</strong></td>
<td>Efficiency (48)</td>
</tr>
<tr>
<td><strong>Customer role</strong></td>
<td>Non-customer involvement (12)</td>
</tr>
<tr>
<td><strong>Industry focus</strong></td>
<td>Healthcare (8)</td>
</tr>
<tr>
<td><strong>Theoretical lens</strong></td>
<td>System theory (12)</td>
</tr>
<tr>
<td><strong>Literature domain</strong></td>
<td>Information systems (43)</td>
</tr>
<tr>
<td><strong>Literature type</strong></td>
<td>Journal article (72)</td>
</tr>
<tr>
<td><strong>Research method</strong></td>
<td>Literature review (3)</td>
</tr>
</tbody>
</table>

#### 4.2 Findings on peripherally addressed service functions

The first column (Table 3) comprises the 6 service functions that do not belong to the core functions. Surprisingly, the analytics function does not draw much attention. Just 2 articles were identified. The first article is concerned with the usage of analytical techniques for taking advantage of customer intimacy [Habryn et al. 2012]. This article yielded data and process mining as relevant technical capabilities for service analytics. Both techniques were confirmed by vom Brocke et al. [2014] who analyzed the potential of in-memory technology for principles of value generation in the manufacturing industry. One in-memory application, named Track ‘n’ Aid, allows the upgrade of both product design and customer service by permanently gathering data regarding position, status and usage of tools in the field [vom Brocke et al. 2014, p. 156]. This application is based on sensor and communication technology, which can transfer live data to the manufacturer’s base [vom Brocke et al. 2014]. Thus, the manufacturing company can anticipate maintenance work and avert costly repair processes, interruptions and down times at construction sites [vom Brocke et al. 2014].

Contract management receives more attention in the literature, ending up with 6 articles. The extant literature differentiates three contract types: Fixed free, time and material, and performance contracting [Roels et al. 2010]. Among the contract types, scholarly literature focuses on the design of efficient managerial and performance-based contracts [Jiang/Seidmann 2014] by, for example, determining the optimal managerial compensation. Within the healthcare literature stream on services, contract management is understood as continuous updates of the key performance measures for prognostic health management and interaction. This prognostic technology can support...

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16 B2B is the appreciation of business to business, while B2C refers to business to consumer.
17 In total, 12 service functions were investigated. Some 6 service functions are classified as peripheral (less than 10 articles identified for an individual function) and 6 were classified as thorough (at least 10 articles).
service contracts by ensuring a high level of asset availability and capability, dealing with unpredicted events during the execution of the contract, online simulation, and continuous updates of the key performance measures [Teixeira et al. 2012]. Key performance indicators have to address customer-related\(^\text{18}\), contract-related\(^\text{19}\), and product-related attributes\(^\text{20}\). A prototype web-based decision support system for standardizing the process of managing service contracts can be positioned as a controlling mechanism [Sundarraj 2004].

Six articles consider customer communication issues in the service planning and execution context. Customer communication is one of the main pillars of customer relationship management. A shift in emphasis from managing product portfolios to managing portfolios of customers can occur, necessitating changes to working practices and sometimes to organizational structure [Ryals/Knox 2001]. There is a general consensus in the extant literature (4 out of 6 articles) that technology-mediated customer contact is a must to sustain competitiveness at the operative level [Glushko/Nomorosa 2013]. With the replacement or supplementation of interpersonal interaction with technology-based information exchange, experiential service encounters have become more information-intensive ones [Glushko/Nomorosa 2013]. Customer representatives can access data (e.g. customer profile, product and logistics) to analyze problems and provide a rapid online response to customer queries. CRM supported communication channels comprise call centers, telephone, database and local area networks [Froehle/Roth 2004, Torkzadeh et al. 2006].

Data management is addressed in 7 articles with 2 foci. The first group in the literature understands this function as track patterns in customer transactions, data collection and tracking [Westelius/Valiente 2004], while the second group aims to establish a comprehensive customer database, different types of data (transaction data, human data, etc.), and data integration [Davenport et al. 2001]. Although both financial and operational results are positively related to the data-driven decision-making of a company, numerous enterprises fail in adequately managing data from different sources with differing degrees of data quality [McAfee/Brynjolfsson 2012]. In particular, the combination of multiple data sources (e.g. mobile devices and embedded sensors) [Candell et al. 2009] with various information systems (e.g. analytical and transactional systems) [Li et al. 2012, Peltier et al. 2013] bears the risk of deteriorating data quality [Neff et al. 2014a]. Using in-memory technology for improving customer service and product design by capturing “the position, status, and usage data of tools in the field continuously” provides a tangible example of the data quality risks [vom Brocke et al. 2014, p. 156].

\(^{18}\) Please see the work of Sundarraj [2004, p. 345] to find the customer-related attributes: customer type, customer application type and customer participation.

\(^{19}\) Please see the work of Sundarraj [2004, p. 346] to find the contract-related attributes: contract response duration, contract size, contract age and contract type.

\(^{20}\) Please see the work of Sundarraj [2004, p. 346 f.] to find the product-related attributes: product age, product criticality and product unit age.
The search results provide 7 articles concerning inventory management. The importance of IS in the achievement of integrated supply chain logistics has been shown in previous studies [Stenger et al. 1993, Cooper et al. 1997]. The service transformation of manufacturers requires inventory management to support new functions such as the auto replenishment of spare parts and consumables. With the aim of satisfying the increased service level agreements, the application of emerging IT, for example condition based maintenance, radio frequency identification and web services [Cheng/Prabhu 2012], and more accurate forecasting methods [Frazzon et al. 2014] becomes inevitable. *Inventory planning and distribution* refers to the planning activities of the supply chain such as a multi-echelon system involving factory, central warehouse, regional warehouses, service center, field stocking locations and customer facilities [Frazzon et al. 2014]. The configuration of spare supply chains mostly depends on the control characteristics of serviceable parts, for example “criticality of the product, specificity of the components, demand pattern and value of parts” [Frazzon et al. 2014, p. 148]. Forecasting the service demand presents the major capability that builds on technical condition data to perform eradication analysis. *Logistics execution* is concerned with the operational implementation of the planning activities for the local entities. This includes warehouse management, stock control, inventory status and control and customer order processing [Faber/van de Velde 2002, Sohal 2002].

Warranty claim management is sparsely addressed in the extant literature. The literature search yielded, in total, 3 articles. Scholars suggest a warranty management process that is closely linked to maintenance, service outsourcing, quality management and management accounting [González-Prida/Crespo Márquez 2012]. The realization is usually accompanied by technical tools such remote assistance, cooperative warranty service, on-line assistance, predictive warranty service, and failure diagnosis [González-Prida/Crespo Márquez 2012, p. 961].

<table>
<thead>
<tr>
<th>Service functions</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analytics</strong> [2]</td>
<td>Customer intimacy analytics</td>
</tr>
<tr>
<td></td>
<td>Advanced business analytics and in-memory technology</td>
</tr>
<tr>
<td><strong>Contract management</strong> [6]</td>
<td>Service contract types and issues, e.g. fixed fee, time and material and</td>
</tr>
<tr>
<td></td>
<td>performance contracting</td>
</tr>
<tr>
<td></td>
<td>Performance contracting</td>
</tr>
<tr>
<td></td>
<td>Performance indicator and controlling mechanism</td>
</tr>
<tr>
<td><strong>Customer communication</strong> [6]</td>
<td>Customer relationship management</td>
</tr>
<tr>
<td></td>
<td>Technology-mediated customer contact</td>
</tr>
<tr>
<td><strong>Data management</strong> [7]</td>
<td>Customer interaction and customer master data</td>
</tr>
<tr>
<td></td>
<td>Access to an integrated view on different data types, e.g. equipment,</td>
</tr>
<tr>
<td></td>
<td>workforce, spatial and sensor data</td>
</tr>
<tr>
<td><strong>Inventory management</strong> [7]</td>
<td>Inventory planning and distribution (supply chain integration, demand</td>
</tr>
<tr>
<td></td>
<td>forecasting)</td>
</tr>
<tr>
<td><strong>Warranty claim management</strong> [3]</td>
<td>Logistic support analysis</td>
</tr>
<tr>
<td></td>
<td>Procurement</td>
</tr>
<tr>
<td></td>
<td>Maintenance support and service management</td>
</tr>
<tr>
<td></td>
<td>Technical documentation and e-learning</td>
</tr>
</tbody>
</table>

*Table 3. Analysis of the peripherally addressed service functions*
4.3 Findings on thoroughly addressed service functions

With 13 articles, field service is one of the most debated core service functions (Table 4). Along the field service process, four streams can be distinguished. Planning functions for field service on site customer visits constitutes the first stream. Activities include, for example, the determination of manpower requirements based on the actual structure and operating policies of the workforce [Watson et al. 1998], the development of optimal in-field paths to be followed by service units (e.g. transport) for agriculture customers [Bochtis et al. 2010], and customer reports (including service job experience, customer and installed equipment information) [Stieger/Aleksy 2009]. For the actual service execution in the field, the workforce needs to access and manipulate service transaction data [Matijacic et al. 2013]. There is a broad range of information processed with common stock on equipment, customer, contract, spatial and a composition of the previous service transactions (service history) [Thomas et al. 2007, Fellmann et al. 2011, Matijacic et al. 2013, Neff et al. 2014a]. If an unplanned maintenance situation occurs or equipment configurations do not match with documented information, collaboration and co-creation with different stakeholders will become necessary to get the situation under control in order to fulfill the service level agreements. The literature here refers to established approaches such as call center support, expert network consultation, and remote collaboration [Dollmann et al. 2009]. The accurate documentation completes the field service process and serves as the primary information source for backend functions such as accounting and analytics [Dausch/Hsu 2006, Thomas et al. 2008, Karray et al. 2014].

Installed base management is hotly debated in the extant literature (18 articles). The equipment’s installed base accounts for the total amount of equipment currently under use at the customer site [Oliva/Kallenberg 2003]. Accordingly, the installed base has to be considered, in the core of its definition, as customer-oriented. Managing the installed base is critical, since operational service processes essentially count on installed base information [Oliva/Kallenberg 2003]. A significant overlap with other functions demonstrates this dependency in the extant literature. The first research stream addresses offer and configuration. Equipped with precise and accurate information and knowledge about the installed base, the manufacturer is able to derive a better customization of the service offerings [Kowalkowski et al. 2009] and to develop tailored services that are required by the end-user to obtain a desired functionality (i.e. use the product in the context of its operating process) [Oliva/Kallenberg 2003]. The second stream, delivery and installation, focuses on the integration with logistics execution of spare parts and industrial equipment [Jalil et al. 2011] and the planning of installation.

21 The subsequent functions belong to the thoroughly addressed service functions (i.e. each function is addressed by at least 10 articles).
22 As a result, the categories refer to the various service execution activities of, e.g., the maintenance function, but are also associated with contract management, data management, field service, inventory management and remote service.
services [Dollmann et al. 2009]. Having installed base data allows the manufacturer to replace “stock location demand forecasts” with “planning via machine location demand forecasts” [Jalil et al. 2011, p. 446]. These forecasts form the decision base for the positioning of the spare parts inventory throughout the geographical network and hence the optimization of the provisioning of spare parts to customers [Jalil et al. 2011]. The third stream refers to maintenance activities using installed base information (7 articles). The scope ranges from installed base information on machine location data, contractual data, bill of material, service history and machine type data [Krikke/van der Laan 2011, Neff et al. 2014a] to unplanned and planned maintenance services based on enterprise applications [Neff et al. 2014a, Nikolopoulos et al. 2003]. The literature further reports on innovative maintenance practices in the light of shortened product lifecycles, such as using phase-out returns obtained from customers that replace systems to serve other customers that do not replace the systems yet [Krikke/van der Laan 2011]. The fourth stream addresses the monitoring activities of the installed base with a clear focus on the usage for product and service design [Bailetti/Litva 1995, van den Ende et al. 2008, Visintin et al. 2013]. Perceptions of a service provider’s installed base of equipment are understood as a valuable requirement for design groups in research and development [Bailetti/Litva 1995]. Monitoring the installed base can provide fruitful insights (e.g. usage behavior of customers or field data from equipment in use) to align complementary products with the remaining components of the system [van den Ende et al. 2008] and to achieve more accurate demand predictions for spare parts [Visintin et al. 2013].

The literature search confirms the central notion of knowledge management by yielding 12 articles for analysis. Demanding service level agreements, as part of an ambitious service transformation, push the manufacturer’s service units beyond resource limits. The lack of well-educated field (service) technicians in developing countries is reported, while service engineers in the back office are not trained for remote service interaction [Neff et al. 2014a]. This holds particularity true for the increasing complexity in industrial equipment and health care systems [Weinrauch 2005], since product configurations and technical variants can easily exceed several thousand options. Knowledge management is deemed promising to support information intensive tasks, such as service operation processes [Lehtonen et al. 2012]. Knowledge management systems store, retrieve and share service data in the knowledge database [Matijacic et al. 2013] to increase efficiency in technical customer service [Fellmann et al. 2011]. Such unstructured and structured service data is characterized by a high semantic and structural heterogeneity [Stieger/Aleksy 2009]. Service manuals, repair guidelines, data sheets, spare part lists and best practice reports refer to typical structures [Fellmann et al. 2011] that have led to stand-alone knowledge management applications. Search and retrieval of this heterogeneous data, updating the knowledge database and data quality remain unsolved challenges in the knowledge management which prevent accessibility [Fellmann et al. 2011, Matijacic et al. 2013]. Further, globally acting or-
ganizations have to build knowledge networks [Anderson/Parker 2013] with competence centers and cross-organizational collaboration modes. This starts with the collaboration of field service and back office engineering and can end with subcontractors and service providers [Leimeister/Glauner 2008]. Beyond efficiency optimization, knowledge-related data objects are used for product development [Fellmann et al. 2011].

Maintenance, repair and overhaul activities\(^\text{23}\) are concerned with service transactions that retain or restore equipment or to maintain the state in which the equipment is able to perform its designed function. Maintenance is initiated by planned periodic repair (planned), equipment breakdown or deterioration indicated by a monitored parameter (unplanned) [Nikolopoulos et al. 2003, Krikke/van der Laan 2011]. This function presents the core operations of a manufacturer’s service division. This notion is confirmed by 13 articles that differentiate four types of maintenance. Corrective maintenance is more likely part of a reactive (i.e. fault-based maintenance) maintenance strategy [Jonsson et al. 2009] and might be immediate or deferred [Gulledge et al. 2010]. The first form of preventive maintenance (sometimes referred to as proactive maintenance) is usually initiated by a planned service event. The underlying notion is to replace components before something happens. This forms a contrast to corrective maintenance, which sticks to planned service until the equipment breaks down [Tsang 2002]. For example, the elevator manufacturer Schindler uses a geographic information system for service planning and route optimization [Blakeley et al. 2003]. Equipment manufacturers use diagnostic tools that can measure indicators such as vibration, noise, temperature and corrosion in order to determine when maintenance should take place. The second form of preventive maintenance is condition-based maintenance. The condition of the equipment is monitored in-use to maintain the operation conditions at the customer site [Tsang 2002]. Applied techniques comprise performance-parameter analysis, vibration monitoring, thermography, and oil analysis [Jonsson et al. 2009]. With the shift to condition-based maintenance comes a drastic increase in IT use and a new working organization that can deal with the new information-rich maintenance [Jonsson et al. 2009]. Predictive maintenance\(^\text{24}\) exceeds the condition-based approach through the complementary addition of forecasting techniques. Diagnostic and prognostic techniques are able to forecast failures. They measure the gradual degradation status of machines or parts and, through these inputs, can estimate the probability rate as well as the date of future breakdowns [Frazzon et al. 2014]. Data generated through these forecasting methods is used in mature implementations processed for product improvement, where the design of the equipment is modified to minimize recurring failures [Jonsson et al. 2009].

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\(^{23}\) The terms “maintenance, repair and overhaul” and “maintenance, repair and operations” are used synonymously in the extant literature with a trend toward the “overhaul” version in the airline, defense and aerospace industries.

\(^{24}\) Sometimes the terms “predictive” and “intelligent” are used synonymously.
Remote service plays a leading role in the service transformation of industrial equipment enterprises in terms of new business models [Zolnowski et al. 2011], service model implementation [Akram/Akesson 2011], customer satisfaction [Paluch/Blut 2011], efficiency gains for service operations [Vardar et al. 2007, Neff et al. 2014a], trust issues in outsourcing [Westergren 2010], bridging organizational boundaries to acquire customer information [Jonsson et al. 2008] and field service automation [Brax/Jonsson 2009]. The presence of remote technology and digitalized equipment can be applied to diminish organizational boundaries [Jonsson et al. 2008]. This approach is implemented to a different extent depending on customer involvement, service models and contract, technical capabilities of remote technology, digitalization level of physical equipment and internet bandwidth. Three categories were identified in the extant body of literature. Remote diagnosis incorporates equipment troubleshooting, remote advice on customer operations, knowledge consultation and send-in machine report for service visit preparation. Remote diagnosis applications are heavily customized, as they “are made up of collections of heterogeneous technologies: sensors that collect data, […] networks […] that transmit it into a centralized repository; and analytics and operational rule systems that store and retrieve the data, analyze it, visualize it and make recommendations, generate alarms, or launch responses” [Jonsson et al. 2009, p. 237]. While remote diagnosis is most likely initiated by the customer operation unit, smart digitalized equipment triggers callback and automatic interaction. This exceeds the remote diagnosis function by simultaneously processing callbacks to the manufacturer’s service center. Once identified, the smart equipment instantly sends an automatic notification to the control station and the manufacturer’s service center. The most mature approach implementing this notion is called remote operations. These services are used to manage the machines deployed in the process lines in industrial companies [Jonsson 2009]. Measurement points in the equipment’s sensor systems are monitored continuously by the remote service center. Once irregularities are sensed, the service center operation staff evaluates the data and summarizes it in a list of service jobs. A considerable amount of data on this issue has been collected in the agricultural machinery industry. With the aim of improving temporal accuracy in decision-making, this technical prototype addresses a dynamic application task for precision agriculture [Kaivosoja et al. 2014]. The data sources comprise “onboard sensors”, “weather and forecasts (rain, wind, temperature, heat sum)”, “disease pressure information”, “sensitive environment information (ground water, neighboring plants and crops)”, external “flood” and “fire” risk, “real-time remote sensing” (e.g. “satellites”, “aerial images”, distinct working units), equipment calibration parameters and distinct working units [Kaivosoja et al. 2014, p. 114].

25 14 articles were identified, which makes remote service the second most debated function.
26 In this case, the primary external boundary lies between the manufacturer and the customer organization.
27 In most cases, remote diagnosis applications are custom-built or refer to proprietary systems [Jonsson et al. 2008, Neff et al. 2014a, Neff et al. 2014b].
28 Irregularities in the analyzed data might be, for example, derivations from the norm or exceeding limit values.
The extant literature discusses service collaboration along three research streams in 11 articles. In the first research stream, *business networks and strategic partnering*, scholars address design issues in business networks that enable collaboration. Kimura et al. [2003] study engineering enterprises that service manufacturing systems in collaboration with supplying vendors. While the first stream obtains a service provider’s view, the second stream, *service system and customer co-creation*, pays significantly more attention to customer co-creation as part of the service system. Kumar and Telang [2011] investigate the collaborative process for planned development in which corporations iteratively develop prototypes to allow customer groups to articulate their needs. In a more theory-driven approach, Edvardsson et al. [2011] compare service-dominant logic with a service system design informed by goods-dominant logic. The third stream, *inter-organizational systems*, is concerned with enterprise applications and adjacent technologies to electronically integrate business processes with corporate partners [Legner 2009]. Collaborative services rely on a sound IS infrastructure that connects remote stakeholders [Muller et al. 2008]. The use of IT allows the flow of data between two or more organizations (i.e. extending traditional organizational boundaries) [McLeod Jr et al. 2008]. An effective platform enables collaboration among enterprise areas and key stakeholders (c.f. Wang et al. [2011]) along the product lifecycle [Muller et al. 2008]. Exchanging information regarding modules and dimensions requires an integrative platform that converts data from existing enterprise applications [Wang et al. 2011]. Adjacent technologies comprise “electronic data interchange”, “extranets”, “electronic funds transfer”, “supply chain management systems” and “e-hubs” [Daniel/White 2005, p. 190 f.].

<table>
<thead>
<tr>
<th>Service functions</th>
<th>Categories</th>
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<tbody>
<tr>
<td><strong>Field service [13]</strong></td>
<td>Planning (e.g. manpower requirements, path analysis)</td>
</tr>
<tr>
<td><strong>Installed base management [18]</strong></td>
<td>Offer and configuration</td>
</tr>
<tr>
<td><strong>Knowledge management [12]</strong></td>
<td>Technical customer service, structural and semantic heterogeneous, on-site challenges</td>
</tr>
<tr>
<td><strong>Maintenance, repair and overhaul [13]</strong></td>
<td>Corrective</td>
</tr>
<tr>
<td><strong>Remote service [14]</strong></td>
<td>Diagnosis</td>
</tr>
<tr>
<td><strong>Service collaboration [11]</strong></td>
<td>Business networks and strategic partnering</td>
</tr>
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**Table 4.** Analysis of the thoroughly addressed service functions

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29 Goal vector is the more favorable customer experience [Edvardsson et al. 2011].
30 Business partners negotiate mid- to long-term contractual agreements to govern transactions [Legner 2009].
31 Wang et al. [2011, p. 89] refer to the following enterprise applications: CRM, supply chain management, MES, product lifecycle management, ERP, knowledge management, remote data acquisition and tele-service.
32 Processing of information primarily refers to create, read, update and delete (CRUD) operations.
5 Discussion

After elaborating on the individual functions, the elements of the functional reference model also have complementary effects. This means that a particular function depends on a distinct function’s information output for reliable processing. For instance, field service comprises the collaboration and processing of information sub-functions. While the former points at service collaboration (i.e. collaboration with a remote service engineer), the latter is closely related to the retrieval and storage of service related data (i.e. data management). The subsequent sections discuss these findings according to boundary-spanning\textsuperscript{33} service functions that might foster the acquisition of customer knowledge into the manufacturer’s organization.

5.1 Service functions as boundary-spanning clusters

One of the most decisive distinctions between production and service is the interaction with external customer stakeholders [Sampson/Froehle 2006]. Service scholars refer to the term co-creation to formally identify this characteristic [Maglio/Spohrer 2008]. The number of stakeholders involved varies, however, there is a trend toward multiple vendors, multiple providers, and multiple customers\textsuperscript{34}. The ongoing transformation of the operation model reinforces this growing number and leads to numerous organizational boundaries.

For the industrial equipment manufacturer, mastering competitiveness is intrinsically tied to the ability to protect knowledge within or to allow it to flow across organizational boundaries [Kogut/Zander 1992, Nonaka 1994, Grant 1996, Jonsson et al. 2009]. Digitalized services can process this flow of information across both internal and external organizational boundaries to enable collaboration [Mathiassen/Sørensen 2008]. When those digitalized services are able to assimilate and diffuse knowledge across internal and external boundaries, scholars refer to boundary-spanning [Leifer/Delbecq 1978] practices. The extant literature provides a strong indication for the enabling role\textsuperscript{35} of IT in boundary-spanning practices [Hayes 2001], for example in terms of inter-organizational transaction system within a supply chain [Malhotra et al. 2005] and a collaboration system supporting inter-organizational design work [Majchrzak et al. 2000]. Jonsson et al. [2009] render the mediating role of IT for boundary-spanning practices by stating that “IT eliminates the problem of distance, increases speed, provides universal access and cuts down on communication costs”

\textsuperscript{33} Similar as Leifer/Delbecq [1978] boundary spanning is understood as the activity of organizational members to attain external knowledge across (organizational) boundaries.

\textsuperscript{34} The reasons behind this are multifaceted. Amongst them, however, is a lack of qualified service engineers in developing countries, the increased complexity of the equipment and knowledge deficits on the part of the service workforce.

\textsuperscript{35} Studies investigating the positive impact of IT on boundary-spanning practices report mixed results. In particular scenarios, even reinforcing effects have been noticed (c.f. Levina/Vaast [2006]). However, these studies neglect certain aspects, e.g. material differences in the IT resources [Lindgren et al. 2008, Jonsson et al. 2009].
While IT enhances the external assimilation of knowledge with information exchange and collaboration [Bharadwaj 2000], heterogeneous internal information sources can be better demarcated to shape knowledge integration [Ross et al. 1996, Jonsson et al. 2009].

The service operation functions model this inter-organizational challenge from the manufacturer’s view. Clusters of service functions outline ways to assimilate customer knowledge and diffuse it to the relevant service stakeholders. These boundary-spanning clusters start with the two functions that collect customer initiation (i.e. field service and remote service).

5.2 Field service as a boundary-spanning practice

In traditional maintenance scenarios, the manufacturer’s inspections are pursued to prevent downtimes at the customer site. The technicians’ sensing capabilities are used to monitor the equipment’s condition [Jonsson et al. 2009]. Since service technicians know the individual pieces of (serialized) equipment, the customer’s production plants and the production staff, their superiors tend to make them informally responsible36. In fact, this good relationship and the individual skills allow the technicians to obtain a boundary-spanning role [Jonsson et al. 2009]. While a service technician collects information from the local staff responsible for usage (local conditions of equipment and contextual information), his advice is well-respected to optimize usage and behavior (maintenance best practices and experiences from other customers facing similar challenges) [Jonsson et al. 2009]. With the systematic and intensive cultivation of local contacts, the discussed boundary between the service technician and the customer site has gradually dissolved [Jonsson et al. 2009].

The subcategories of the field service function demonstrate complementary effects. While field service presents the boundary-spanning practice at the boundary of customer / manufacturer and serves as an “entry point”37, the subcategories appoint to different service functions that are closely intertwined with this practice. Planning activities suggest a relation to the maintenance, repair and overhaul function, since both modules use the former applied data objects (e.g. service order) [Matijacic et al. 2013] that have been created by the latter function. Further, important planning specifications in terms of reliability, availability and performance [Dausch/Hsu 2006] such as reaction times (taken from contract management) and spare parts inventory (inventory management) are essential input values for the field workforce’s job preparation. The processing of service information refers to the on-site retrieval and manipulation of

36 Of course, making this informal practice a working routine takes time. Jonsson et al. [2009] report on several years in a concrete case they present in their study.

37 Field service and remote service are accepted boundary-spanning practices that deliver valuable customer information [Jonsson et al. 2009]. Both functions can be considered as “entry points” into the manufacturer’s organization.
installed base data [Thomas et al. 2007, Fellmann et al. 2011, Neff et al. 2014a]. When the service technician is servicing on-site equipment and becomes stuck due to knowledge reasons, he can access best practice instructions, drafts or an expert network (knowledge management) [Dollmann et al. 2009]. The sub-function of collaboration and co-creation goes beyond knowledge access. If the equipment is digitalized and connected, a remote service engineer will be able to collaborate with the on-site technician (remote collaboration as depicted in Figure 3) in order to fulfill the service task [Brax/Jonsson 2009]. The information flow is bi-directional (i.e. service technicians do not only retrieve information from the mobile device38, but also generates data during service execution that is sent back to the manufacturer’s enterprise applications). When documenting the service order after fulfillment, the service technician updates the installed base, the service order, the spare parts used, the actual working time, and more [Dausch/Hsu 2006, Thomas et al. 2008, Karray et al. 2014]. All these information elements are transferred to the manufacturer’s IT environment and stored centrally in the manufactures’ database systems [Dollmann et al. 2009]. The database systems manage service transactions that arrive from the entire equipment fleet in the field. Advanced business analytics and in-memory technology can help to consolidate and merge the data elements that are relevant for customer service and product development [vom Brocke et al. 2014].

Figure 3. Field service’s remote collaboration (based on Jonsson et al. [2009, p. 244])

38 Mobile computing is not explicitly considered, since it lies beyond the scope of this paper. Please see the previous work of Matijacic et al. [2013], Lehtonen et al. [2012], Legner [2009] and Thomas et al. [2007] for more detail on the use of mobile technology for field service.
5.3 Remote service as a boundary-spanning practice

With the digitalization of physical equipment, which had not been digital in the recent past, vast amounts of information that were invisible in the past can now be captured [Yoo et al. 2010]. Embedded into products and the environment [Lyytinen/Yoo 2002], ubiquitous computing technology supports the collection of contextual data [Henfridsson/Lindgren 2005]. By intertwining digital objects with the physical item, the equipment’s basic properties have changed in terms of communicability, addressability and sensibility [Yoo 2010].

The use of remote technology makes the digitalized equipment accessible from a centralized service center and diminishes the organizational boundaries between equipment manufacturer and serviced customer. The equipment is enriched with embedded sensors to foster data exchange, to enable condition monitoring from remote locations and to allow time-based views [Jonsson et al. 2008]. The manufacturer can outperform his peers, while preventing service providers from entering the market. This is achieved in two ways. First, the (partial) computerization of manual field service practices increases efficiency and allows more aggressive pricing. Second, remote service technicians sense irregularities in the installed base. After analyzing the collected operation data, the upcoming service events (including field service events) can be well-prepared and executed more effectively [Jonsson et al. 2008]. With the appropriate sensing devices installed in the equipment, remote service applications can read out and gather humidity, torque, pressure, temperature or vibration of bearings [Jonsson et al. 2009, p. 243]. The remote service center monitors these data objects and performs extensive analysis to spot, prevent or predict problems. When the remote operation is in place, the service operations become almost invisible for the customer organization [Jonsson et al. 2009]. On a regular basis, they receive statuses reports and performance analysis of the equipment. In urgent cases the remote technician can inform local production staff [Jonsson et al. 2009]. Depending on the service model and contract, the labor is divided between customer plant workers, remote service center and field service [Jonsson et al. 2009].

Remote service bridges the boundary between customer and manufacturer by establishing a continuous interaction with the machinery equipment. The subcategories, diagnosis, monitor and operation outline the flows on which information is supplied to different service functions. For a corrective maintenance, repair and overhaul mode, remote analysis is used to identify the service need. This information (e.g. machine report) serves as the input value for the creation of the service order object. Field service is then capable of conducting more accurate planning to prepare an on-site visit, for example deciding on the required skill sets of service technicians or spare parts inventory. Data captured by remote diagnosis is also utilized to investigate a customer’s claim [González-Prida/Crespo Márquez 2012]. In order to meet higher customer expectations in preventive maintenance models, smart digitalized equipment is moni-
tored and initiates callbacks to a remote service center. Besides faster reaction times for unplanned maintenance or repair incidents, these callbacks send status information on a regular basis. Status information is transmitted to the manufacturer’s IT environment and stored in the manufactures’ database systems. Merging and consolidating status information from all installed equipment in the field, analytical capabilities analyze and visualize patterns that, for example, allow the calculation of the remaining lifetime of a component. The customer will be notified with an offer for replacement. With the fulfillment of demanding performance-based contracts, the remote operation of customer production processes becomes a must. The serviced equipment base can also include competing assets. Output oriented contracts are more likely to result in strongly intertwined service functions. Customer production lines are monitored continuously to ensure high availability and quality. In order to decrease costs, maintenance plans are subject to the equipment’s condition. Service transactions have become invisible for the local customer operations staff and are subject to the equipment’s condition. Real-time remote sensing allows a fast reaction to establish a workaround in case the production is crippled. Remote operation implements the alignment with the output-oriented ratio as a boundary-spanning activity. Misuse of equipment or optimization potential is immediately reported and can be fixed within a short period of time. For example, an agriculture equipment manufacturer optimizes the customer’s spraying operation during task execution (c.f. Kaivosoja et al. [2014]). Precision in agriculture can be improved as temporal accuracy by using a variety of technologies such as real-time sensing satellites and aerial images [Kaivosoja et al. 2014].

5.4 Data management as a boundary-spanning practice

Field service and remote service are boundary-spanning practices that allow the manufacturer to acquire valuable customer knowledge on equipment in use and on the customer production environment (c.f. Chapter 5.2, Chapter 5.3). Both service functions generate and collect valuable information. Although data quality and quantity vary, this information is stored centrally and made available for other service functions. This data serves numerous purposes, for instance to better understand customer needs, to increase service quality, to offer consultancy services, to predict incidents or ensure operation uptimes. However, to make the information flow and diffuse within the industrial equipment manufacturer to the corresponding service functions, a rethinking of data management becomes necessary. Data objects, such as the “electronic machine record”, that are being processed are present in all service functions and play a central role as units of exchange to bridge organizational boundaries [Becker et al. 2013, p. 477]. Scholars have recognized that proprietary implementations are intertwined with a variety of enterprise applications leading to a highly customized architectural setting. Each of them has been made for a different purpose and, consequently, the data model is not tailored to service specific needs [Neff et al. 2014b].
The understanding of data management as an individual function is limited to quite a narrow scope. Scholars refer to an auxiliary function that, for example, allows track pattern identification in customer transactions [Westelius/Valiente 2004] or data integration for obtaining a comprehensive view [Davenport et al. 2001]. However, the role of data objects as knowledge resources is far beyond that one of a supporting function. The value lies in the service functions that are supplied with those objects. Installed base management, for instance, models the entire customer equipment in the field as serialized objects. This function retrieves entries (such as service orders, as-is maintained bills of material or functional locations) from the centralized database and transforms those into customer information. When the manufacturer aggregates these information pieces over all customers, the organization can perform a cross-analysis to identify which component of the built-in the equipment constitutes a bottleneck. This knowledge can then be used to determine the appropriate stock level for inventory planning of spare parts or to identify upcoming service requirements over the lifecycle.

Those data objects present valuable information, since they stand for a lower knowledge acquisition cost [Oliva/Kallenberg 2003]. With the aim to achieve or defend market leadership in the service business, the company must take advantage of its capabilities and knowledge as an equipment manufacturer.

If data objects were considered as units of exchange to let information flow and diffuse across internal and external organizational boundaries, data quality would be the predominant impact factor to turn this into success. However, collecting and storing data itself will not result in better organizational results. In order to achieve a competitive advantage, companies need to make better predictions and smarter decisions, which are based on relevant dimensions [McAfee/Brynjolfsson 2012]. Data quality considerably influences all analytical processes that end with a decision support for the stakeholder. However, many organizations have failed in combining data from distinct sources at varying data quality levels [McAfee/Brynjolfsson 2012]. For instance, the integration challenge has to overcome data quality issues of multiple data sources, such as sensors and smart equipment [Candell et al. 2009, vom Brocke et al. 2014], analytical and transactional enterprise applications [Li et al. 2012, Peltier et al. 2013] and proprietary applications [Jonsson et al. 2008, Neff et al. 2014a].

The service functions can form a complementary cluster. First, a boundary-spanning practice such as remote service or field service collects data from the field usage of the customer. Data management fosters data quality assurance initiatives, so that management can realize more value from the integration of service- and product-related data types. “High data quality (vertical and horizontal reconciliation) and fully automated data integration capabilities enable a unified view” on “customer equipment” [Neff et al. 2014a, p. 907]. The analytical capabilities enable the transformation of customer information into specific knowledge of the service function. Decision-makers can take advantage of this knowledge applied as decision support. For example, predictive
models allow the calculation of the remaining lifetime of customer equipment. This ratio serves as decision support to the service division for the planning of component replacement. The customer is informed about the upcoming service incident and is highly satisfied that production downtimes will be prevented.
6 Conclusion

The present paper investigates the current state of knowledge on service planning and execution functions and the corresponding information systems. Based on previous work by Neff et al. [2014b], a structured literature review has been conducted on 12 service functions. In total, 91 articles were analyzed and synthesized in a comprehensive matrix. The results were discussed along theoretical lines on organizational boundaries.

The functional reference model [Neff et al. 2014b] has been constructed using empirical data and standards from the literature such as ISO, NIST, DIN and VDI. For this reason, the present paper complements extant work by reflecting on the results with the theoretical body of knowledge. The contribution lies in the structuration and the conception of the service functions as well as the critical reflection on the functional reference model in accordance with the extant literature. The results allow for a differentiation between the service functions in terms of thoroughly and peripherally addressed functions. A variety of categories can be identified that outline different streams in the individual search results for a particular function and confirm the strong interdependency that may actually result in redundant elements. These interdependencies were examined in the discussion part of this paper. The boundary-spanning and complementary characteristics of the service functions can be drafted. This theoretical lens fits very appropriately to the original study framework and its organizational boundaries (see Figure 2). Field and remote service obtain the roles of boundary-spanning practices, while the supporting data management collects and diffuses information (see Figure 3). Those functions supply valuable data to the other functions that then use analytics to turn the data into applied knowledge to achieve competitive advantages.

There are some restrictions when considering the research results. While the scope is laid on service operations, service design and development are not considered explicitly. Although the analyzed journals and conference proceedings were chosen as a result of a structured database search, there is no assurance of the complete coverage of all relevant articles. In particular, the emphasis on the IS perspective constitutes substantial bias. This research is focused on the back stage perspective on service systems (i.e. on the service operations of the equipment manufacturer). The search phrases used are quite subjective. A different selection of search phrases will hence yield a significantly altered list of articles.
Literature

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**Abstract**

Achieving regulatory compliance, a 360 degree view on customer data, and an effective and efficient reporting are critical business requirements that can be traced back to a high quality of IT and data resources. Addressing these requirements, the regulation of decision rights and accountabilities for organisational decision-making about IT and data assets has become a key success factor for organisations. The aim of this paper is to analyse the performance impact of a combined IT and data governance concept. The study uses the resource-based perspective and integrates the theory of complementarities and the concept of relatedness. The proposed increase in business process performance is grounded in the generation of sustainable competitive advantages. The framework is developed by using nine exploratory case studies in multi-business organisations. The results suggest that IT and data governance are positively related with business process performance through the mediators of IT relatedness and data relatedness.

**Keywords**

IT Governance, Data Governance, IT Relatedness, Data Relatedness, Resource Based View

**INTRODUCTION**

Information Technology (IT) spending amounts up to 15% of corporate revenues (Gartner 2011). IT expenses have been growing steadily over the past decade. Analysts’ estimates for IT spending in 2012 range from 3.7% to 6.9% increase compared to IT spending in 2011 (Gartner 2011; Shirer and Murray 2011). Hence, IT has been widely acknowledged as indispensable for the support, sustainability and development of businesses. This trend triggered a de-escalation of the discussion about the IT productivity paradox and the contribution of IT to firm performance (Dedrick et al. 2003; Melville et al. 2004; Silvius 2006). A number of well-known accounting scandals led to the passage of the Sarbanes-Oxley Act by the United States government. In addition, the IT landscape has been shaken by a number of spectacular failures of large IT investments, such as incorrectly planned or badly executed e-business projects, imperfect enterprise resource planning (ERP) systems, and newly developed IT systems that have never been employed effectively (Davenport 1998). As a result, many companies have been sharpening their focus on monitoring and assuring satisfactory returns on technology investments (Brown and Grant 2005). Organisations are collecting and storing huge amounts of data for business analytics but collecting data itself will not lead to a competitive advantage at all. In order to achieve a competitive advantage, companies need to make better predictions and smarter decisions that are grounded in the relevant dimensions (McAfee and Brynjolfsson 2012). The identification of business-relevant dimensions remains an unsolved issue in many organisations. Although financial and operational results are positively associated with data-driven decision making of a company, numerous enterprises fail in adequately managing their data which comes from different sources with differing degrees of data quality (McAfee and Brynjolfsson 2012).

Therefore, a concept of how to achieve above-industry-average returns on IT and data investments is desperately desired. The regulation of decision rights and accountabilities for an organisation’s decision-making about its IT and data assets, also referred to as data governance (DG), has become a key success factor (Khatri and Brown 2010). For balancing both needs, a combination of IT governance (ITG) and DG practices is required. These activities mainly focus on the fulfilment of legislative regulations, the achievement of a 360-degree-view on the customer, and the development of a reporting system through a “single point of truth” (Khatri and Brown 2010). Only very few studies deal with the organisation of DG on a company-wide level even though the need has already been identified (Otto 2011). The concept is designed as a control framework for IT value creation and for synchronising IT decisions in order to enhance decision consistency (Weill 2004).

The relationship between IT resources, data resources, and organisational performance calls for further investigation (Melville et al. 2004; Tanriverdi 2006; Tanriverdi and Venkatraman 2005). Departing from the resource-based view (RBV) of the firm (Mata et al. 1995; Melville et al. 2004), the concept of relatedness (Campbell and Goold 1998; Davis and Thomas 1993), and the theory of complementarities (TOC) (Milgrom and Roberts 1995), a positive relationship between IT relatedness and organisational performance has been shown.
encourage desirable behaviour in the use of IT

Whereas ITG has been quite precisely defined six influence factors of BITA though (Luftman and Kempaiah 2007), which limits its implications (Lazic et al. relationship positively influences organisational performance (Sabherwal and Chan 2001). ITG is only one out of BITA are positively related (De Haes and Van Grembergen 2009; Luftman and Kempaiah 2007) and that this organisational performance present some exceptions from this trend. Most researchers find out that ITG and 2011). However, business-IT alignment (BITA)-centric models considering the relation between ITG and models and results remain strictly descriptive and lack rigorous depth in their theoretical foundation (Lazic et al. The heated scientific debate on ITG has concentrated on two main streams: Contingency analysis and the locus of decision-making structures (Brown and Grant 2005). Despite the practical value of the past research, most researchers find out that ITG and BITA are positively related (De Haes and Van Grembergen 2009; Luftman and Kempaiah 2007) and that this relationship positively influences organisational performance (Sabherwal and Chan 2001). ITG is only one out of six influence factors of BITA though (Luftman and Kempaiah 2007), which limits its implications (Lazic et al. 2011). Furthermore, the definition of BITA remains disputed among scholars (Chan and Reich 2007).

Whereas ITG has been quite precisely defined as a “framework for decision rights and accountabilities to encourage desirable behaviour in the use of IT” by Weill (2004), there is no consistent definition of DG in literature (Pierce et al. 2008). Literature scholars were inspired by this ITG definition and consider DG as a framework for decision rights and accountabilities to encourage desirable behaviour in the use of data (Khatri and Brown 2010; Weber et al. 2009). Otto (2011) identifies basic characteristics of DG based on the assumption that data is a company asset which has to be deployed usefully. DG is therefore the regulation of decision rights and decision tasks (duties) in regard to data handling. Logically, DG is defined as “a company-wide framework for assigning decision-related rights and duties in order to be able to adequately handle data as a company asset” (Otto 2011). DG and ITG are understood as intertwined concepts whose alignment is essential for the successful management of both data and IT assets (Begg and Caira 2012). A significant number of scholars mentions also the importance of data quality management for DG, especially with regard to establishing data quality guidelines and supervising data quality management (Khatri and Brown 2010). IT business value (ITBV) has been one of the most intensively discussed topics in IS literature over the past 20 years. Most scholars have been analysing the value of IT, which can be described as the contribution of IT to organisational performance, from the resource-based view (RBV) of the firm (Rivard et al. 2006). The RBV assumes that a firm is a compound of resources including assets, humans, knowledge, and processes. The fundamental assumption of the RBV is that resources are heterogeneously distributed among competitors and since some resources are imperfectly mobile, this different allocation can create a source for sustainable competitive advantage (Barney 1991; Mata et al. 1995). The value created by IT is not created directly but through the mediation of complementary and strongly related resources (Mata et al. 1995; Melville et al. 2004). The improvement of business processes represents a fundamental mediating effect (Melville et al. 2004). At the same time, the growth of a company is related to the correct identification and employment of suitable resources (Penrose 1959; Rivard et al. 2006). Selecting, coordinating and managing resources such as IT (Mata et al. 1995) and data (Barney 1991) refer to governance practices.

Resource Relatedness and Performance Effects

The economic rationale for multi-business firms is grounded in the RBV which argues that strategic interrelations (synergies) between business units (BUs) have a positive effect on the organisational performance (Peteraf 1993; Robins and Wiersema 1995). Multi-business firms can exploit more synergy potential than single-business firms (Tanriverdi 2006) as they can exploit both economies of scale and economies of scope (Teece 1982). Synergies are defined in strategy and economic literature as either sub-additive cost synergies (Teece 1982) or super-additive value synergies (Davis and Thomas 1993). Strategic management scholars claim that proven synergies between different BUs increase the value of a multi-business firm (Goold and Luchs 1993). Known as the most prevalent source of synergy in multi-business firms (Tanriverdi and Venkatraman 2005), resource relatedness incorporates the presence of shared resources and related activities across BUs (Davis and Thomas 1993). Based on the RBV perspective, scholars argue that the organisational performance can be
enhanced by sharing of strategic resources across BUs as cross-business resource-based synergies are generated (Markides and Williamson 1994; Robins and Wiersema 1995). Unfortunately, the concept of resource relatedness is not designed to include the super-additive value dimension of resource combinations (Tanriverdi and Venkatraman 2005). In order to account for the shortcoming of the concept, we apply the TOC (Milgrom and Roberts 1995). Including the TOC, we assume that sub-additive costs that origin from relatedness are imitable by competitors and hence can only guarantee a temporary competitive advantage. In contrast, super-additive values from a complementary set of resources with high relatedness are imperfectly mobile and thus difficult to imitate; as a result, they are a potential source of a sustainable competitive advantage. IT relatedness is a source of cross-unit IT synergy and has a direct impact on organisational performance but also facilitates the realisation of cross-unit business synergies. This leads to the conclusion that IT relatedness has indirect effects on organisational performance through the mediation of cross-unit capabilities (Tanriverdi 2006). The construct of IT relatedness consists of a narrow set of IT resources necessary for conceptualization that are linked to the relatedness concept and that can be traced back to the ITBV literature (Wade and Hulland 2004): joint IT infrastructure (shared tangible resources), joint IT strategy (coordinated strategies), joint IT vendor management (pooled negotiating power), and joint IT human resources (shared know-how). Academic scholars investigating the relationship between IT relatedness and organisational performance revealed that the relatedness of singular IT resources leads to sub-additive costs only whereas the relatedness of complementary IT resources additionally generates super-additive value and hence increases organisational performance (Tanriverdi 2006).

The interconnection between IT and data resources seems obvious. Data refer to the product of IT resources (Raghunathan 1999) but are treated separately in extant RBV analyses (Khatri and Brown 2010). In line with this reasoning, we positioned each construct separately while considering the complementary effects in the resource relatedness construct. In concord with the development of business process relatedness (Lazic et al. 2011), we can extend the definition of resource relatedness to data relatedness as the extent to which a multi-business firm uses common data management practices across its BUs. We state that data relatedness is a source of cross-unit synergies. We used the procedure approach of Tanriverdi (2006) as a guideline to derive data relatedness from extant literature on data management and to connect them to the relatedness concept. Coordinated strategies refer to a major source of synergies. Strategies are the result of decision-making processes (Eisenhardt 1999) which influence data quality on the decision quality (Bansal et al. 1993; Fisher et al. 2003). Data management enables the vertical integration (Campbell and Goold 1998) with suppliers and customers. Synergy potential is created in terms of different system applications, e.g. in enterprise asset management systems (Lin et al. 2006). However, all applications are strongly dependent on high quality master data for software support (Haug et al. 2009). Shared tangible resources correspond to data defined as resource (Goodhue et al. 1992). The data architecture capability represents a means to make resource transferrable and usable by providing a “framework of standards and guidelines within which all new systems and revisions to old systems would be designed, gradually moving the firm toward a set of integrated applications and databases” (Goodhue et al. 1992). The capability is investigated in various studies, e.g. in data warehousing context (Wixom and Watson 2001). Value generation in multi-business firms heavily builds on shared know-how (Campbell and Goold 1998; Tanriverdi 2006). Data analytics capabilities serve as one of the major levers to develop know-how. Consequently, usability requirements have to be fulfilled in the data design to enable an integrated data analysis with improved user behaviour. Wang & Strong (1996) explain this phenomenon as “fit for use” and derive four data quality requirement blocks building on prior research conducted by Ballou & Pazer (1985). More recent studies examine the special effect of data consumer influence in service firms (Chang et al. 2011) and the influence of data and information sharing (Mithas et al. 2011).

RESEARCH APPROACH

In order to provide additional value for both scientists and practitioners, we selected a qualitative research design in accordance with the theoretical lens of the RBV and built on theoretical constructs. According to the stringent literature review in the field of ITG, the best-suited model to guide the research process is the model of processes, structures, and relational mechanisms (De Haes and Van Grembergen 2009). Since “DG decisions should be tightly integrated with those in IT governance” (Khatri and Brown 2010), we selected the relevant DG practices and constituted a comprehensive ITG and DG concept. We firstly conducted a structured literature review (vom Brocke et al. 2009) using a two stage keyword filter (Stage 1: "data governance" OR "information technology governance"; stage 2: "information systems" OR "information technology"). By evaluating the results of five relevant databases (EBSCOhost, Proquest (ABI/INFORM), Emerald, Science Direct, and Web of Science) through two iterative circles and a forward-backward search cycle 18 scholarly articles of interest were selected. The articles were subsequently coded with DG practices. The DG practices which are addressed in at least two articles were finally selected. The seven DG practices were classified as processes, structures and relational mechanisms (Peterson 2004; Peterson et al. 2000) and afterwards assessed in the multiple case study approach.
As depicted in Figure 1, we assume a positive association between ITG and IT relatedness since the harmonisation and consolidation of the IT landscape and IT management procedures is described only as a matter of time (Lazic et al. 2011). Further, ITG facilitates the coordination and exploitation of cross-unit IT synergies, i.e. IT relatedness (Tanriverdi 2006). In accordance with the RBV and other researcher streams, we are convinced that data assets are corporate resources (Barney 1991). Due to the often observed and strong interrelationships between IT and data (Khatri and Brown 2010; Raghunathan 1999), we position data relatedness as a second mediating construct affected by ITG and DG. Super-additive value can be created only through a complementary set of related resources, because competitive advantage generated by single IT-dimensions is imitable and thus not sustainable (Barua and Whinston 1998). Since ITBV scholars conclude with the positive association between IT and business process performance (Melville et al. 2004), we adopt that construct to conceptualise the performance effects of IT and data resources. Following the extant literature, harmonising business processes is attended by improved organisational performance (Ramakumar and Cooper 2004; Wüllenweber et al. 2008). To sum up, we employed well-established constructs (see Table 1).

Table 1. Research model constructs

<table>
<thead>
<tr>
<th>Construct (Literature source)</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>ITG-DG processes (Peterson 2004; Peterson et al. 2000)</td>
<td>Formalization and institutionalisation of strategic IT and data decision-making or IT and data monitoring procedures.</td>
</tr>
<tr>
<td>ITG-DG structures (Peterson 2004; Peterson et al. 2000)</td>
<td>Structural (formal) devices and mechanisms for connecting and enabling horizontal contacts, or liaison, between business and IT &amp; data management (decision-making) functions.</td>
</tr>
<tr>
<td>ITG-DG relational mechanisms (Peterson 2004; Peterson et al. 2000)</td>
<td>Active participation of and collaborative relationship among corporate executives, IT management, data management, and business management.</td>
</tr>
<tr>
<td>Resource relatedness (Davis and Thomas 1993)</td>
<td>The use of common resources (i.e., common factors of production) across business units.</td>
</tr>
<tr>
<td>IT relatedness (Davis and Thomas 1993; Tanriverdi 2006)</td>
<td>Usage of common IT resources and management processes across business units.</td>
</tr>
<tr>
<td>Data relatedness (Campbell and Goold 1998; Davis and Thomas 1993; Lazic et al. 2011)</td>
<td>Usage of common data resources and management across business units.</td>
</tr>
<tr>
<td>Business process performance (Melville et al. 2004)</td>
<td>Operational efficiency of specific business processes, measures of which include customer service, flexibility, information sharing, and inventory management.</td>
</tr>
<tr>
<td>Organisational performance (Melville et al. 2004; Sabherwal and Chan 2001)</td>
<td>Overall firm performance, including productivity, efficiency, profitability, market value, competitive advantage, etc.</td>
</tr>
</tbody>
</table>

A qualitative research design based on a multiple case study approach was chosen in order to investigate the relatedness between DG practices and ITG (RQ.1) and DG practices and organisational performance (RQ.2) (Eisenhardt 1989). Case study research has broadly been applied within the field of IS research (Benbasat et al. 1987; Yin 2009). The research method appeared to be suitable for our investigation as well, since it lead to a better understanding of the complex phenomena and enhanced validity at the same time (Eisenhardt 1989). For the case selection, we assumed that companies with a diversified multi-business structure have significantly more potential for economies of scope and hence relatedness (Tanriverdi 2006). As unit of analysis we chose an organisation that implements governance practices (ITG and DG) and selected nine diversified corporations which all had considerable potential for economies of scope (Tanriverdi 2006). Data was collected by expert interviews which lasted between 50 and 120 minutes and were hold by two researchers between March 2012 and
October 2012. The interview partners held different ranks in their companies representing senior executives (CIO, Head of ITG), line managers (BU executives), and data analysts (Head if BI in sales, service or production BUs). Participating companies were active in different sectors, including manufacturing, financial services, utilities, and consumer services with revenues above two billion Euros. The data collection was supported by established ITG theoretical constructs (inter alia those in (De Haes and Van Grembergen 2009; Tanriverdi 2006)) and included an open component for aspects which were not addressed in the questions. Once the interviews were conducted, the interview-based data were enriched by further analysing corporate reports and afterwards discussed and approved by the industry partner. The data analysis was structured as iterative process following Miles and Huberman (1994). The interview data and company documentation were coded by different researchers focusing on ITG and DG, resource relatedness, and business process performance independently and afterwards mapping the dimensions in a qualitative assessment in order to answer RQ.1. In a second iteration, key levers were deduced from the discussions of the results (RQ.2) in a focus group workshop.

CASE STUDY RESULTS

IT and Data Governance

De Haes & Van Grembergen (2009) suggested a minimum baseline for ITG which we integrated for the purpose of comparison (represented in the legend of Table 2). As the RBV assumes that resources are deployed to their fullest extent, we evaluated ITG practices if they were implemented or not. The combination of all implemented processes, structures, and relational mechanisms into a single score enabled us to derive three maturity levels by comparing the scores across individual firms (see Table 2). A LOW ITG level means that companies are implementing their first relational mechanisms and structures whereas MEDIUM ITG level describes firms that show well-established structures and relational mechanisms but have room for process improvement. Finally, a HIGH ITG level is assigned to companies with mature processes that have gained real authority over the IT. For each firm we counted the processes, structures, and relational mechanisms and thereby derived the respective maturity level. In order to investigate the association between governance and consolidation initiatives, we confronted ITG and DG maturity with IT relatedness and data relatedness in a qualitative assessment (Figure 2).

Similar to ITG, which is concerned with the encouragement of desirable behaviour in the use of IT (Weill 2004), DG addresses the optimal usage of data resources closely linked with IT-related decisions and ITG activities (Khatri and Brown 2010; Begg and Caira, 2012). Since IT and data assets represent essential and closely-related resources, management takes advantage of available information and control structures to achieve the maximum output of both resources. A mature ITG and DG concept fosters information aggregation and data-driven decision-making. Accordingly, we propose: The higher the maturity of ITG and DG processes, structures, and relational mechanisms the higher the IT relatedness [P1]. BETA’s application portfolio management follows a two vendor approach across business units. While SAP applications are used as back end transaction systems, front end software mainly is comprised of Microsoft products instead. EPSILON is undergoing a large ERP consolidation project to reduce the instance by using multi-tenancy. To balance the data needs of local BUs with the efficiency focus of the holding, a data steering committee has been enacted. The definition of standard attributes of the material master data is reported as first success towards a higher level of IT relatedness. DELTA, classified as low maturity, has recently introduced a budget control and reporting process. Being a strongly diversified enterprise, IT resources are coordinated and organised by a shared service centre. For the reporting, however, the data collection is mostly done manually, since the data quality and data properties are different - an example of a low level of IT relatedness. The CIO of DELTA explains that “an efficient implementation of this reporting process requires a standardisation of data management processes”.

Grounded in the RBV, data resources are arrangements of corporate assets. In order to realise critical business requirements, such as a 360 degree view on customers, management drives data-related harmonisation efforts throughout the BUs. ITG and DG practices do not only affect IT management procedures and IT landscape, but also result in an increased harmonisation of data management procedures and data quality principles. On the lines of IT relatedness, we position the construct data relatedness as the second instance of resource element (Davis and Thomas 1993; Tanriverdi and Venkatraman 2005) and claim a positive association between the maturity of ITG and DG and data relatedness [P2]. The CIO of LOTA reports on serious data issues that resulted in the wrong pricing for products: “LOTA encountered an issue with the pricing group assignment to customers. That defect led to over hundred inaccurate invoices and caused costs of 3% of the EBIT! Incorrect figures were printed in the quarterly reports, while customer complaints overstretched the call centre capacity.” The cleanup work took two months and finally makes the management constitute a data steering committee. BETA, classified as high maturity, harmonised its customer data across business units by launching a comprehensive customer data consolidation initiative. This initiative was triggered when BETA found out that its global-operating customer was redundantly managed in different CRM systems and hence a consistent view on the customer was very hard to obtain.
Super-additive value synergies arise from a complementary set of common IT resources and data management processes on the one hand, and complementary set of common IT management processes on the other, have a positive impact on business process performance of a multi-business firm [P3].

Table 2. IT and Data Governance assessment and maturity level

<table>
<thead>
<tr>
<th>Structures, Processes, Relational mechanisms</th>
<th>IT governance</th>
<th>Data governance</th>
<th>Maturity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Beta</td>
<td>✓</td>
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<td>Gamma</td>
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<td>Delta</td>
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<td>Epsilon</td>
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<td>Zeta</td>
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<td>Theta</td>
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<tr>
<td>Lota</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Legend

IT Governance
S1 IT steering committee
S2 CIO on executive committee
S3 IT strategy committee on board level
S4 IT project steering committee
S5 CIO reporting to CEO or COO
P1 Portfolio management
P2 IT budget control and reporting
P3 Strategic information systems planning
P4 Project management methodologies
R1 IT leadership

Data governance
S1 Data steward
S2 Data steering committee
S3 Data architect
P1 Data quality management
P2 Data life-cycle management
P3 Training / documentation
R1 Coop. data scientist / business expert

Resource Relatedness Analysis and Business Process Performance

Performance analyses of IT resources conclude with mediating effects of complementary and strongly related resources (Mata et al. 1995; Melville et al. 2004). The improvement of business processes performance (Melville et al. 2004; Wüllenweber et al. 2008) can be confirmed by our data set. In accordance with Tanriverdi (2006), we propose that super-additive value synergies arising from a complementary set of common IT resources and common IT management processes have a positive impact on the business process performance of a multi-business firm [P3].

While IT resources refer to the technological assets that foster automation of well-defined tasks, data resources are concerned with the factual documentation (Khatri and Brown 2010). After achieving a medium level of IT relatedness, it becomes transparent that plenty of data processes are governed sub-optimal. As part of an IT efficiency program, the IT steering committee in THETA enacted the database consolidation and discovers valuable information for the sales unit: “We did a large database consolidation project to optimise ETL load in the reporting process. Doing so, we realised what valuable customer data were buried in the legacy systems.” Hence we come to the following proposition: Super-additive value synergies arising from a complementary set of common data resources and data management processes have a positive impact on the business process performance of a multi-business firm [P4].

BETA is characterised as a typical engineering company that relies heavily on its innovation and customer service capability. A continuous product improvement process presents a well-recognised means in achieving both value synergies. The head of the service division points out the value of service operations data for product re-engineering activities of the R&D department: “Digital failure protocols and sensor data are aggregated and consolidated. In the data cleansing process we prepare the information for defect analytics. The compiled information can contribute to the development of new products and services.” When the implementation of cross-business processes is combined with the smart usage of IT resources (transaction processing of business processes) and data resources (documentation of facts) to achieve improved customer satisfaction, super-additive value synergies can be realised. Hence, we propose that: Super-additive value synergies arising from a complementary set of common IT resources and common IT management processes on the one hand, and common data resources and data management processes on the other, have a positive impact on business process performance [P5]. Confronted with changing legislative regulations and uncoordinated rules in different markets, ZETA had to separate two BUs organisationally and treat them like competing organisations. The regulation further pertained to the corresponding enterprise systems and corporate data. The head of ITG points out that “the licence to operate in three markets was heavily dependent from the capability to separate the business units and the IT systems. To conform to these requirements, we had to project new enterprise systems and databases within a pretty short period of time. Data quality and data integration requirements have also changed.” Thereby ZETA serves as a negative example contrary to P5.

Due to the high complexity of the equipment and inefficiency issues in service operations, ETA launched a project with the objective to develop a mobile client for the service unit in the U.S. The CIO outlines the use case in which “the service technician performs maintenance, repair or overhaul operations at customer facilities.”
After concluding that existing CRM solutions (including back end data and their front end replications) do not provide the required technical depth of the material data, the project steering committee makes the decision for a proprietary solution instead. As explained by the CIO, the solution comprises IT resources and data management processes. "For the back end data provisioning, we enrich the bill of material from ERP [for production planning] with the customer master data from the CRM to provide our technicians with detailed technical specifications when they are on tour." The developed solution settles the information needs (e.g. coherent view on customer equipment) of the technician that finally lead efficiency increases and higher customer satisfaction.

After providing first proof and practical examples for each proposition, we merged the investigated constructs IT relatedness, data relatedness and governance over IT and data resources in a qualitative assessment for cross-case analysis (see Figure 2). More recent findings on the consolidation and harmonisation efforts in IT and business processes can be confirmed (Lazic et al. 2011) and extended in terms of the data resource. DELTA’s Head of ITG suggests “a unified terminology, corporate guidelines and frameworks, cost and standard definitions” as the very basic incentive for governance initiatives, since only those instruments “put us into the position to govern the group with the aim of achieving synergies.” In fact, we were able to derive three phases for a combined ITG and DG concept. The implementation of a basic set of ITG and DG practices (structures and processes) constitute the first phase that aims at the consolidation of IT and data assets. DELTA recently employed an ITG steering committee and IT budget control process. IT infrastructure consolidation and the definition of IT costs determine the agenda in the steering committee (LOW IT relatedness). When data issues escalate e.g. in financial reporting, they are managed in projects. However, a structural and holistic approach to govern data resources is not given. Once a basic governance body is established, case companies in the second phase strive for the harmonisation of IT processes in the entire organisation, a standardised IT service portfolio, and the consolidation of the application landscape (activities for HIGH IT relatedness). Data quality plays a central role to bring efficiency into central business processes such as customer service. In order to coordinate marketing and sales activities for global acting business customers, ALPHA’s customer master data are stored centrally as one version of the truth. In the third phase, innovative business processes are realised that are based on the smart usage of IT and data resources. The enterprise wide harmonisation and consolidation of IT resources (HIGH IT relatedness) fosters the synergy potential that can be achieved by the implementation of common data resources. ETA uses data on sold equipment for providing a 360 degree view on the business customer’s installed equipment. By analysing the usage behaviour and condition of all sold equipment, this view allows not only a single version of the truth for one particular customer, but also outlines up-selling opportunities. Top-performing firms were able to implement an end-to-end optimisation of a valuable business process across different BUs and thereby achieving cross-unit value synergies. The prudent increase in interaction and knowledge sharing between IT, data scientists and business fosters the harmonisation of data and IT supported processes.

CONTRIBUTION, LIMITATIONS, AND OUTLOOK

The aim of this paper was to analyse resource relatedness and ITG and DG in the context of business process performance. The concept of resource relatedness was specified as IT relatedness and data relatedness. Relevant theoretical constructs (see Table 1) were identified in a structured literature review. In order to answer the first research question (RQ.1) on “relevant data governance elements and the relationship to IT governance”, the authors analysed the concepts of ITG, resource relatedness, and business process performance independently and conducted a structured literature review to identify the mostly cited DG elements. The interrelation between ITG and DG was verified in a multiple case study with nine multi-business firms. For the second research question (RQ.2) on how ITG and DG practices are associated with organisational performance, five propositions were derived from these theoretical constructs and transformed in an analytical framework for the multiple case study. The application of the relevant ITG and DG dimensions to the case study companies enabled us to derive three
maturity levels for ITG and DG. The maturity levels were then mapped to the levels of data and IT relatedness and qualitatively assessed in a cross-case analysis. Companies with higher ITG and DG maturity levels proved to have higher levels of data relatedness and IT relatedness. The results of the multiple case study approach support the five propositions implying that a well-developed ITG and DG positively influences IT relatedness and data relatedness which in turn have a positive impact on business process performance.

The study comes also with limitations; the qualitative research design with nine case study companies allows for inductive theory building but lacks the necessary sample size for quantitative theory testing. An enlarged company sample could help to verify the stated propositions quantitatively in the future. The proposed set of mediating constructs in our research model may not be complete and may be subject to scientific extensions. The interview partners work predominantly in the IT departments of the participating companies. The inclusion of business department representatives could further enrich the analysis. Further, an extension of the sample to non-European companies and single-business firms could support the understanding of resource relatedness in a broader variety of companies. The research project focuses on business value generation of IT although ITG gives attention to business value preservation too. Cultural dimensions have been excluded from the study to reduce the degree of complexity. Nevertheless, cultural dimensions and additional potential moderators, such as specificity of knowledge, top-management characteristics (as evaluated by Li and Tan (2013), industry and the size of the corporation could improve the generalisability of the findings. The integration of the knowledge-based view would provide an expedient extension of the research as it would distinguish between resources and knowledge (Teoh and Pan 2009). Finally, the transformation of competitive advantages from the business process performance level to the organisational performance level requires further research to evaluate the organisational performance impact of data relatedness and IT relatedness.

REFERENCES


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ABSTRACT

The ongoing shift towards stronger service orientation is leading to a rising number of industrial services offered in the manufacturing industry. In the attempt to fulfill ever-increasing service demands while at the same time reducing operating costs, manufacturing firms search for appropriate information technology (IT) solution for planning and execution. The industry has not yet reached a common understanding of product-service systems and the corresponding processes and IT systems. In order to holistically support such broad design and transformation tasks, we develop a maturity model capturing the key requirements for the information systems (IS) support of product-service systems based on a multiple case study. For a critical reflection on the extant literature, we compared those requirements with scientifically recognized maturity models and standard specifications. Being an integral part of the design science research approach, the model evaluation is organized in accordance with approved evaluation perspectives.

Keywords

Industrial Services, Service Transformation, Product-Service Systems, Design Science Research, Maturity Model.

INTRODUCTION

The paradigm shift from a product-dominant to a service-dominant logic in the manufacturing industry can hardly be refuted (Vargo and Lusch, 2004). The fraction of industrial services offered is constantly rising (Stille, 2003). Being confronted with ever-increasing service demands and shrinking margins in the product business, IT departments in manufacturing enterprises encounter problems in finding the appropriate IT solution for planning and execution (Dietrich, 2006). The service component depends on expensive proprietary systems and highly customized standard solutions (Thomas, Walter, Loos, Nüttgens and Schlicker, 2007), while legacy systems need to be replaced. Supporting management accounting and plant maintenance causes serious issues for product-service systems in manufacturing organizations (Dietrich, 2006; Thomas et al., 2007). In particular, it is difficult to obtain detailed and accurate status information on the service execution process. The situation is even more challenging, since manufacturing processes and service processes require different management approaches and are built upon different IT artifacts. So far, information systems support for service business has hardly been addressed as a dedicated research stream. Service research has focused on the front stage of service delivery, studying phenomena such as provider-client relationships, co-creation of value, service quality, and service encounters (Glushko and Tabas, 2009), while studies investigating the back stage of service systems are missing (Glushko and Tabas, 2009).

Overcoming the above mentioned challenges, a concept is needed allowing a holistic support for such broad design and transformation tasks. Turning out to be successful in the software engineering domain (Paulk, Curtis, Chrissis and Weber, 1993), maturity models are an established means that aims at the effective management for complex and heterogeneous tasks (Ahern, Clouse and Turner, 2004). Our objective is to develop a maturity model which should be capable to holistically assess the IT support of a product-service system in the manufacturing industry. Hence, we address the following research questions (RQ):

RQ.1) What are key requirements for the IS support of product-service systems in the manufacturing industry and how are they addressed in existing models?
RQ.2) How could a product-service system specific maturity model be designed that targets key requirements of multinational manufacturing enterprises?

The remainder of this paper is structured as follows. Next, foundations of product-service systems and maturity models are presented, while the following chapter describes the selected research approach. Answering RQ.1, the subsequent chapter derives exploratory requirements and analyzes their reflection in existing maturity models and publicly available specifications (PAS). The development of the maturity model is presented thereafter (RQ.2). Finally, we conclude with our major contribution, supplemented with a critical reflection and an outlook on future research.

THEORETICAL FOUNDATION

Over the last thirty years, academics as well as practitioners have begun to investigate services as a distinct phenomenon with its own body of knowledge and rules of practice (Spohrer and Kwan, 2009). Their approaches are being revitalized under the emergent discipline of service science, management, and engineering (SSME). Requirements for planning, operating and disposing of customer solutions are discussed in several academic disciplines such as in SSME, information systems, marketing and operations management (Bardhan, Demirkan, Kannan, Kauffman and Sougstad, 2010; Rai and Sambamurthy, 2006). Recently, the notion of the “service system” has been put forward as the basic abstraction of service science, representing “a dynamic value co-creation configuration of resources, including people, organizations, shared information [...], and technology” (Maglio, Vargo, Caswell and Spohrer, 2009).

Due to the broad conception of the service system and the industry focus of this study, we considered the body of knowledge in operations management. Scholarly literature combines products and services in terms of systems, solutions and bundles (Oliva and Kallenberg, 2003). We decided to apply the definition of product-service systems, since it achieves most hits in a literature search (as compared to the terms bundle and solutions) and fits best with the manufacturing focus (Neff, Herz, Uebernickel and Brenner, 2012). The definition refers to the “customer life cycle oriented combinations of products and services, realized in an extended value creation network” (Aurich, Fuchs and Wagenknecht, 2006). Current research in SSME tends to focus on customer value, such as value creation in service marketing issues or service encounters, as well as value co-creation with customers (Clarke and Nilsson, 2008). However, little insight into business processes (Glushko and Tabas, 2009), enterprise systems and software applications that are required to integrate manufacturing and service processes in service systems has yet been provided. Information asymmetries are well-accepted as a challenging problem in SSME, since the co-generation aspect leads to new levels of coordination complexity (Chesbrough and Spohrer, 2006). Nonetheless extant literature shows considerable deficits in designing and explaining IT artifacts that are capable of providing the appropriate information through the life cycle stages (Becker, Beverungen, Knackstedt, Matzner and Müller, 2011). In order to develop an integrated solution with selected information exchange, the authors begin with the requirements of product-service systems and the corresponding IS / IT implementations.

The term “maturity” constitutes a state of completeness, perfectness or readiness (Simpson and Weiner, 1989). Researchers and managerial experts have developed maturity models to guide an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired end stage. Scholarly literature in IS understands maturity as an evaluation measure for corporate capabilities (Rosemann and De Bruin, 2005). Accordingly Becker, Knackstedt and Pöppelbuß (2009) suggest that a maturity model helps designing and using IT efficiently and effectively. Multiple archetypal levels for a class of objects form together the evolutionary path in a particular domain (Rosemann and De Bruin, 2005). Being part of corporate steering practices, maturity models typically serve as benchmarking instruments which ensure continuous improvement of enterprise capabilities (Paulk et al., 1993). Since IS scholars assume a strong association between the maturity level of a particular capability and the effectiveness of the IT providing that capability, maturity models outline how the contribution of IT to that particular capability can be optimized along an evolutionary path.

RESEARCH APPROACH

We selected the design science research (DSR) approach (Hevner, March, Park and Ram, 2004; Peffers, Tuunanen, Rothenberger and Chatterjee, 2007) to build a maturity model and thereby addressing the RQS of this paper. This type of research is well suited to engage relevant problems, while simultaneously ensuring a contribution to the scientific body of knowledge (Baskerville and Myers, 2009). DSR aims at the construction and evaluation of artifacts in order to overcome existing capability limitations (Hevner et al., 2004). Being the outcome of the DSR process (Peffers et al., 2007), a maturity model is an artifact that describes an anticipated, desired or typical evolution path (Becker et al., 2009).

Neff et al.  Fostering efficiency in IS support for product-service systems

In order to investigate heterogeneous phenomena (product-service systems) with a homogenous model, a maturity model is well-suited to guide our research. Driven by the success of popular models such as the capability maturity model (CMM) (Paulk et al., 1993), IS scholars developed and published numerous instantiations (Becker, Niehaves, Poeppelbuss and Simons, 2010; Mettler, Rohner and Winter, 2010). Anyway (“the procedures and methods that led to these models have only been documented very sketchily” (Becker et al., 2009), since IS most scholars seldom expose their development process. Addressing the requirement of a stringent and transparent development process, we decided to follow a maturity development approach (Becker et al., 2009) that is subject to the DSR guidelines (Hevner et al., 2004).

For the development of our maturity model we slightly adapted the process model (Figure 1). In order to increase the understandability of the eight-step procedure model (in terms of complexity of the model and alignment between the process and the structure), we decided to combine three process steps in the evaluation step. Starting with the problem identification (step 1), we specified the research problem, provided practical relevance and justified the value of the artifact. A case study research design was selected because the boundaries between service and manufacturing processes and their contexts (i.e. the service systems in which they are embedded) have not been explored evidently (Yin, 2009). In summer 2012, two researchers conducted seven exploratory case studies at worldwide leading manufacturing firms. The data collection can be traced back to semi-structured interviews as our primary method. The multiple case study approach is favorable to the single case study approach in terms of enhanced validity (Eisenhardt and Graebner, 2007). We documented interview transcripts for each case analyzed and supplemented the data collection with corporate reports. Due to the differences in firm-specific terminologies, tailored service processes and custom-built IT systems, we had to acquire additional information sources such as system landscapes and process maps in order to make the cases comparable. For example, data are distributed throughout the entire organization in terms of product and service division as well as different systems (i.e. operative and analytical). The final results were documented in a case study report.

Based on the problem identification (1) and the identification of shortcomings or lack in transferability in the analysis of existing maturity models, we continued with the comparison of existing maturity models (2). Part of this second step was a structured literature review in accordance with vom Brocke et al. (2009). Our aim was to identify existing maturity models devoted to the same or similar domains. After that, we analyzed the maturity models according to their domain and functionality as well as their capability to address the research problems. During the third step, determination of the research approach (3), we defined the research approach that is outlined within this section of the paper. As part of the iterative maturity model development (step 4), we used model adoption mechanisms (i.e. configuration, instantiation, aggregation, specialization, analogy (vom Brocke, 2007)) in a rigorous creation of a maturity model (structure and content). For the model evaluation (step 5), we merged the three process steps, conception of transfer and evaluation, implementation of transfer media and the evaluation, into one step (Becker et al., 2009).

REQUIREMENTS DERIVATION

The interviews constitute a large number of specific challenges and requirements for product-service systems. After analyzing all of our data thoroughly, the authors aggregated and consolidated the aforementioned requirements. This process resulted in the derivation of a list of six highly relevant requirements (Table 1).
ANALYSIS

We analyzed the existing literature that seemed promising for addressing the discussed requirements based on a structured literature review approach (vom Brocke et al., 2009). More concretely, we conducted a keyword search in which, using relevant keywords from literature reviews (Bardhan et al., 2010; Berkovitch, Leimeister and Krčmar, 2011; Spohrer and Kwan, 2009), we performed the searches of certain databases (EBSCOhost, ProQuest (ABI/INFORM), Emerald, ScienceDirect, Web of Science, and AISel). We limited our search to title, abstract, and keywords, and it resulted in 57 matches for in-depth analysis. After the actual content analysis, 53 articles were excluded, since they did not include maturity models in the targeted domain or they referred to previous models instead. The findings can be narrowed down to four articles. Since these maturity models do not address two requirements (R4 and R6), we continued the literature search with a forward / backward search that yields four PAS developed by the German Standards Institute (referred from now on as the DIN).

Ensuring a critical reflection, the authors mapped the explored requirements with the identified models and specifications (Table 2). Each article was assessed for every requirement whether the requirement is analyzed, mentioned or not mentioned.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Case study participant [CASE COMPANY]</th>
</tr>
</thead>
</table>
| [R1] Business model | - The business model influences the service portfolio and hence the business processes  
- Keeping heavy equipment goods operating at the customer site is essential to succeed | Process Automation IS Manager [ALPHA]  
Within the ALPHA group the shift from rudimentary spare parts services to more sophisticated business model stereotypes such as life cycle service and full service is undisputable. The big challenge is now to bring productivity into the service operations. |
| [R2] Controlling objects | - Since the value of industrial services lies in the customer usage; service quality must be controlled along the entire value chain  
- Applied methods: roll-out global service processes, establishing audits and certifications, and performance indicators | CIO [DELTA]  
Service processes have to be executed across organizational borders involving subsidiaries and subcontractors, since service locations in small markets are often not profitable. Hence, we rolled out standardized service processes worldwide and check the service locations in a comprehensive audit program once a year. |
| [R3] Installed base management | - Managing the installed base is salient  
- Generates critical insights about customers and the machines in operation | Vice President Service Division [BETA]  
Equipped with the comprehensive source of information, business analytics are able to perform extensive analyses that generate deep insights about the customer usage of their productive machinery equipment. |
| [R4] Mobile solution | - Service technicians need to be supported during the customer visit  
- Providing master data, historical data, service catalogs, access to the knowledge base, and triggering the billing and accounting processes | Head of IT Strategy & Transformation [EPSILON]  
Traditional mobile CRM solutions obtain replication-based and technically limited information on the installed equipment, but our service technicians need full access to back stage information. |
| [R5] Enterprise integration | - Larger production entities, smaller service entities and local subcontractors form a comprehensive service network that requires appropriate architectural solutions  
- The resulting complexity provides additional challenges to the IT architecture | Process Automation IS Manager [ALPHA]  
Locations with production and service hubs require substantially more information systems support than smaller locations with less budget. Hence we started to provide cloud-based solutions for small entities. |
| [R6] Data quality | - Ensuring high efficiency in the service processes requires substantial investment in corporate data quality to establish standards  
- A set of profound and reliable master data is crucial for automated service processes | Vice President Service Division [BETA]  
We have built large-scale proprietary systems for service support that combine detailed knowledge of the heavy equipment (bill of material) with the customer knowledge which is buried in the CRM. |

Table 1. Exploratory requirements
The business model requirement (R1) achieves the highest coverage (4 points) of all investigated requirements. After dealing with transaction-based services, manufacturing organizations shift their focus to relationship-based business models (Oliva and Kallenberg, 2003). Hildenbrand et al. (2006) break down the strategic service management of industrial organizations into five stages of service orientation. Nägele and Vossen (2006) posit a customer-oriented view during the service development. Spath and Demuß (2006) consider the organizational design and engineering capabilities to realize customer-individual solutions. DIN PAS 1082 emphasizes the development phase of product-service systems in networks, while innovative business models are not taken into account. DIN PAS 1091 addresses component-based interface specifications for supporting controlling, sales and organization but neglects the implications on business models. DIN PAS 1094 remains on a very generic level. Being addressed in two articles, the lowest coverage (0.5 points) was achieved by the mobile solution requirement (R4). The IS requirements specified by DIN PAS 1090 are based on a particular case study analysis merely and, hence, lack in validity (Thomas et al., 2007). Further, the document does not incorporate latest technological shifts such as cloud computing, refers to custom-built software for the service technicians and does not address billing transactions.

Summing up, the analysis revealed that the majority of maturity models only partially address these requirements, while the DIN specifications make up a broader set but remain very generic.

<table>
<thead>
<tr>
<th>Framework [Source]</th>
<th>Orientation</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
<td>Maturity</td>
</tr>
<tr>
<td>Hildenbrand et al. (2006)</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Nägele &amp; Vossen (2006)</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Oliva &amp; Kallenberg (2003)</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Spath &amp; Demuß (2006)</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>DIN PAS 1082 (2008)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>DIN PAS 1090 (2009a)</td>
<td>✓</td>
<td></td>
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<tr>
<td>DIN PAS 1091 (2010)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>DIN PAS 1094 (2009b)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Assessment*</td>
<td>4</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Legend: ○ not mentioned [0]; ◯ mentioned [0.5]; ● analyzed [1]
*) Points are summed up for assessment

Table 2. Model fit assessment

SYNTHESIS

The authors considered the development of a new maturity model preferable, since the relevant requirements are not adequately addressed in extant literature. However, we based our maturity model on the well-established dimensions, elements, levels, and functions of the investigated models. The maturity model was developed within two iterations. In the first iteration, we defined the basic characteristics and the structure of the model. Drawing from popular maturity models such as the CMM (Paulk et al., 1993), we conceptualized five levels: prepared, engaged, established, managed, and optimized. In order to create a holistic perspective, we structured the requirements according to three segments (strategy, process, and information systems) (Österle, 2010). The first iteration satisfies the need for relevance through the content analysis of the case study reports and concluded with the inclusion of the following elements: safeguarding approach (based on R1 & R2), installed base management (based on R3), mobile solutions (based on R4), data integration (based on R5 & R6) and data reconciliation (based on R6). The element data integration addresses R5 implicitly, since e.g. [C.1.4] refers to “data integration with major business entities”. By assessing the requirements against prevailing models and standards, also rigor is ensured in the first iteration. This assessment leads to a better alignment and specification of the maturity model. Consequently a lack of coverage of the analyzed maturity levels was pointed out, why the maturity levels had to be further specified. Therefore the scope was extended to the DIN PAS. The focus group (comprising a senior researcher and two case study participants) analysis in the second iteration generated the elements business model (R1) as well as the specifications for the installed base management and mobile solution maturity levels and allowed a slightly adjustment of the model in terms of details and wording. Finally, the contributions of the discussion were consolidated and aligned the model (Table 3).

Considering the scope of this paper, we decided to focus on the two extreme levels of the developed model. Level 1, product-service systems prepared, implies that, in addition to the heavy equipment goods only basic spare parts services are offered.
[A.1.1]. There is no safeguarding approach in place [A.2.1]. Service processes are not adequately covered in the IS landscape, so that neither an installed base management [B.1.1] nor a mobile solution [B.2.1] can be provided. The required data for the analytical functions and sophisticated business processes are collected on an ad hoc basis [C.1.1] and a stringent quality assurance has not yet been introduced [C.2.1]. In contrast, level 5, product-service systems optimized, implies a customer-driven, highly integrated and real-time organization. On this level, the business model is extended by managing the entire customer operation [A.1.5], instead of managing particular functions associated with the installed base. Through a variety of financial, non-financial and customer-oriented safeguarding mechanisms, the organization fully integrates customer’s need [A.2.5]. By real-time monitoring the customer’s operation, efficient procession and velocity in managerial decision-making are ensured [B.1.5]. Service technicians are equipped with fully integrated mobile devices, allowing them to update installed base data, trigger billing transactions and access the knowledge database [B.2.5]. It is essential, that data from the production are ensured [B.1.5].

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Sub-dimension</th>
<th>Level 1 [Prepared]</th>
<th>Level 2 [Engaged]</th>
<th>Level 3 [Established]</th>
<th>Level 4 [Managed]</th>
<th>Level 5 [Optimized]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[C] Information Systems</td>
<td>[C.1.] Data Integration</td>
<td>Data is collected on ad-hoc basis without an integrated approach</td>
<td>[C.1.2] Data collection is done manually with basic integration applications</td>
<td>[C.1.3] In addition to [C.1.2], data collection is partially automated with partial data integration</td>
<td>[C.1.4] In addition to [C.1.3], data collection is fully automated, data integration with major business entities</td>
<td>[C.1.5] Data integration is fully automated and optimized as real-time integration for the whole enterprise</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[C] Information Systems</td>
<td>[C.2.] Data Reconciliation</td>
<td>[C.2.1] Data will be not reconciled</td>
<td>[C.2.2] Rudimentary data reconciliation is in place</td>
<td>[C.2.3] In addition to [C.2.2], data is reconciled horizontally</td>
<td>[C.2.4] In addition to [C.2.3], data is reconciled vertically</td>
<td>[C.2.5] In addition to [C.2.4], continuous optimization of reconciliation process</td>
</tr>
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</table>

Table 3. Maturity model (after second iteration)
EVALUATION

The evaluation step is an essential part of DSR to prove the “utility, quality, and efficacy of a design artefact” (Hevner et al., 2004). This was conformed by following a multi-perspective approach. Since maturity models are particular instances of references models, the four evaluation perspectives of Frank (2006) were applied to structure and document the evaluation results. These perspectives and the evaluation results are listed below (Table 4).

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Detailed Criteria</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>• Cost</td>
<td>As the model has not been broadly applied yet, costs and benefits are hard to measure at the current state. It has been observed, that the model eases the alignment of service initiatives of manufacturing firms by framing the analysis of the actual situation. It supports the establishment of a unified terminology and thus can foster inter-organizational standardization. The model appears to be useful to deduce roadmaps for improvement activities by identifying and analyzing the capabilities of the next higher level.</td>
</tr>
<tr>
<td></td>
<td>• Benefit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Coordination</td>
<td></td>
</tr>
<tr>
<td>Deployment</td>
<td>• Understandability</td>
<td>Due to the applied business engineering framework (Österle, 2010) and the DIN PAS, the model presents a holistic and integrated approach for assessing and improving organizations that implement product-service systems. It even provides first ideas for developing a reference model for mapping the functional requirements with an appropriate IT support.</td>
</tr>
<tr>
<td></td>
<td>• Appropriateness</td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td>• Purpose</td>
<td>The research approach was appropriate for the intended purpose of the maturity model (defining and explaining) and the application domain (heavy investment goods industry). The requirements are aligned with the elements of the artifact. The mix of business-related and technical items supports the comprehensiveness of the model.</td>
</tr>
<tr>
<td></td>
<td>• Application domain</td>
<td></td>
</tr>
<tr>
<td>Epistemological</td>
<td>• Theoretical foundation</td>
<td>The applied literature review framework ensured a sufficient coverage of existing maturity models. Case study research seems to be an appropriate research methodology to explore the requirements, followed by an established procedural model for the development of maturity models. As a result, the model is embedded into the design science approach and critically evaluated in accordance with approved evaluation perspectives. Our contribution to the scientific body of knowledge is the application of the maturity model to the IS support of product-service systems.</td>
</tr>
<tr>
<td></td>
<td>• Scientific value</td>
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</table>

Table 4. Evaluation perspectives

For managerial practitioners, in turn, the contribution lies in the assessment of their organization and the identification of levers for corporate improvement. Managers are able to draw a preliminary roadmap to increase the performance of the product-service systems.

CONCLUSION

The authors proposed a maturity model for the IS support of industrial product-related services. In contrast to the traditional focus on customer value such as co-creation with customers in SSME, we emphasized the needs of manufacturing firms offering an integrated product-service portfolio. Our maturity model is a management instrument, which can be used to analyze the current setup in order determine possible areas of improvement. It reduces the effort needed to unleash the full potential of the product-service system and the corresponding information systems support. Therefore, this paper answers two RQs in line with the DSR approach. The first part of this paper investigates key requirements for the IT support of product-service systems and their coverage in extant literature [RQ.1]. Our research indicates that existing maturity models and DIN PAS only partially address the exploratory identified requirements, and hence that none of the models is capable of assessing the problem holistically. Hence, an appropriate maturity model was developed in the second part of this paper [RQ.2]. It follows the structure of existing maturity models and inherits conceptualizations and methodologies from extant literature. Consistent with the fundamental principle in DSR of addressing real-world problems and simultaneously contributing to the scientific and practitioners’ body of knowledge, we produced consumable results for literature scholars and managerial practitioners.

One possible limitation of the presented study is the case selection. The generalization and validation of the results could be improved by examining more cases and applying a quantitative research design. A further limitation is the focus on German
and Swiss companies as the derived requirements are influenced by the multinational setting of the firms. The maturity model presents an important step in understanding why manufacturing firms struggle with the IS implementation of product-service systems and why they apply proprietary systems. The model development follows a top-down approach in which levels are first defined, while the characteristics are derived afterwards. A bottom-up approach, however, first derives characteristics, dimensions and levels and assigns afterwards the level of maturity. Since top-down approaches are often criticized for weaknesses in the theoretical foundation, we plan to follow the bottom-up approach by using an explicit maturity concept and empirical data. These data are then transformed into maturity levels by applying the Rasch algorithm in combination with rating scales (Cleven, Winter and Wortmann, 2012). This combined approach of behavioral and of DSR methods allows a more rigorous derivation of the underlying maturity concept and makes the relationships between different parts of the model more comprehensible.

REFERENCES
<table>
<thead>
<tr>
<th>Article VI</th>
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<tbody>
<tr>
<td><strong>Title</strong></td>
<td>Developing a Maturity Model for Service Systems in Heavy Equipment Manufacturing Enterprises</td>
</tr>
<tr>
<td><strong>Author(s)</strong></td>
<td>Alexander A. Neff, Florian Hamel, Thomas Ph. Herz, Falk Uebernickel, Walter Brenner, Jan vom Brocke</td>
</tr>
<tr>
<td><strong>Conference / Journal</strong></td>
<td>Information &amp; Management 51 (2014) 895–911</td>
</tr>
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<td><strong>State</strong></td>
<td>Published</td>
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<td>Heavy equipment manufacturing firms are increasingly challenged by the integration of service planning and execution in their established product-centred information systems (IS) environment. Despite a few standardisation efforts, there is no common understanding of service systems in industry goods companies and the corresponding requirements for the appropriation of information systems. We address this need by developing a maturity model. The design of the model is grounded in extant literature, focus group and case study research involving eleven organisations over 1.5 years. The evaluation confirms that the maturity model makes a novel and useful contribution to the design of service systems.</td>
</tr>
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</table>
Developing a maturity model for service systems in heavy equipment manufacturing enterprises

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Abstract

Heavy equipment manufacturing firms are increasingly challenged by the integration of service planning and execution in their established product-centred information systems (IS) environment. Despite a few standardisation efforts, there is no common understanding of service systems in industry goods companies and the corresponding requirements for the appropriation of information systems. We address this need by developing a maturity model. The design of the model is grounded in extant literature, focus group and case study research involving eleven organisations over 1.5 years. The evaluation confirms that the maturity model makes a novel and useful contribution to the design of service systems.

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1. Introduction

The market environment for heavy equipment manufacturers is changing rapidly and demands players to adapt their business models and to find a beneficial modus operandi for respective IS support.

1.1. Trends

Today, the manufacturing industry is undergoing significant structural economic changes. In the German mechanical engineering sector, the total turnover related to industrial services has made significant advancement from 16.8% in 1997 to 22.5% in 2000, while the fraction in the electrical engineering industry has almost doubled during this period. On a European scale, services account for almost half of the profits of industrial goods manufacturers, with an average annual profit growth of five percent. The constantly rising fraction of industrial services in all Organisation for Economic Co-operation and Development (OECD) countries except Luxembourg faces manufacturing firms with the need to transform their business strategy. By constantly adding new service businesses to their product portfolio, companies trigger a transformation process that requires not only changing strategy and structures but also changing business processes. This trend is particularly incisive with heavy equipment manufacturing companies. The equipment goods that are produced by this industry are characterised as long-living and highly productive. Consequently, services such as maintenance, repair and change operations are particularly important capabilities of the heavy equipment manufacturers for achieving and maintaining high profit margins. Specifically this means they have to complement their primary business focus on engineering and production with the completely different service component. An example of a metal-forming company which had built a large equipment base but did not meet the after-sales needs of its customers illustrates this. Concretely, 80% of the service business on the equipment was captured by competitors. In order to exploit this potential the company had to adopt a new business model including broader geographic coverage, an expanded service product portfolio, a new management team and a more proactive customer management.

However, the successive integration of services into business models often drives service operation divisions beyond their physical resource limits; i.e. human resources lack sufficient
qualified staff to provide the newly offered services. Call centre employees, for example, are often neither trained to deliver technical remote services for the installed base nor do they have access to the necessary information to manage the service request (e.g. information on the installed base, sensor data, etc.). Information technology (IT) artefacts have an enabling effect on this transformation process because they provide technological capabilities to reshape the service processes more efficiently [12]. Mobile computing, remote machine control and data management represent technical means that allow efficiency increase in service processes such as service quality controlling, knowledge management, mobile workforce, call centre processing and predictive analytics. Under limited resources, the development of these technical capabilities is difficult to obtain. For example, customers are physically unable to maintain operational condition on machinery in production facilities at 99.3% availability. Hence, the customer demands an extension in the service offering from call centres’ triggered reactions to a prediction-based model. Heavy equipment manufacturers’ service divisions need more precise and accurate information about the equipment to establish a professional monitoring and derived prediction process. Precision refers to the provisioning of serialised descriptions on sold assets in combination with deep technical information (e.g. bills of material), while accuracy addresses electronic machine records that give information on the past service activities performed on the machines (e.g. maintenance, repair and overhaul).

1.2. Research gap and research questions

Organisations are challenged by coordinating and managing the broad business-to-IT scope of this transformation. Confronted with the wide array of service business and technology related issues, management needs to obtain a comprehensive view on design and transformation tasks. Since the execution of this holistic transformation processes is a heterogeneous and complex task, it is crucial to prioritise and control the individual measures. Unfortunately, the existing research has not provided deeper insight into business processes [44] and enterprise application systems that are required to integrate manufacturing and service processes in service systems. Service system scholars (e.g. Spohrer et al. [105]) define business processes for service systems but concentrate on service companies, which are not subject to a fundamental transformation process. In particular, heavy equipment manufacturing companies that traditionally have their business focus on product-related business processes struggle with the implementation of service business processes. Oliva and Kallenberg [81] describe the business process challenges of the aforementioned transformation process but lack a description of how IS could support this process. Becker et al. [11,12] mention the transformation process for manufacturing companies and describe the customer-related IS challenges (front stage). In summary, there is a research gap in how back stage IS can support the service transformation process for heavy equipment manufacturing companies and what IS tools could help the management of those companies to master the service challenge. This context of service systems for heavy equipment manufacturing companies hence calls for further research.

Being successfully implemented in the software engineering domain [86], maturity models (MM) represent an established means of supporting effective management for complex and heterogeneous phenomena [2]. Hence, MMs provide valuable instruments to manage this transformation process [27]. To the best of our knowledge, there is no instrument, such as an MM, available in literature that facilitates the transformation process from traditional manufacturing companies to those embracing service systems [11,44]. We apply an information systems research perspective of service science. In view of the foregoing, a concept is needed allowing holistic support for such broad design and transformation tasks.

The objective of this article is to develop an MM that is capable of holistically assessing the IS support of service systems in the heavy equipment manufacturing industry and that is based on highly relevant requirements. Hence, we address the following research questions (RQ):

1) What are key requirements for transforming the IS support of service systems to offer service-oriented business in the heavy equipment manufacturing industry?

2) What are characteristics of an MM for service systems targeting key requirements of multinational heavy equipment manufacturing enterprises?

To address these research questions, we conducted a multiple case study and two focus group workshops with leading heavy equipment manufacturing firms from the heavy equipment goods industry. We contribute to the body of knowledge by identifying requirements that are not covered in existing MMs. Based on the identified requirements, an MM suitable to fulfill these needs is both developed and evaluated. The remainder of this article is divided into four parts: the first part lays the foundation by considering the central terms and the research gap studied in this paper; the second part describes the research methodology; the third part answers RQ1 by exploring unaddressed requirements and analysing existing MMs and standard specifications; and the fourth part as well as the fifth part are concerned with the development and evaluation of the MM (RQ2). Finally, we conclude with our major contribution, supplemented with a critical reflection and an outlook on future research.

2. Background

For our work, we apply the IS concept formulated by Agarwal and Lucas [1], who differentiate between the micro domain of IS, namely the IT artefact, and the macro domain, which aims to understand how IS alters organisations, environments and strategy. Since this paper is concerned with managing transformation processes of the integration of service planning and execution in the established product-centred IS environment of manufacturing firms, the concentration on the micro level (the IT artefact), as proposed by Benbasat and Zmud [14], would be inappropriate.

In accordance with the service dominant logic [114], IS scholars define services as the application of competence and knowledge with the aim of creating value between providers and receivers [104]. Lately, the notion of the ‘service system’ has been put forward representing ‘a value-coproduction configuration of people, technology, other internal and external service systems, and shared information (such as language, processes, metrics, prices, policies, and laws)’ [106]. Service systems aim at the co-production of value [105] through manifold interactions between service providers and service consumers. Interestingly, the theoretical foundation of service systems is rooted in the application of manufacturing system theory to services [68,75]. Similarly to manufacturing systems, service systems are composed of a front stage with direct customer interaction and a back stage with IS support [44], consisting of enterprise applications and the underlying data management systems [54]. The service providers and service consumers can be external (different companies) or internal (e.g. a business unit of the same company) [115].

The traditional focus of value creation in manufacturing firms has long been on developing and producing physical products and not so much on servicing these products [55]. Accordingly, the IS of
manufacturing firms centre around production business processes and not around service processes [11]. The challenge for the IS function is hence to integrate product business process with service business processes.

Being defined as ‘the state of being complete, perfect or ready’ [102], the term ‘maturity’ implies evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired end stage. IS scholars refer to a measure for the evaluation of corporate capabilities [94]. Along this line of argumentation, Becker et al. [7] explain that an MM serves as a tool for designing and using IT effectively and efficiently. In essence, these models consist of multiple archetypal levels that together represent the evolution of a certain domain [34,94]. The user, e.g. an organisation, applies MMs to benchmark and continuously improve enterprise capabilities [86]. Assuming a strong link between the maturity level of a particular capability and the effectiveness of the IT providing that capability, MMs describe how the value gained from IT increases along the evolutionary path [113].

Maturity dimensions should be rooted in both scientific grounding and practical relevance. IS success is often conceptualised as a combination of IS use and the benefits of IS, the IS impact [28]. The use of IS is affected by quality criteria, namely information quality, system quality and service quality. To integrate these constructs in an MM concept, IS needs to be specified in further dimensions. Henderson and Venkatraman [47] expand in the IS alignment model the narrow, technological view of IS to a combination of strategy and the technological dimension of IS processes and infrastructure. Drawing from organisational sciences Agarwal and Lucas [1] differentiate micro level that is generally viewed as being at the individual or group level of analysis from macro research focuses on ‘organisations, environments, and strategy’ [67]. The IT artefact is concerned with the former micro domain as technical view on IS, while the macro research seeks to understand how technology is changing organisations, environments, and strategies. The organisation dimension refers to the impact of IT on the internal unit or department and the resulting transformation. The environment dimension addresses how external factors (e.g. customer, government or partner enterprises) are influenced by the usage of IT. The strategy dimension covers the understanding of the critical components of IT strategy and its role in supporting and implementing business strategy decisions [47].

In this study, we focus our analysis on IS as an enabler of the transformation process from pure manufacturing to service systems. Hence, in combination with the core of IS, the IT artefact [14], the transformational aspect of IT serves as a conceptual basis for our MM. The dimensions, as summarised in Fig. 1, are as follows: ‘strategy’, ‘environment’, ‘organisation’ and ‘IT artefact’.

### 3. Methodology

An initial analysis of the literature revealed a lack of suitable constructs for quantitative research, so we chose a qualitative explorative research design, in which we empirically identified requirements for the design of service systems in heavy equipment manufacturing companies, which we aim to document by means of an MM. More specifically, we applied a design-oriented research approach [49,87] that is established in information systems research to contribute to the extant body of scientific knowledge through finding innovative solutions to a class of real-world problems [6]. Design-oriented research strives to build and evaluate ‘artefacts’ with the aim of overcoming existing capability limitations [49]. These artefacts, in combination with the evaluation results, represent the outcomes of the design science research (DSR) process [87]. Using DSR, we argue that MMs can serve as reference models [48] and hence artefacts that show ‘an anticipated, desired, or typical evolution path’ [7].

Our research aims at developing an MM as a specific type of artefact that is particularly suitable to investigate heterogeneous phenomena with a homogeneous model. The development of MMs is established in the IS field [27], and numerous models for a variety of purposes have been developed [10,73]. In contrast to the large number of MMs, the research on how to develop these models is rather sparse [7]. Additionally, most authors seldom demonstrate their development process, as our literature review indicates, and we identified two popular models [7,27] on how to conduct MM design. We decided to apply Becker et al. [7] to develop our MM since they follow a DSR development process according to Hevner’s DSR guidelines [49].

Becker et al. [7] propose a seven-step development process for MMs. To reduce the complexity of the model and to align the procedure process with the structure of this paper, we merged three process steps (the conception of transfer and evaluation, the implementation of transfer media and the evaluation) into one, the evaluation step. Furthermore, we included the ‘determination of a development strategy’ in the second process step, as it is based on the results of the comparison process step. Since DSR refers to a problem-oriented approach, the development of the MM is usually initiated either by a ‘need and require’ intention or by opportunity-based innovation [60]. The procedure applied in our research consists of four steps, and we describe each of them in Fig. 2 according to the tasks performed, the techniques used, and the output achieved in complementing our research.

Our approach starts with the problem identification (step 1). We specified the research problem, provided practical relevance and justified the value of the artefact. Since the boundaries between service and manufacturing processes and the service systems in which they are embedded are not well researched, there

![Fig. 1. Derivation of MM dimensions.](image-url)
are no a-priori variables that we could include in the model. This gives the first research stage an explorative character and requires the need for the controlled manipulation of variables. The poorly researched relation between enterprise applications, product business processes and service business processes highlights the contemporary focus of the research subject. The case study methodology seems most appropriate for this study [13,122]. Scholarly literature emphasises the benefits of the multiple case study approach in terms of enhanced validity [32]. Multiple researchers can improve the creative potential, while the convergence of observations strengthens confidence in the findings [31].

The case selection was based on a theoretical sampling approach [31] applying the criteria of ‘company size’ (defined by turnover and number of employees) and ‘industry’. For each criterion, companies with different characteristics were included (small, medium-sized and large companies as well as companies from different industries) to ensure a sample that is representative of the heavy equipment manufacturing industry in Germany, Austria, and Switzerland. The inclusion of companies from different industries should assure a holistic requirement evaluation and replication and mitigate the possibility of missing important potential requirements [32]. The individual cases of this multiple case study are the analytical unit for the course of the research. Over a period of three months, from April 2012 to June 2012, a team of two researchers conducted seven exploratory case studies at worldwide leading heavy equipment manufacturing firms (Table 1). The interview partners were carefully selected to balance both the business view and the IS view of the company with the aim of avoiding a respondent bias in either of the views. The ambiguity of the position descriptions in the participating companies called for multiple interviews to ensure an equal representation of both views.

Based in the high-wage countries of Germany and Switzerland, the heavy equipment manufacturing firms rely heavily on innovation and customer service for achieving cost and value synergies. Data were collected using a variety of methods. The primary method of data collection was semi-structured interviews with company representatives. We designed the interview guideline (Appendix A) based on the initial literature review process according to well-accepted qualitative research methodologies [74,122]. Since robust data collection should rely on a triangulation of sources, we collected both publically available company documentation and detailed, confidential process descriptions and data. The combination of interviews and real process data also reduced the informant bias in our data collection. After transcribing the interviews, we complemented the interview-based data collection by further analysing enterprise

Table 1: Profile of the case study participants; numbers are based on fiscal year 2012.

<table>
<thead>
<tr>
<th>Case company</th>
<th>Industry</th>
<th>Size</th>
<th>Interview partner</th>
<th>Number of interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALPHA</td>
<td>Electrical equip</td>
<td>Large</td>
<td>Process Automation IS Manager</td>
<td>2</td>
</tr>
<tr>
<td>BETA</td>
<td>Machinery</td>
<td>Small</td>
<td>Vice President Service Division</td>
<td>2</td>
</tr>
<tr>
<td>GAMMA</td>
<td>Industrial services</td>
<td>Small</td>
<td>CIO</td>
<td>2</td>
</tr>
<tr>
<td>DELTA</td>
<td>Machinery</td>
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<td>CIO</td>
<td>1</td>
</tr>
<tr>
<td>EPSILON</td>
<td>Electrical equip</td>
<td>Medium</td>
<td>Head of IT Strategy &amp; Transformation</td>
<td>1</td>
</tr>
<tr>
<td>ZETA</td>
<td>Utilities</td>
<td>Large</td>
<td>CIO</td>
<td>2</td>
</tr>
<tr>
<td>EFA</td>
<td>Industrial services</td>
<td>Medium</td>
<td>Head of Corporate Solutions &amp; Technology</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2
Initial set of requirements (before case study exploration).

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Domain</th>
<th>Selected sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration rules</td>
<td>IT artefact</td>
<td>DIN PAS 1091 [42]</td>
</tr>
<tr>
<td>Computer-aided design (CAD) data availability</td>
<td>IT artefact/environment &amp; organisation</td>
<td>DIN PAS 1091 [42]</td>
</tr>
<tr>
<td>Terminological conventions</td>
<td>Environment &amp; organisation</td>
<td>Becker et al. [11]</td>
</tr>
<tr>
<td>Definition of roles &amp; responsibilities</td>
<td>Environment &amp; organisation</td>
<td>DIN PAS 1090 [41]</td>
</tr>
<tr>
<td>Data processing structure</td>
<td>IT artefact/environment &amp; organisation</td>
<td>DIN PAS 1090 [41]</td>
</tr>
<tr>
<td>Implementation of data architecture</td>
<td>IT artefact/environment &amp; organisation</td>
<td>DIN PAS 1090 [41]</td>
</tr>
<tr>
<td>Service information data</td>
<td>IT artefact</td>
<td>DIN PAS 1090 [41]</td>
</tr>
<tr>
<td>Life cycle characteristics</td>
<td>Strategy</td>
<td>Becker et al. [11]; Berkovich et al. [16]</td>
</tr>
<tr>
<td>Innovative business models</td>
<td>Strategy</td>
<td>Oliva &amp; Kallelenberg [81]; Davies et al. [26];</td>
</tr>
<tr>
<td>Customer involvement</td>
<td>Environment &amp; organisation</td>
<td>Gebauer et al. [37]</td>
</tr>
<tr>
<td>Technology management</td>
<td>Strategy</td>
<td>Nageli &amp; Vossen [76]</td>
</tr>
<tr>
<td>Human resource management</td>
<td>Strategy</td>
<td>DIN PAS 1094 [40]</td>
</tr>
<tr>
<td>Regulatory compliance</td>
<td>Strategy</td>
<td>DIN PAS 1094 [40]</td>
</tr>
<tr>
<td>Product and service parameters</td>
<td>Strategy</td>
<td>Geng, Chu, Xue &amp; Zhang [38]</td>
</tr>
<tr>
<td>Installed base management</td>
<td>Environment &amp; organisation</td>
<td>Oliva &amp; Kallelenberg [81]</td>
</tr>
<tr>
<td>Data quality assurance processes</td>
<td>IT artefact</td>
<td>Becker et al. [11]</td>
</tr>
<tr>
<td>Data integration</td>
<td>IT artefact</td>
<td>Becker et al. [11]</td>
</tr>
<tr>
<td>Process assessment model</td>
<td>Environment &amp; organisation</td>
<td>ISO/IEC TR 15504-7:2008 [57]</td>
</tr>
<tr>
<td>Comparability with other assessments or organisations</td>
<td>Environment &amp; organisation</td>
<td>ISO/IEC TR 15504-7:2008 [57]</td>
</tr>
</tbody>
</table>

application landscapes and process maps. The final results were documented and triangulated in a case study report, which was consecutively reviewed and approved by the industry partners. The second step, a comparison of existing MM(s) (2), builds on the problem identification (1) and the identification of shortcomings or lack of transferability in the analysis of existing MMs. As part of this step, we conducted a structured literature review in accordance with vom Brocke et al. [118] to identify existing MMs devoted to the same or similar domains. Subsequently, we analysed the MMs according to their domains and functionalities as well as their capability to address the research problems we outlined. During the iterative MM development (step 3), we used model adoption mechanisms (i.e. configuration, instantiation, aggregation and specialisation analogy [117]) in the rigorous creation of an MM (structure and content). The first iteration included the conceptualisation of an MM with the relevant elements and maturity levels using model adoption techniques and content analysis of the case study reports. After the elements and concepts of the MM had been designed, we evaluated the model with selected interview partners from the case company to create the maturity level descriptions for each dimension. The second iteration included a focus group workshop to adapt and balance the maturity levels across the dimensions to maximise the practical use of the MM. Then we structured the elements along the maturity concept that serves as sensitising device.

For the next step, model evaluation (step 4), we combined the conception of transfer and evaluation, the implementation of transfer media and the evaluation into one step [7].

4. Design of the MM

In the following, we document the design process of the MM, as outlined in our methodology section. For each of the three design steps, we present our procedure and results along with major considerations of our research. We then discuss our findings in chapter 6.

4.1. Problem identification

We conducted a structured literature search using five relevant databases for IS research [EBSCOhost, ProQuest (ABI/INFORM), Emerald, ScienceDirect, Web of Science and AISel]. Since requirements can exist implicitly as concerns or challenges for firms, we applied the search combination ‘challenge’ OR ‘concern’ OR ‘requirement’ combined with a term for IS and IT (‘information technology’ AND ‘information systems’) and different terms for service systems (‘service science’; ‘product service bundle’; ‘product service system’; ‘product service solution’). The search yielded 14 usable articles. Furthermore, we conducted a search on process standard specifications, which resulted in four additional publicly available specifications (PAS), developed by the German Standards Institute (the DIN), and three ISO/IEC standards [56–58] formed by the International Standardization Organization (ISO) and the International Electrotechnical Commission (IEC). Both articles and standard specifications were used to derive an initial list of requirements (Table 2). To create a holistic perspective and to identify the critical levers, we structured our findings according to the MM dimensions derived in section 2 (Fig. 1).

To prepare the data collection in the case study approach, we conceptualised a semi-structured interview guideline. The questions were informed by the initial list of requirements. We complemented the results from the literature review with empirical data from two exploratory expert interviews. The experts were asked to verify the initial requirements list. The interviews indicated the absence of relevant issues, e.g. the requirements of a mobile solution for the field staff or the need for service quality measurement. Moreover, the experts criticised the extent list for being too superficial and unspecific for the heavy equipment focus. For both reasons, we added more open as well as scenario-related items. The semi-structured interview guideline (Appendix A) presents the outcome of this process. Equipped with the interview guideline and first insights, we consecutively conducted data collection for seven case studies in the heavy equipment industry. The ambiguity of roles and responsibilities in the participating companies called for multiple interviews to ensure an equal representation of business and IS view.

In the coding process, we triangulated interview transcript data with the process documentation, the application landscapes, the interview notes and internal documents provided by the interviewees after the interviews (i.e. organisational charts and corporate documentation). First, we derived the context- and corporate-specific information. Second, we searched for cross-case patterns in the requirement, which were within-group similarities determined by the service systems. The coding process concluded with the aggregated requirements that are embedded into context-specific scenarios. Then we coded requirements with the scenarios and assessed their importance according to their explicit appearance. The requirements were
included in the workshop list when at least three case study participants explicitly pointed out the need. After analysing all of our data thoroughly, we discussed and consolidated the aforementioned requirements in workshops with experts [111]. This process resulted in the derivation of a list of six highly relevant requirements. The interviews with experts from different heavy equipment manufacturing corporations revealed that neither a common definition nor a standardised business model classification of the service systems for heavy equipment manufacturing firms was available. Regarding the strategy dimension, these firms have developed their firm-specific terminology, including classification approaches for business models. A similar case holds true for analytical objectives and performance indicators. The environment & organisation dimension showed that mature cases of installed base management and mobile solutions take advantage of valuable operational and customer-centric data. Analysing the cases in the IT artefact dimension, we encountered a wide spectrum of enterprise application approaches. The spectrum ranges from legacy applications through loosely coupled proprietary applications to fully integrated enterprise application systems. Applying the most pragmatic approach of using proprietary enterprise applications was criticised by participants due to the high level of software development and integration effort. In addition to this problem, a high risk of low data quality has a serious impact on the effectiveness and efficiency of the service system. Furthermore, service processes need to be supported by a flexible and global service infrastructure.

According to our case study participants, the following factors are not fully covered by existing industry models and standard specifications:

- **(R1) Integration of a service offering into the business model:** The business model influences the service portfolio and hence the business processes. However, all case study participants acknowledge that keeping heavy equipment goods operating at the customer site is essential to succeed in the service business. The IS manager of ALPHA stated that ‘the ALPHA group distinguishes three business model stereotypes: spare parts, life cycle service and full service. Each of them requires different business processes for realisation’.

- **(R2) Service quality:** Since the value of industrial services arises when the business customer applies it, the service quality must be ensured along the entire value chain, including external vendors. For that reason, the following methods have been applied: roll-out global service processes, establishing audits and certifications, and performance indicators. The CIO of DELTA outlined that ‘we rolled out standardised service processes worldwide. Once a year, the service locations are checked in a comprehensive audit program’.

- **(R3) Installed base management:** Managing the installed base is salient, as it presents valuable customer knowledge and creates critical insights about the machines in operation. The following elements characterise this requirement: collecting and updating historic data after repair and maintenance events, the use of condition monitoring for preventive maintenance and optimising the customer processes, including equipment investment goods from competitors. As stated by the manager of BETA, ‘the application of emerging technologies such as remote setup, repair, and maintenance can help to keep up the operation condition with efficient resources’.

- **(R4) Mobile support for the service workforce:** There is a clear need to support service technicians during the customer visit. The main purpose is to provide master data, historical data, service catalogues and access to the knowledge base and to trigger the billing and accounting processes. The manager at EPSILON reported ‘on a mobile solution that guides the service technicians during repair and maintenance activities. However, expensive proprietary applications serve as a technical basis for the mobile support of our service technicians’.

- **(R5) Enterprise integration:** Most of the case companies primarily produce in their European home market, while local entities are responsible for sales and service activities. Larger production entities, smaller service entities and local subcontractors form a comprehensive service network that requires appropriate architectural solutions. The resulting complexity provides additional challenges to the IT architecture. As specified by the manager of ALPHA, ‘locations with production and service hubs require substantially more information systems support than smaller locations with a smaller budget. Cloud-based information systems present a contemporary approach for such small entities’. The manager of GAMMA refers to expensive customisation projects for adapting enterprise applications to the service-specific needs.

- **(R6) Data quality & integration:** Ensuring high efficiency in the service processes requires substantial investment in corporate data quality to establish standards. A set of profound and reliable master data is crucial for automated service processes. Five case study participants clearly indicated that service and product businesses are separated organisationally, and that is reflected in a separation of the adjacent information systems. As a result, product and service components are covered by distinct data models. However, efficient contract management requires an integrated view of product and service objects. The manager of BETA mentioned that ‘the service level is specified as long text in the product object’.

### 4.2. Comparison of existing MMMs

Based on the exploratory findings, we analysed extant contributions concerning the extent to which they address the discussed requirements. The selection of existing MMMs, DIN PAS and ISO/IEC was based on the structured literature review approach [118]. We present below (Table 3) the results of the keyword search in which, using relevant keywords from literature

<table>
<thead>
<tr>
<th>Database</th>
<th>AND</th>
<th>‘Stage model’ OR ‘maturity model’</th>
<th>‘Information technology’ OR ‘information systems’</th>
<th>‘Service science’</th>
<th>‘Product service bundle’</th>
<th>‘Product service system’</th>
<th>‘Product service solution’</th>
<th>Net hits*</th>
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</thead>
<tbody>
<tr>
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<td>0 (9)</td>
<td>2 (8)</td>
<td>0 (1)</td>
<td>9</td>
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<td></td>
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<tr>
<td>ProQuest</td>
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<td>4 (37)</td>
<td>0 (5)</td>
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<td>Emerald</td>
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<td>1 (10)</td>
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<td>3 (3)</td>
<td>1 (7)</td>
<td>16</td>
<td></td>
<td></td>
<td>51</td>
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</tbody>
</table>

(‘) Double counts are removed manually.
reviews [5,16,18,79,106], we performed searches of certain databases [EBSCOhost, ProQuest (ABI/INFORM), Emerald, ScienceDirect, Web of Science, and AISel] [118]. We limited our search to titles, abstracts and keywords, and it resulted in 51 matches for in-depth analysis.

The forward/backward search provides seven standard specifications (i.e. ISO/IEC or DIN PAS) that outline particular requirements. For the actual content analysis, we mapped the explored requirements with the 51 identified MMs, the four DIN PAS (Table 4) and the three ISO/IEC standards [56–58]. Two researchers used a five-point Likert scale to rank every article for every addressed requirement according to the degree of coverage from 1 (very low) to 5 (very high). This method has been widely applied to IS research, e.g. by Alavi [3] and Igbria and Tan [53]. Evaluation was ensured through the usage of a predefined guideline that comprises a set of five properties and a definition for each of the requirements. Equipped with this replicable guideline each researcher assessed these articles by counting the fulfillment of the properties. After both researchers discussed their findings, they conjointly derived the result as presented in Table 4. All articles

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Literature source</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
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<td>1</td>
<td>3</td>
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(*) Articles are counted when the requirement is addressed at least with a low coverage (2).
Grey shaded articles and standard specifications were selected for an in-detail content analysis.
Degree of coverage: 1 very low; 2 low; 3 medium; 4 high; 5 very high.
with coverage of less than two requirements (49 out of 58) were excluded, which left four articles, one ISO/IEC standard and the four DIN PAS for further in-depth analysis (grey shaded articles in Table 4).

After the first assessment, the four existing MMs, one ISO/IEC and the four DIN PAS were examined in detail. This selection was also confirmed by two conceptual publications of service systems in the industrial context [9,88]. Hildenbrand et al. [50] break down the strategic service management of industrial organisations into five stages, each of which reflects a distinct degree of service orientation. While Nägele and Vossen [76] focus on the integration of the customer into the service development, Oliva and Kallenberg [81] outline the transition of the corporate focus from product to service in a procedural model. They claim that new organisational structures and business processes become necessary for the adequate support of this transition. Spath and Demuß [103] describe in their MM the different roles that industrial service can obtain through combination with physical goods in the manufacturing industry. Special requirements are given through the integration of heterogeneous service and product components, properties of life cycle management, innovative business models, customer integration and regulatory compliance. In accordance with DIN PAS 1094 [40], three additional DIN PAS have been developed to deepen particular aspects. While DIN PAS 1082 [39] presents a standardised process for the development of industrial services in networks, DIN PAS 1091 [42] encompasses interface specifications for the integration of service systems in manufacturing companies. DIN PAS 1090 [41] is concerned with IS requirements developed for the mobile support of technical customer service. ISO/IEC 16680:2012(E) [58] provides a guideline to implement the Open Group Service Integration Maturity Model (OSIMM) to connect service offerings better across a multi-business company.

To derive the appropriate elements for the MM, we mapped the explored requirements with the identified MMs and the standard specifications (Table 5). As in the first assessment step, we used a five-point Likert scale to rank every article for every requirement according to the degree of coverage from 1 (very low) to 5 (very high). The evaluation of coverage was conducted by the research team focusing on quantifying the conceptual differences of the analysed models. In the next paragraphs, we will outline examples that illustrate the ranking process and the mentioned imperfect coverage of the requirements by the existing industry models. None of the existing models covers can be called holistic, as no model addresses all requirements at the same time.

The business model requirement (R1) achieves the highest average of all the requirements investigated. Most attention in the literature is directed toward the strategic debate about the appropriate business model in the ‘servitization’ [78] of the manufacturing industry, resulting in seven articles for analysis. After dealing with transaction-based services, manufacturing firms recalibrate their focus toward relationship-based activities such as professional services and sophisticated maintenance [81]. They claim that new business models such as the provision of spare parts, life cycle service and full service become necessary to support this strategic transition. Hildenbrand et al. [50] break down the strategic service management of industrial organisations into five stages, each of which reflects a distinct degree of service orientation, but they neglect the full service conception. Nägele and Vossen [76] posit a customer-oriented view from a purchaser to a partnering role in the service development and thus lack the provisioning function of a manufacturing firm. Spath and Demuß [103] consider the organisational capabilities to realise customer-individual solutions that arise in the transition from a product to a service business. However, they focus on design and mechanical engineering issues. DIN PAS 1082 emphasises the development phase of service systems in networks, while the need to develop an innovative business model is only outlined. DIN PAS 1091 addresses component-based interface specifications for supporting management accounting, sales and organisation but neglects the implications for business models. DIN PAS 1094, rather, provides an overview and stays on a very generic level. ISO/IEC 16680:2012(E) [58] provides an in-depth MM of service integration that features a business model dimension that evaluates the business/IT alignment for internal and external services. Although particular publications achieve a relatively high coverage of R1, the average is at a medium to high level (3.6). The lowest coverage was achieved by the mobile solution requirement (R4). The IS requirements specified by DIN PAS 1090 are based merely on a particular case study analysis and, hence, lack validity [110]. Furthermore, the document does not address billing transactions, refers to custom-built software for the service technicians of the construction industry and does not incorporate the latest technological shifts such as cloud computing. We hence found very low to low coverage (1.4) of the mobile solution requirement, addressed in three articles. However, specialised articles on mobile process design give insights on potentially relevant aspects of the topic, although not in the context of an MM. Matijacic et al. [71] derived and ranked functional requirements for mobile service processes, which we also incorporated into the maturity level definitions of the mobile solution dimension.

The analysis revealed that the majority of MMs only partially address these requirements, while the DIN specifications make up a broader set but remain very generic.

4.3. Iterative model development

In view of the unsatisfactory coverage of the relevant requirements, the development of a new MM is preferable to the evolution of an existing model. Nonetheless, our MM adopts

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<tr>
<th>Framework [Source</th>
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Legend: Degree of coverage: 1 very low; 2 low; 3 medium; 4 high; 5 very high.

Table 5

In-depth model fit assessment.
the well-established dimensions, elements, levels and functions of the investigated MMs.

We developed the MM in two iterations. In the first iteration, we defined the basic characteristics and structure of the model. Drawing from popular MMs such as the capability MM integration (CMMI) for services [25], we conceptualised five levels: prepared, engaged, established, managed and optimised, which translate into five maturity levels. However, the CMMI for services remains too broad, as it provides a general rating framework for establishing, delivering and managing services across industries such as health care, finance and transportation. As the CMMI Product Team highlights the contextual interpretation of the CMMI, we translate the CMMI levels into service system-specific levels for heavy equipment manufacturing companies. The five levels are staged; i.e. a company must achieve a certain level in all sub-dimensions to be ranked overall in the respective level. The staged level design reduces the outlier bias in averaged or continuous MMs [34]. Although the MM builds on the CMMI concept, there are major adaptations for the intended use to evaluate service system maturity in heavy equipment manufacturing companies. First, the MM was designed to serve as a coordination instrument for the identified requirements (see section 3). Second, the MM uses particular specifications tailored for heavy equipment manufacturing companies, whereas CMMI and standard specifications such as DIN PAS and ISO/IEC remain generic.

Whilst the first iteration satisfies the need for relevance through the content analysis of the case study reports, rigour is also ensured by assessing the requirements against existing models and standard specifications. As a result, we integrated the elements of performance measurement of industrial services (based on R1 and R2), installed base management (based on R3), mobile support for the service workforce (based on R4), integration of product and service data (based on RS and R6) and data quality assurance (based on R6). In this light, the second iteration is concerned with the alignment and specification of the MM. Confronted with the lack of coverage of the analysed maturity levels, we extended the scope to the DIN PAS to specify the maturity levels further. Finally, a focus group analysis yielded the specifications for the installed base management and mobile support for the service workforce maturity levels. Further the focus group brought up the central role of the integration of service offering into the business model (R1). The discussion revealed that this requirement should be given a more prominent position in the MM than being a dedicated element, i.e. the level descriptions should indicate how the transformation evolves along the cells. This insight is congruent to our findings of the case study analysis and the model fit assessment. In this light we structured the MM along the ‘integration of service offering into the business model’. For the design of the level description, we triangulated the general findings of the specifications (CMMI, DIN PAS and ISO/IEC) and identified articles with results of the exploratory case studies.

The focus group (comprising two senior researchers and two case study participants) allowed us to slightly adapt and balance the model in terms of details and wording. Finally, we consolidated the contributions of the discussion and aligned the model (Table 6).

After having derived and elaborated the MM elements in two iterations, we concluded the model construction with the classification of the elements with the maturity dimensions. The maturity concept is aligned with our understanding of IS as an enabler of the transformation process from pure manufacturing to service systems. Accordingly we focus on the combination of the core of IS, the IT artefact [14], with the transformational aspect of IT. Hence we employed strategy, organisation, environment and IT artefact [1] as dimensions that serve not only as a conceptual basis for collecting the exploratory identified requirements but also as a theoretical lens for the MM (see dimensions in Fig. 1). The intention is not to ensure a complete coverage, but to structure the elements with a theoretical lens. In accordance to Giddens we position those dimensions as theoretical constructs that are utilised in a selective way for structuration. Rather than providing detailed guidelines for the procedures [43,89], we treat those dimensions pragmatically and provide concepts that help to inform the artefact that can be seen as sensitising device [77,119]. The inclusion of these dimensions in a bottom-up approach as a sensitising device represents a well-established approach in IS research (c.f. [69,89]).

Intertwining the maturity concept with the maturity levels we validated each maturity element with its instantiations against the definitions of the dimensions. The dimension performance measurement of industrial services [A.1] is organised with KPIs and each of them closely reflects the current business strategy, i.e. corporate positioning for the integration of the service offering into the business model. Designing, controlling and modifying KPIs present management tasks that are strongly related to strategic management decisions, such as the selection of service models for product and service bundles. Therefore we listed the element [A.1] under the strategy dimension. The installed base management [B.1] refers to a service operations process that contributes customer knowledge and collects data on heavy equipment in usage. It presents an internal process to manage repair, overhaul and maintenance operations on the customer equipment. Remote technology is used to bring efficiency in the service operations management by automating information exchange with the sensors of the installed equipment. The usage of IT alters this service process and thereby allows the offering of output-based service contracts at high service level. While installed base management fulfils the characteristics for the dimension organisation, the customer interaction outlines also environment issues. Hence we classified the installed base management as part of both dimensions. Mobile support for service workforce [C.1] is centred around mobile computing and the provisioning of back stage enterprise applications functionality. The technical component, i.e. mobile device and software application, gives strong indication to the IT artefact dimension. The integration of service and product data [C.2] as well as the data quality assurance [C.3] are listed under the IT artefact dimension. Both elements refer to operational IT processes that manage data resources to fulfil information needs in the service processes.

Rudimentary spare parts services, service systems prepared (level 1), implies that, in addition to the heavy equipment goods, only rudimentary services such as spare parts sales are offered. There are no service specific key performance indicators (KPIs) in place, but logistic centred KPIs such as order fulfil rate or average turnaround rate are implemented for inventory management [A.1.1]. Since the installed base is not equipped with sensors, there is no professional installed base management process [B.1.1] rolled out. On-site service technicians are not required for the spare parts service business model and accordingly a mobile solution for the service workforce [C.1.1] is obsolete. The data necessary for the analytical functions and sophisticated business processes are gathered on an ad hoc basis [C.2.1], but a basic spare part equipment to machine relation is available. However a consistent quality assurance has not been implemented [C.3.1]. With the reactive maintenance service model, service systems engaged (level 2), the company has made first steps in adding reactive services to its business model. The company is focused on efficiency-raising initiatives for the own operations and maximising service interactions with the customer. Accordingly the company exclusively processes financial KPIs such as answering time and working capital ratios [A.1.2]. The installed base management collects electronic reports from customer machines that are manually released by the customer to the manufacturer’s headquarters.
Table 6
MM for service systems in heavy equipment manufacturing companies (after iteration 2).

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Element</th>
<th>Integration of service offering into the business model</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Strategy</td>
<td>[A.1.] Performance measurement of industrial services</td>
<td>Rudimentary spare parts service (level 1)</td>
</tr>
<tr>
<td>[B.1.2] No service specific KPIs are in place, but logistic KPIs, e.g. order fulfil rate, average turnaround rate</td>
<td>[A.1.1] No service specific KPIs are in place, but logistic KPIs, e.g. order fulfil rate, average turnaround rate</td>
<td>[A.1.2] Focus on financial KPIs (efficiency driven for service processes, travelled route, answering time, working capital)</td>
</tr>
<tr>
<td>[B] Environment &amp; Organisation</td>
<td>[B.1.] Installed base management</td>
<td>[B.1.1] No coordinated interaction</td>
</tr>
<tr>
<td>[C] IT Artefact</td>
<td>[C.1.] Mobile support for the service workforce</td>
<td>[C.1.1] No mobile support necessary</td>
</tr>
<tr>
<td>[C.2.] Integration of service and product data</td>
<td>[C.2.1] Data is collected on an ad-hoc basis without an integrated approach (equipment to machine mapping)</td>
<td>[C.2.2] Data collection is done manually with basic integration applications (combination as-is built of material and customer data)</td>
</tr>
<tr>
<td>[C.3.] Data quality assurance</td>
<td>[C.3.1] No data quality assurance in place</td>
<td>[C.3.2] Rudimentary quality assurance (plausibility checks)</td>
</tr>
</tbody>
</table>

[B.1.2]. These reports are used by the service centre in the back stage for clarification and by the service workforce for on-site visit. Equipped with the mobile device during the on-site visit, the service workforce has access to customer data and information on the installed base (e.g. bill of material) on the mobile device [C.1.2]. However, the still manually entered data are integrated by basic applications [C.2.2], and plausibility checks of the entered data are conducted frequently [C.3.2]. When advancing to predictive maintenance service model, service systems established (level 3), non-financial KPIs, particularly remaining machinery lifetime, equipment and machine failure rate, become inevitable for implementing a professional performance measurement [A.1.3]. The implementation of the predictive maintenance service model requires more accurate and timely information on the installed base. The back stage service centre performs remote calls to achieve real-time access to the machinery state (failure code, software release, etc.) and sensor reports (temperature, humidity, oil state, etc.). The installed base management contributes very accurate data on the installed equipment and provides deep insights into the usage behaviour of the customer that puts the organisation into the position to fulfil the increased customer requirements, e.g. reaction times, incident prevention and machine availability [B.1.3]. Moreover, information on the installed base are analysed and combined to derive best practices and cross-selling opportunities. For the processing of maintenance and overhaul transactions, the mobile workforce can consult a knowledge database [C.1.3] that combines best practices documentation, equipment blueprints with the technical view on the history of the installed equipment. After performing the service transactions, the service workforce enters the transactions on the mobile device which then updates the as-is maintained list in the back stage enterprise application as batch processing. The prediction based service model requires the heavy equipment manufacturer to perform extensive analyses (e.g. to calculate remaining lifetime) on customer and installed base data which are stored in multiple database sources. Hence there is a clear need to automate data collection and integration (e.g. an intranet-based Web tool) [C.2.3]. These enhanced automation procedures in the integration of service and product data widens the scope of data quality assurance, i.e. these procedures have to be extended towards horizontal integration between different business units, particularly the product and service division [C.3.3]. Companies that decided to offer performance contracting service models, service system managed (level 4), need to master the shift towards the alignment with the customers’ business model. In fact the minimisation of service transactions with reliable equipment replaces the efficiency and maximisation objectives of customer interactions in the levels 1–3. This shift to the customer’s need is reflected in KPIs as quality maximisation, equipment reliability measures and production up times become inevitable. The increasing customer focus is translated into a balanced mix between financial and non-financial KPIs [A.1.4]. The operative implementation of performance contracting service models requires the enhanced usage of remote technology in the installed
base management. The service centre remotely monitors the installed equipment, since timeliness and accuracy in the condition and environment data are necessary to keep up the operative state at the customer site and thereby to fulfil the service level agreement [B.1.4]. If the machine communicates a need for maintenance, repair or overhaul transactions and the service centre confirms the diagnosis, the workforce will be sent out to the customer site. In addition to the availability of technical specification, customer data and service history, the mobile device is enriched with billing and contract functionality. The customer is able to digitally sign billing documents and receives an electronic confirmation, while the billing data are automatically processed in the accounting applications [C.1.4]. Using spatial data the service technician can be routed and guided through customer installations and production facilities. Both, installed base management and mobile support, in the performance contracting model require more sophisticated data integration and quality management. The integration of service and product data has to incorporate a variety of data types, particularly customer, contract, sensor and spatial data. The data collection should be fully automated and integrated across all business units [C.2.4], with automatic data quality assurance for both horizontal and vertical integration (for different enterprise application systems, e.g. operative and analytical systems) [C.3.4]. Managing the customer’s operations, service system optimised (level 5), refers to the most advanced integration of the service offering into the manufacturer’s business model. Instead of managing particular functions associated with the own labelled installed base, the alignment between customer and manufacturer is extended for competitors-made equipment. The KPIs are regularly adjusted to customer needs for the overhaul production process [A.1.5]. Similar to the performance contracting service model in level 4, the operative implementation of managing the customer’s operation requires the enhanced usage of remote technology in the installed base management. Using interfaces to sensors, embedded software and customer’s manufacturing execution system, the service centre remotely monitors and controls the customer production processes in real-time [B.1.5]. Moreover, fully integrated mobile devices are deployed for the service technicians’ use, allowing them to perform create, delete, update operations for the installed base management, to trigger billing transactions and to access the knowledge database [C.1.5]. These aforementioned business processes require substantial investments in the information systems landscape. Data from the production and service divisions must be automatically integrated on a real-time basis [C.2.5]. However, efficiency and effectiveness in the service system depend on consistent data quality (e.g. master data, operational data, transaction data and knowledge base data) encompassing vertical and horizontal reconciliation [C.3.5]. Intermediate levels are designed to be clearly distinguishable so that a higher level corresponds to additionally offered features.

5. Model evaluation

A substantial element of design-oriented research is the evaluation step that investigates the utility, quality, and efficacy of a design artefact [49]. To thoroughly evaluate the MM designed, we applied a multi-perspective approach. Following Frank [33], we investigated three evaluation perspectives, namely an economic perspective, a deployment perspective and an epistemological perspective. As a strategy of inquiry, we conducted a focus group workshop with representatives of four heavy equipment manufacturing companies that have not been involved in the design process of the model to make a confirmatory investigation of the MM [111]. The two-hour focus group workshop took place in October 2012 and was made up of five managerial practitioners as participants (see profile in Table 7), a senior researcher as the moderator and a junior researcher as an observer. Two participants have a business role in their company, whereas three participants work in IT roles. This balancing is necessary to avoid biased focus group workshop outcomes. The focus group was asked about comprehensiveness, validity in self-assessment and the capability of supporting the development of a roadmap.

From an economic perspective, an evaluation of the MM based on the criteria of cost, benefit and coordination was conducted. The assessment revealed that, in principle, costs and benefits can only be estimated at this stage due to the lack of cases in which the model has been applied. Still, the focus group participants expressed that it helps to align the service initiatives of heavy equipment manufacturing firms by framing the analysis of the situation and outlining the required activities for advancement in maturity. It was further mentioned that the MM can also foster inter-organisational standardisation since it supports the establishment of a unified terminology that is compatible with the DIN PAS, the ISO/IEC and existing MMs. Further, it was expressed that the MM can provide a better understanding of the requirements of service systems not only for the industry but also for software vendors to allow them to develop standardised support tools. Since improvement activities can be easily identified by analysing the capabilities at the next higher level, the MM was found particularly useful as a foundation for the development of a preliminary roadmap serving as a basis for investment decisions. Regarding the deployment perspective, the MM was evaluated according to its understandability and appropriateness as assessed by the focus group participants. Applying the IS concept [1] and the standard specifications, the participants agreed that the model presents a holistic and integrated approach to assessing and improving heavy equipment manufacturing companies that implement service systems. Moreover, it was argued that it provides first insights into developing a reference model to map the functional requirements with the appropriate IS support.

The two-hour focus group workshop started with a presentation on the service system requirements in the heavy equipment manufacturing industry (i.e. the results of the case study reports) given by the moderator. This 20-min presentation addressed the problem identification and motivation as well as best practice service system implementations, followed by a subsequent discussion (10 min). After that, two selected case study participants presented their success stories for requirements R3 and R4. Then the moderator briefly introduced the MM as a management instrument and explained the tasks for the self-assessment of service systems. All the focus group participants were able to position their organisation by applying the MM within a working session within 10 min. The results are presented subsequently.

Table 7
Profile of the focus group participants; numbers are based on fiscal year 2012.

<table>
<thead>
<tr>
<th>Company [Industry]</th>
<th>Employees &gt; 10k</th>
<th>Turnover € &gt; 5 Billion</th>
<th>Function of the participant</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>THETA [Industrial]</td>
<td>–</td>
<td>–</td>
<td>Head of IT Services for Sales</td>
<td>2</td>
</tr>
<tr>
<td>IOTA [Industrial]</td>
<td>–</td>
<td>–</td>
<td>Head of Customer Service</td>
<td>2</td>
</tr>
<tr>
<td>KAPPA [Industrial]</td>
<td>–</td>
<td>–</td>
<td>Director of ERP Systems</td>
<td>1</td>
</tr>
<tr>
<td>LAMBDA [Industrial]</td>
<td>–</td>
<td>–</td>
<td>CIO</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Head of Service Transformation</td>
<td>1</td>
</tr>
</tbody>
</table>
Most of the managers located their service systems between maturity levels 2 and 4. Table 8 visualises the average scores across all case study participants; however, the averaging has only an illustrative purpose since the maturity levels of the individual companies are designed to be bottom-staged; i.e. the overall maturity level for each company equals the lowest maturity level of all sub-dimensions. As a result, the total average across all heavy equipment manufacturing companies was 2.5. The individual elements of the MM varied between a maturity level of 1.8 and 3.3. B.1, ‘installed base management’, turned out to be difficult to implement and hence achieved the lowest average of 1.8. However, one managerial expert in the focus group positioned his company at level 4. He justified this self-assessment level by stating that ‘today, we are able to remotely monitor the installed base at the customers' plants. Our solution continuously analyses the sensory data and informs the service staff, when problems occur. By doing so, we are not only able to ensure an immediate replacement of the correct defect product [one assembly line can be driven by dozens of heavy equipment goods], but also provide accurate predictions on the remaining lifetime. The customer value lies in the reduced downtimes of production facilities. As a consequence our sales went up, while the company saved money by streamlining and accelerating the service processes’. C.2 ‘integration of service and product data’ had the highest average of 3.3. One of the focus group participants attributed this to the large data warehousing and business intelligence projects that have been undertaken in recent years. In this light, he stated that ‘we realised that our databases contain much valuable information on the products deployed at the customer’s place when we were consolidating our services and systems. By means of combining pieces of data from several data warehouses, it is possible to find out which customer possesses which product at which location’. From an epistemological perspective, the scientific value and the fulfilment of scientific requirements were to be assessed. The development of the MM uses a combination of established research methods: The literature review is based on an established literature review framework and ensures sufficient coverage of the existing MMs. The initial keyword search yielded 518 hits, of which 51 papers were deemed useful for deeper analysis. Together with seven ISO/IEC and DIN PAS standards, 58 papers and standard specifications were evaluated according to the requirements. The research methodology applied case study research to explore the requirements, follows an established procedural model for the development of MMs that is embedded into the design science approach and critically evaluates the artefacts in accordance with approved evaluation perspectives and approaches. The contribution to the scientific body of knowledge comprises the application of the MM approach to the IS support of service systems in the heavy equipment manufacturing industry. For managerial practitioners, in turn, the contribution lies in the assessment of their organisation and the identification of capabilities that serve as levers for corporate improvement. Managers can to draw a preliminary roadmap to increase the performance of the service systems within their organisations according to their individual requirements. The model was evaluated according to the extent to which the suggested design is aligned with the intended purpose of the MM (defining and explaining) and the application domain (the heavy equipment manufacturing industry).

Summing up, the general reactions to the presented model were positive. The mix of business-related and technical items supports the comprehensiveness of the model. Nonetheless, two managerial practitioners criticised the lack of a human-centred dimension. In particular, they argued for addressing factors such as skills or specialisations. Since the other participants strongly opposed this idea, we finally decided not to change the MM by adding a human dimension.

6. Discussion

We presented the development and evaluation of an MM to assess and develop the service system capabilities of heavy equipment manufacturing companies. The feedback from the broad range of experts who were involved in the various stages of developing and evaluating our MM provides convincing evidence of the usefulness of the MM. In phase one (problem identification), the need to design the model was—apart from the literature—also drawn from two expert interviews. Equipped with the resulting semi-structured interview guideline, seven case studies were conducted to explore the service system requirements. In phase two (comparison of existing MMs), the results of the exploratory case studies were analysed and compared to the dimensions in existing MMs. In phase three (iterative model development), two iterations of concurrent research were conducted based on the case study analysis and the focus group refinement involving two senior researchers and two case study participants. In phase four (model evaluation), the resulting model was then formatively evaluated from an economic, a deployment and an epistemological perspective involving five experts from four companies in a focus group setting. Based on the rigorous model-development process and the perceived usefulness of the model by the intended users involved, we conclude that our study provides a comprehensive model with which to assess and develop the service system capabilities of heavy equipment manufacturing companies. Next, several consequential questions that arose regarding the application of the model are discussed, considering implications for both research and practice.

6.1. Implications for research

We discuss our findings both in the field of IS research and service science research. Our research complements the service system research conducted by Spohrer et al. [104], who describe the connection between the front stage and back stage of service systems, connecting enterprise applications with service processes. Similar studies [e.g. [44]] define the requirements and specifications for service systems that compromise enterprise application systems as essential. The developed MM extends the

Table 8
Self-assessment of four heavy equipment manufacturing firms.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Element</th>
<th>Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>[A] Strategy</td>
<td>[A.1]</td>
<td>–</td>
<td>3</td>
<td>1</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.3</td>
</tr>
<tr>
<td>[B] Environment &amp; Organisation</td>
<td>[B.1]</td>
<td>#1</td>
<td>#2</td>
<td>–</td>
<td>#1</td>
<td>–</td>
<td>#1</td>
<td>1.8</td>
</tr>
<tr>
<td>[C] IT Artefact</td>
<td>[C.1]</td>
<td>–</td>
<td>–</td>
<td>#3</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>[C.2]</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>#3</td>
<td>#1</td>
<td>#1</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>[C.3]</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>#2</td>
<td>#1</td>
<td>2.8</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
</tr>
</tbody>
</table>
connection of front stage and back stage IS systems to heavy equipment manufacturing companies that adopt service systems as part of their business model.

The product system-oriented approach is part of enterprise resource planning (ERP) research. Jacobs and Weston [59] provide a comprehensive overview of the manifold research streams in this field. Since the manufacturing business processes lack a service dimension, our MM helps to connect the research on manufacturing-business processes with service systems research in the area of back stage IS support.

The area of business processes linking product and service offerings has already been widely researched by scholars, including Sawhney et al. [95] and Oliva and Kallenberg [81], who specify the business process modifications for manufacturing companies while adding services to the traditional product portfolio. The MM for service systems at heavy equipment manufacturing companies complements the business process research, as it adds IS as a supporting factor for the business process transformation process.

Further, the findings can be embedded in the debate on the role of IS initiated by Benbasat and Zmud in 2003 [14] and triggered a number of responses from well-reputed IS scholars. To develop our concept of maturity for IS support of service systems, we utilised the notion of IS success [28]. While the conceptualisation of IS success as IS use and IS impact, affected by quality criteria, has been widely accepted and applied in MMs, the role and identity of IS have been defined in multiple forms. Benbasat and Zmud [14] describe IT artefacts and their respective capabilities, practices, use and impact as the core properties of the discipline. Agarwal and Lucas [1] broaden this notion by laying the focus on the transformational aspect of IT, the way in which technology is altering organisations, environments and strategy.

Given the central role of IS for this research endeavour and the understanding that IS is an enabler of the transformation process in the manufacturing sector, this IS concept has been integrated into the MM. Concretely, the elements of the encompassing definition of IS provided by Agarwal and Lucas [1], namely the IT artefact and strategy, environment and organisation, have been adopted as MM dimensions. These dimensions are understood as theoretical constructs that are utilised in a selective way for structuration and are treated pragmatically as sensitising device [77,119]. The integration of service and product data and data quality assurance as IT artefacts are only one part of IS. With the strategic and the environmental/organisational dimension, we meet the requirement that most of the IS research should focus on the macro aspect of IS, as pure research on the IT artefact is often too narrow. The MM for service systems illustrates the transformational macro aspect of IT. Further, the utilisation of the role of IS in the MM is in line with the knowledge that IS comprises human, task and technology and thus has both a technical and a social component [20].

6.2. Implications for practice

The transition in the service operations presents a holistic business-to-IT related issue. The transformation process from reactive models to performance contracting-based business models requires a shift in service operations. It is no longer beneficial to charge atomic service transactions as part of the customer interaction. Instead, the interests of customer and manufacturer are aligned in terms of the usage state and output generation of the machinery equipment. The ETA case outlines that reactive service is not optimised to account for a permanent and cost-efficient maintenance of the customer equipment. As stated by the IT executive, when introducing performance-contracting, the organisation has to fulfil a 180 degree shift in their operational goals. Our activities are measured against their capability to minimize the total costs and [no longer] to maximise transactions with the customer’. Therefore, technical capabilities such as remote diagnosis and monitoring were deployed to decrease human-intensive and hence costly service activities. Once repair, overhaul and maintenance become inevitable, the service technician is supported by professional mobile workforce management. The workforce is prepared for on-site visits with the appropriate physical equipment and the accurate human- and knowledge-based capabilities. These service operation capabilities process precise and accurate data. Both service managers of BETA reported that machine data represent the reference point for all service processes. Precision is achieved by enriching serialised descriptions on sold assets in combination with bill of material data, while accuracy addresses electronic machine records that give information on the past service activities performed on the machines (maintenance, repair, overhaul, etc.).

While the elements of the model are distinct, they are also interdependent. As indicated, the capabilities mutually reinforce and support each other. In this sense, the MM serves as a management instrument to coordinate complementary capabilities in a transformation process. In addition, the MM facilitates the isolation and structuring of relevant elements of the service system transformation process at heavy equipment manufacturing companies. For example, when the manufacturing enterprise fosters data quality assurance initiatives, management can realise more value from the integration of service- and product-related data types. High data quality (vertical and horizontal reconciliation) and fully automated data integration capabilities enable a unified view of customer equipment. Sophisticated installed base management (remote services and condition monitoring), in turn, processes service transactions with efficient means so that it becomes more valuable to the manufacturer to increase the service offering. Once physical service operation activities become inevitable, the service technician is supported by professional mobile workforce management. The service workforce is prepared for on-site visits with the appropriate physical equipment and the accurate human- and knowledge-based capabilities. Performance measurement ensures profitability calculations and the controlling of service offerings with the transformation process.

7. Conclusion

7.1. Summary and contribution

This paper aims to develop an MM for the IS support of service systems. In contrast to the traditional focus on customer value, such as co-creation with customers in service science, we adopt the perspective of heavy equipment manufacturing firms offering an integrated product-service portfolio. The MM can be used as a management instrument to analyse the current set-up to determine the key levers for improvement. The overall goal is the reduction of the effort needed to unleash the full potential of the service system and the corresponding information systems’ support. Accordingly, this paper addresses this need by answering two RQs in line with the DSR approach. The first part of this paper investigates ‘what are key requirements for transforming the IS support of service systems to offer service-oriented business in the heavy equipment manufacturing industry’ [RQ1]. Therefore, we conducted a multiple case study to elaborate key requirements that serve as a reference baseline for investigating whether existing MMs are capable of holistically assessing the IS support of service systems in the heavy equipment manufacturing industry. Using a structured literature review framework [118], we analysed the coverage of these requirements in current managerial and scientific frameworks. The findings indicate that existing MMs,
ISO/IEC and DIN PAS standards only partially address the exploratory identified requirements and hence that none of the models is capable of assessing the problem holistically. Therefore, we develop an MM in the second part of this paper. The model and its evaluation address the second research question; ‘What could a service system-specific MM targeting key requirements of multinational manufacturing enterprises look like?’ [RQ.2]. The model we developed is based on the structure of existing MM and inherits conceptualisations and methodologies from extant literature in IS, operations management, marketing and general management. Consistent with the fundamental principle in DSR of addressing real-world problems and simultaneously contributing to the scientific and practitioners’ body of knowledge, it was the researchers' aim to produce consumable results for literature scholars and managerial practitioners. Moreover, the MM benefitted from a multi-perspective evaluation according to a scientifically well accepted approach [33]. The focus group workshop outlines the model’s capability in terms of comprehensiveness, validity in self-assessment and supporting the development of a roadmap. In particular, the self-assessment then offers further insights into the current state of four additional heavy equipment manufacturing companies. The model is differentiated from existing MM not only through its holistic coverage of the requirements but also through its exclusive focus on the back stage IS in the service system domain.

7.2. Limitations and future research

The case selection might be described as a possible limitation of the study presented. A generalisation of the results could be enhanced by examining more cases and more industries. Another limitation is the focus on multinational German and Swiss companies. The requirements derived are influenced by the multinational setting of the firms, which has, for example, a strengthening effect on the global service infrastructure and hence on the enterprise integration requirement. Furthermore, the service systems environment is subject to fast structural changes that can result in new relevant requirements or in the loss of relevancy of one of the existing model requirements. We hence suppose a regular re-evaluation of the identified requirements. To derive additional requirements, the case interviews and the literature sources could be coded by multiple researchers to evaluate the requirements using quantitative measures, such as inter-coder reliability. Additionally, the success of knowledge management initiatives depends heavily on the user’s motivation [84] as well as on the managerial ability to make customers and employees contribute [65]. To evaluate the model on a long-term basis, we intend to conduct a longitudinal study of the use and the effectiveness of the MM with those companies that had implemented the MM. Future research should investigate the validity of the model by applying empirical validation instruments [92,97].

Further, a standardised appraisal method for all possible process outcomes along the MM can be understood as a potential limitation of the research study at hand. However, a standardised assessment framework could possibly not be applied on all companies as the same maturity state for two companies must not always be similar. Providing strict guidelines for all possible process outcomes would complicate the model in a way that the applicability could seriously suffer. Building on Fraser et al. [34] we hence opted for a guided self-assessment in a team exercise to minimize the individual response bias.

Our MM describes the desired target stage along the dimensions and associated elements. The model serves as a valuable management instrument to determine the current position and then to make a conscious decision for capability investments to advance in the model. The model helps to prioritize and derive change measures, but the concrete measures are reserved for the management and service workforce since this task is highly individualised and requires very specific technical and managerial knowledge. This study primary answers what back stage IS support is necessary to achieve the transformation levels, but the how question is not intended as explicit model content. The reasons behind this decision lie in the very individual initial situation of the enterprises. After the self-positioning with the management instrument (i.e. the MM), numerous factors possess influence on the how part to advance in the maturity levels. For example, regulatory requirements in a certain market might prevent a data integration of service and product systems or the work council intervenes against the workforce practices such as route tracking of the service technicians. Another indication is given by the position in the supply chain. Component manufacturers are usually limited in their access to the sensor data, since the embedded software in the heavy equipment is installed by the machine manufacturer.

The MM presents an important step in understanding the extent to which heavy equipment manufacturing firms struggle with the IS implementation of service systems and how they apply proprietary enterprise applications. Following this line of argument, we posit the development of a functional reference model (mapping the functions with the IS support) with the aim of forming building blocks and identifying the standardisation potential of existing solutions.

This paper uses a qualitative top-down approach, first defining the maturity levels and then specifying the corresponding characteristics in the second step. An alternative approach starts with the derivation of characteristics and dimensions before assigning maturity levels. To overcome frequent criticism of the top-down approach because of its weak theoretical foundation, we intend to apply the bottom-up approach with an explicit maturity concept and empirical data in the next research step. The data will be translated into maturity levels using the Rasch algorithm in combination with rating scales. This methodology has already been applied in various IS domains such as health care IS [24] and business intelligence research [91]. The combination of a behavioural approach and the DSR method improves the rigor of the maturity concept and increases the comprehensiveness of the underlying relationships between different parts of the model.

Appendix A. Interview guideline

1. Introduction
   1.1. Please describe yourself, your company and your role within the company.

2. Strategy
   2.1. How significant is the service business for your company?
   2.2. Which are the most important services in your portfolio?
   2.3. How do you classify your most important service products?
   2.4. What is the organizational structure of your service business?
   2.5. How is the interaction between the service and the product business organised?
   2.6. What are innovative business models in your company?
   2.7. What service business models could you imagine for manufacturing companies in the future?
   2.8. What challenges do you encounter when aligning IS and service strategy?
   2.9. How do you measure success of your service strategy?

3. Environment & Organisation
   3.1. Which are the processes enabling the business models?
   3.2. Do you develop service processes according to a structured procedure? If yes, which?
3.3. Do you apply specific norms and standards for your service processes?
3.4. How do you define service quality and how is it ensured?
3.5. What performance indicators are in place to control service processes?
3.6. How do you link your service business processes with the product-related business processes?
3.7. Please describe any additional requirements for the industrial service business.
3.8. What challenges do you encounter when connecting service and product business processes?

4. IT artefact
4.1. Which enterprise applications are involved in the support of service processes? Thereof, which are standard systems, proprietary systems and legacy systems?
4.2. How do you manage the integration of the involved enterprise applications?
4.3. What are the critical challenges for the IS support of service and product related business processes?
4.4. What data objects do you need for which service process? Thereof, which information is required by the service technicians and the call center workforce?
4.5. What are data objects did you customise? Thereof, which are the missing attributes?
4.6. How do you address data quality assurance?
4.7. How could enterprise applications contribute to improve service and product related business processes in the future?

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