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Challenges in Product Lifecycle Management - Evidence from the Automotive Supply Industry

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Abstract

Against the backdrop of a steady shift in value added from the automotive original equipment manufacturers to the automotive suppliers, product lifecycle management in the automotive supply industry gains importance. Prior literature has acknowledged product lifecycle management as paradigm for manufacturing industries, yet little is known about the specific characteristics and boundary conditions in this emerging industry branch. Grounded on extensive empirical evidence from a typical and revelatory case study at a global leader for mechatronic assemblies, this exploratory paper identifies, illustrates, and discusses challenges in product lifecycle management in the automotive supply industry. With the limitation of an exploratory and interpretive single-case study approach, we supply scholars and practitioners with grounded, stakeholder-related insights.

Keywords Product lifecycle management, PLM, automotive supply industry, case study.

1 Introduction

Much has been written about automotive original equipment manufacturers (OEMs). Having the well-known "big brands" in mind, the automotive industry is often diminished to those flagship enterprises. A look behind the scenes reveals a not less powerful and absorbing ecosystem: The automotive supply industry. Some figures demonstrate the branch's magnitude: Market research company "Statista" quotes the worldwide revenue outlook for the automotive supply industry to 1,700 billion Euro in 2020, compared to 640 billion Euro in 2001 (Statista 2015). Thereby, a large share of innovation makes its transition from the OEMs to the suppliers. Over the last decades the worldwide proportion of value added by suppliers grew from 56 percent in 1985 to 82 percent in 2015 (Statista 2015). Evermore key technologies for the next wave of automotive innovation are developed outside the OEMs' R&D labs which focus increasingly on their system and assembly competence (VDA 2012).

Within this challenging environment of quality improvement, reduction of cost and time to market, an effective and efficient management of the suppliers' products – expressed in other words "product lifecycle management" – seems more timely and relevant than ever. As an established field of research and practice, a number of conceptualizations for product lifecycle management (PLM) have been suggested (Saaksvuori and Immonen 2002; Ameri and Dutta 2005; Grieves 2006; Eigner and Stelzer 2008; Terzi et al. 2010; Stark 2015), yet the authors understand product lifecycle management as a comprehensive strategy of managing a company's products all the way across their lifecycles. Within the profound digitalization in manufacturing industries (Yoo 2010; Fichman et al. 2014), thought leaders propose novel ideas such as closed-loop product lifecycle management (Kiritsis 2011), digital twin concepts (Boschert and Rosen 2016), or cloud-based approaches (Lehmhus et al. 2015).

Yet, a glimpse at the daily business of manufacturing companies unveils challenges in product lifecycle management at various levels. In this sense, it is crucial to precisely understand the current situation as prerequisite to provide adequate solutions. Although product lifecycle management systems represent one of the essential information systems in industrial enterprises, research on product lifecycle management is not a common subject in the domain of information systems (Fichman et al. 2013; David and Rowe 2015). Despite some adjacent works, it is not clear which specific challenges automotive suppliers face. Hence, grounded on extensive empirical evidence from a typical and revelatory case study at a global leader for mechatronic assemblies, embedded in one of Europe's largest industrial consortia, we explore these obstacles. For this objective, we word the subsequent research question:

[RQ] "What are challenges in product lifecycle management in the automotive supply industry?"

The remainder of this paper is arranged in the following way: In chapter two, we introduce fundamental concepts and provide an overview on related work. In chapter three, we present the applied case study research methodology with data collection and data analysis. In chapter four, we list and illustrate the identified challenges and discuss them in chapter five. In a final step, we close with a summary, implications for scholars and practitioners, and research limitations.

2 Theoretical Foundations

2.1 Product Lifecycle

Existing literature occupies two main perspectives regarding the lifecycle of industrial products: The sales-oriented and the engineering-oriented perspective (Sundin 2009; Cao and Folan 2012). The sales-oriented view distinguishes the stages market development, market growth, market maturity, and market decline (Cao and Folan 2012). In contrast, in the engineering-oriented view an established conceptualization of the product lifecycle is the differentiation into beginning-of-life (BOL), middle-of-life (MOL), and end-of-life (EOL) (Cao and Folan 2012). Thereby, BOL encompasses product conceptualization, definition, and realization. MOL comprises product usage, service, and maintenance. EOL may be shaped by various scenarios from refurbishing to disposal (Terzi et al. 2010; Stark 2015). Beside this evenly distributed engineering-oriented view, a more frontloaded conceptualization with the stages requirements elicitation, product planning, development, process planning, production, operations, and recycling is in wide use (Eigner and Stelzer 2008; Eigner and Roubanov 2014).

2.2 Product Lifecycle Management

2.2.1 Development and Conceptualizations of PLM

The evolution of product lifecycle management from its early days to its present form occurred in several waves over the last decades (Ameri and Dutta 2005; Cao and Folan 2012). In the 1980s, the first isolated computer-aided technologies with focus on product development such as computer-aided design (CAD) came up. As a result, product data management (PDM) systems were developed to administer those technologies to support the design chain. In parallel, enterprise resource planning (ERP) systems were designed to assist the supply chain (Ameri and Dutta 2005). In the 1990s, the concept of PDM evolved to product lifecycle management (PLM) through horizontal integration (upstream and downstream processes) and vertical integration (customers and suppliers) (Eigner and Stelzer 2008). In the 2000s, empowered by new capabilities of intelligent products, the latest manifestation closed-loop PLM targets seamless information and knowledge flows through all phases across the product lifecycle (Kiritsis 2011). In sum, no common perspective on product lifecycle management exists. An impressive number of conceptualizations have been suggested, Table 1 provides an overview.

Conceptualization	Source
"(…) product lifecycle management is a systematic, controlled concept for managing and developing products and product-related information (…)"	Saaksvuori and Immonen (2002, p.3)
"(…) product lifecycle management is a business solution which aims to streamline the flow of information about the product and related processes throughout the product's lifecycle such that the right information in the right context at the right time can be made available (…)"	Ameri and Dutta (2005, p.577)
"(…) product lifecycle management is an integrated, information-driven approach comprised of people, processes/practices, and technology to all aspects of a product's life, from its design through manufacture, deployment and maintenance - culminating in the product's removal from service and final disposal (…)"	Grieves (2006, p.39)
"(…) product lifecycle management encompasses all activities and disciplines that describe the product and its production, operations, and disposal over the product lifecycle, engineering disciplines, and supply chain (…)"	Eigner and Stelzer (2008, p.37)
"(…) product lifecycle management is playing a "holistic" role, bringing together products, services, activities, processes, people, skills, ICT systems, data, knowledge, techniques, practices, procedures, and standards (…)"	Terzi et al. (2010, p.364)
"(…) product lifecycle management is the business activity of managing, in the most effective way, a company's products all the way across their lifecycles (…)"	Stark (2015, p.1)

Table 1. Selected conceptualizations on product lifecycle management

2.2.2 Elements and IT Architecture of PLM

In line with the heterogeneous conceptualizations, a unified perspective what product lifecycle management exactly comprises, does not exist. Following Eigner and Stelzer (2008), five main elements are included: (1) Product data management (e.g., engineering design structures), (2) production development (e.g., manufacturing and assembly processes), (3) customer needs management (e.g., requirements management), (4) material sourcing (e.g., strategic supplier assessment), and (5) management functions (e.g., support for reporting and decision making). Thereby, engineering collaboration (e.g., collaboration tools and integrations) connects the different internal and external stakeholders. Inherently, product lifecycle management should not be regarded as an "out-of-the-box" tool, but rather as an intelligent combination of different systems (Terzi et al. 2010).

From an IT architecture perspective, four layer models are prevalent (Eigner and Stelzer 2008, Eigner and Roubanov 2014). Layer 1 represents the author systems (mechanical computer-aided design (M-CAD), electrical/electronic computer-aided design (E/E-CAD), computer-aided engineering (CAE), and computer-aided software engineering (CASE)). Layer 2 (team data management (TDM)) acts as administrative layer which handles data close to the author systems in native data formats. Layer 3 (PLM backbone) enables the actual engineering functions in neutral data formats. Finally, layer 4 projects the enterprise resource planning (ERP) layer. Recent ideas lean towards a multi-disciplinary repository as smart information collector for both design chain and supply chain with individual applications for each product lifecycle phase (Eigner and Roubanov 2014).

2.3 Related Work

As holistic approach, product lifecycle management touches several academic disciplines. Accordingly, related work can be found in various domains. Beside the field of product lifecycle management as established research area itself, product development and manufacturing, information systems, management, and computer science literature may be qualified to provide a knowledge base. Adjacent research works for the issue at hand include: Burr et al. (2003) explored challenges for computer-aided technologies and engineering data management at an international automotive OEM. Tang and Qian (2008) focused on supplier integration in product lifecycle management targeting automotive applications. With his investigation of critical issues and challenges for product lifecycle management implementation, Hewett (2010) presented another example. Furthermore, Pulkkinen et al. (2013) addressed the state of the practice and challenges in globally networked manufacturing companies.

To summarize: First, product lifecycle management has been investigated rather from conceptual than from empirical points of view. Second, the specific characteristics and boundary conditions of the automotive supply industry have been disregarded so far. Third, in the domain of information systems, research works on product lifecycle management are underrepresented. In the following, we address this research gap with a case study approach.

3 Research Methodology

3.1 Methodological Foundations

The objective of this research is to investigate challenges in product lifecycle management with focus on the automotive supply industry. Despite the availability of similar studies, we selected an exploratory research strategy by three main rationales: First, manufacturing industries are highly specific in nature (Olhager 2003), findings from studies in related industries may not match well. Second, extant studies commonly regard product lifecycle management as technical system (David and Rowe 2016), and do not take the manifestation as socio-technical system into account. Third, with product lifecycle management as inherently information technology-dependent concept, research works from the past may be outdated. Following the type of the posed research question, the control over behavioral events, and the focus on a contemporary phenomenon, a case study approach (Benbasat et al. 1987; Eisenhardt 1989; Yin 2009) was chosen. According to Yin (2009, p.13), a case study represents an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" which is applicable to our research venture. Following Yin (2009), we selected a single-case study (epistemological perspective: interpretive) which is an established approach if the case is (1) typical and (2) revelatory.

During March 2015 and May 2016, we had the opportunity to gain an intensive insight in a "tier one" automotive supply enterprise ("CarSupply") developing, manufacturing, and supplying mechanical and mechatronic assemblies for automotive OEMs. In addition to this unique opportunity for access, we consider this case as typical: First, the investigated case organization exhibits a strong tradition in mechanical engineering, continuously extending its portfolio to mechatronic assemblies. Second, natively characterized by a rather medium size and local footprint, the case organization furthermore features a strong and global expansion. Third, the case organization has implemented an industry-standard four layer IT architecture for product lifecycle management. As qualitative research is often criticized (Lincoln and Guba 1989; Klein and Myers 1999; Myers 2013; Sarker et al. 2013), we pursue a transparent and rigorous approach.

As case study research strongly relies on the case context (Eisenhardt 1989; Yin 2009), characteristics of CarSupply are outlined in detail: Ranked among the top three in its market segment, CarSupply aims to differentiate products by innovation and quality from competitors. For this purpose, CarSupply develops products as well as the required production machinery. From a financial viewpoint, CarSupply features revenues larger than 2,000 million Euro and comprises more than 5,000 employees (2015). The case organization exhibits a global footprint with development and manufacturing locations in Europe, the United States, and Asia. CarSupply is embedded in an interwoven ecosystem, supplying dozens of OEMs and being supplied by hundreds of suppliers. At a higher level, case organization is embedded in one of Europe's largest industrial consortia. At a lower level, case organization is organized in four different operating units. In their daily business, product lifecycle management represents an important approach to manage their vehicle projects. From an IT perspective, CarSupply operates a PDM/PLM system from a top 5 vendor and an ERP system from a top 3 vendor which are integrated (CIMdata 2016). Thereby, a wide range of integrated tools (mainly requirements management, computer-aided design and simulation tools) serve as author systems.

3.2 Data Collection

According to the principle of triangulation (Yin 2009), multiple sources of evidence and methodologies were applied for data collection. Yet, semi-structured interviews (Eisenhardt 1989; Yin 2009) built the foundation. Overall, 21 interviews in three European development and manufacturing locations in relevant managing, operational, and supporting departments were accomplished on a face-to-face and remote basis. In line with the comprehensive scope of product lifecycle management, we included conversational partners from all relevant lifecycle stages. Thereby, the sample was compiled in an iterative manner (Lincoln and Guba 1989). In a first step, we interviewed informants with a broad overview. In the subsequent steps, with the objective to learn more about the discovered issues, we identified additional, more specialized informants. This "snowball approach" (Lewis-Beck et al. 2004; Patton 2014) was applied until additional data resulted in only minimal new information. For the data collection, we utilized a questionnaire with open questions designed along recommendations by Schultze and Avital (2011). The questionnaire included sections related to the study purpose, background of the interviewee, strategic, processual, organizational, cultural, and information technology-related aspects of CarSupply's product lifecycle management, and conclusion. During the research process, the questionnaire was iteratively refined. The interviews lasted between 31 and 123 minutes with an average of 53 minutes. In order to ensure a rigorous processing, all interviews were recorded, anonymized, and transcribed. Table 2 provides an overview on accomplished interviews.

In addition to the interviews, further sources of evidence (Yin 2009) were considered. Studying archival records (e.g., documentations and management presentations) and artifacts (e.g., software applications) illuminated the issue additionally. All collected data was transferred in a central case study database.

Department	Sub-department	Interviewee
Managing departments	Innovation and technology management	Head of innovation and technology management
	Sales and marketing	Head of sales and marketing
	Process and quality management	Head of process management
	Process and quality management	Project staff process management (a)
	Process and quality management	Project staff process management (b)
Operational departments	Product engineering	Head of mechatronics development
	Product engineering	Project engineer engineering design
	Product engineering	Project engineer simulation
	Manufacturing engineering	Head of manufacturing engineering
	Manufacturing engineering	Head of technical editing
	Manufacturing engineering	Project lead manufacturing engineering
	Manufacturing engineering	Project lead equipment procurement (a)
	Manufacturing engineering	Project lead equipment procurement (b)
	Procurement	Project staff parts procurement
	Logistics	Head of logistics
	Production	Head of production
Supporting departments	IT support	Chief information officer
	IT support	Group head of PLM and CAx projects
	IT support	Head of IT engineering
	IT support	Head of PLM application projects
	IT support	Head of CAx application support

Table 2. Overview on accomplished interviews at CarSupply

3.3 Data Analysis and Quality Assessment

Following the exploratory character of our research, we adapted grounded theory techniques (Strauss and Corbin 1990; Strauss and Corbin 1997) for data analysis. More specifically, the rationale for selecting a grounded theory approach which is well-established is information systems is put forth along three lines (Urquhart and Fernandez 2006; Jones and Noble 2007): First, inductive approaches without applying existing concepts or theories from the body of knowledge are useful for developing insights if the phenomenon of interest is novel and data-grounded, unbiased research is desired. Second, grounded theory approaches generate insights with relevance for both scholars and practitioners, and thus contribute to reducing the theory-practice gap. Third, grounded theory approaches provide a comprehensive set of techniques without referring to a specific discipline and are able to complement weaknesses of case study research in terms of data analysis.

In detail, open, axial, and selective coding procedures (Strauss and Corbin 1990; Strauss and Corbin 1997) were employed. First, during the initial open coding stage, the transcribed interviews were put into codes, categories, and subcategories beginning early and iterating during the whole research process. Second, in the subsequent axial coding stage, systematic connections between categories and subcategories were established. Third, in the final selective coding stage, core categories were selected and categories and subcategories were rearranged (Strauss and Corbin 1990; Strauss and Corbin 1997). During the coding procedures, computer-assisted qualitative data analysis software (CAQDAS) NVIVO 10 was utilized as advised by Alam (2005) and Sinkovics et al. (2005) to assure transparent and efficient data analysis. Thereby, two theoretically sensitive investigators – guided by the underlying research question und the fundamentals of product lifecycle management, but as open and impartial as possible – constantly compared the emerging codes and categories to harmonize different perspectives and to occupy a consistent view. Particularly, conceptual maps were used to support the emergence of the relationships in a graphic manner. In total, 513 open codes acted as empirical evidence. For each identified challenge in the selective coding stage, the code frequency ranged from 23 to 84 codes.

Regarding the quality assessment of grounded theory approaches, Glaser and Strauss (1967) annotate that (1) grounded theory is a method for building, not verifying and that (2) insights have been verified in a certain manner if grounded in data. To ensure quality of our research, we stuck to the guidelines for grounded theory studies in information systems as suggested by Urquhart et al. (2010). Furthermore, to cope with the interpretive character of our research, we took the concepts credibility, corroboration, and generalizability (Lincoln and Guba 1989; Klein and Myers 1999; Myers 2013) into account.

4 Results

In the case study, challenges in product lifecycle management in the automotive supply industry were identified. Table 3 provides an overview. We seek to present the most impactful aspects with a subsequent in-depth discussion. Accordingly, nine identified challenges are explained in detail and illustrated by the aid of interviewee quotations.

No.	Challenge
#1	Multiple occurrence of media breaks along the lifecycle
#2	Insufficient integration of mechanical, E/E, and software development
#3	Complex data management and collaboration with OEMs and suppliers
#4	Isolated engineering change management
#5	Heterogeneous and contrarious requirements for tool portfolio
#6	Lacking coverage of the complete lifecycle
#7	Assurance of data security and protection of intellectual property
#8	Deficient management and user commitment
#9	Missing link between product lifecycle and knowledge management

Table 3. Challenges in product lifecycle management in the automotive supply industry

4.1 Multiple Occurrence of Media Breaks along the Lifecycle

As result of the historically grown and distributed system landscapes, automotive suppliers are confronted with the multiple occurrence of media breaks along the product lifecycle. Product data are exported from system (a) and imported in system (b) which interrupts consistency ("silos"). In early lifecycle stages, a seamless transition from requirements management to engineering, simulation, and process planning rarely exists in current product lifecycle management environments. Furthermore, in later lifecycle stages, the transition from the design chain (PDM) to the supply chain (ERP) is frequently afflicted with media disruptions.

> *"Our current product lifecycle management system is a patchwork rug: We have interfaces to ERP, to a file-based equipment database, to a project management tool, to a requirements management tool, to computer-aided design applications. Our departments live in a way on "islands of bliss". The product engineering department is happy, the manufacturing engineering department is happy as well, difficulties always appear at the interfaces." (Head of mechatronics development)*

4.2 Insufficient Integration of Mechanical, E/E, and Software Development

With their traditional mechanics-oriented modus operandi, automotive suppliers face the challenge that mechanical, electric/electronic, and software development is not integrated sufficiently. Electronics and software have become the new enabler of automotive innovation with high shares of realized product functions. Whereas author systems for electrical/electronic design and software engineering were introduced and updated over time, management systems were not adapted to the required systems lifecycle management approach for mechatronic products. In this context, model-based engineering, the description by models, not by documents, is not widespread across all operational areas.

"The location for electronics and software development is a great distance off our headquarters where mechanical development is located. We started with embedded systems about five years ago and this metaphor represents very well the situation that these streams are often seen as two worlds. Although some final software versions are integrated in our central PLM application, we generally have separate IT landscapes." (Head of mechatronics development)

4.3 Complex Data Management and Collaboration with OEMs and Suppliers

Being situated in an intermediate position between OEMs and subordinate suppliers, complex data management and collaboration with those stakeholders represent an increasing obstacle for automotive suppliers. Value chains in the automotive industry become more decentralized and distributed, accordingly data and information exchange at an inter-organizational level gains importance. Despite constant efforts on harmonization and standardization between OEMs, tier one, and tier two suppliers, challenges reasoned in different processes and systems are a common issue. Frequently, not the product itself is the bottleneck, but the considerably more complex production machinery to manufacture it.

"Parallel to the machine delivery, we get 30 gigabyte of data with 30,000 CAD files from our equipment supplier. A manual integration of that data into our current PLM application would costs about two man months. Overall, our installed base encompasses more than 1,000 machines. This fact becomes even more difficult as those machines have a lifecycle with modifications, too. Internally, we call this "Ping Pong" with the equipment supplier." (Head of technical editing)

4.4 Isolated Engineering Change Management

Although development and manufacturing for high-volume quantities is a most widely standardized process, engineering changes with minor and major implications regularly impede automotive suppliers in their daily business. Drawing upon the logic of exponential growth of change and error correction costs with every passed through lifecycle stage, engineering change management represents an essential component of product lifecycle management. Conditioned by high product complexity involving different engineering disciplines and globally spread stakeholders, assessing, managing, and communicating engineering changes constitutes a major obstacle.

"Engineering changes are ok, they cannot be avoided, caused by customers, suppliers, or internal necessities. Most of our efforts focus on the optimization of regular activities, but we do not pay much attention to the handling of unscheduled events. Currently, we have two engineering change processes implemented in our PLM system which offer basic functionalities. In my opinion, engineering change management lacks in creating transparency and enabling communication." (Head of manufacturing engineering)

4.5 Heterogeneous and Contrarious Requirements for Tool Portfolio

From a tool perspective, automotive suppliers are challenged by boundary conditions such as working principles and software standards. On the one hand, working with dozens of OEMs imposing different requirements results in a redundant system landscape. On the other hand, also strategically important supplier monopolists raise similar requirements. Finally, the IT strategy department of the affiliated group pursues enhancements in terms of harmonization and simplification of the tool portfolio in their business areas and business units. Although every stakeholder has its rationale, in sum heterogeneous and contrarious requirements for the automotive suppliers' tool portfolio result.

"Currently, the IT engineering department administrates seven different CAD tools ("the tool zoo"). In my opinion, a large share of daily CAD tasks can be attended with one standardized application. One challenge is especially "the company in the company" which has its own specialties. Beyond our subsidiary, in our automotive business area [company1] has [tool1], [company2] has [tool2], and so forth. Although many discussions are ongoing, almost no synergies are leveraged." (Group head of PLM and CAx projects)

4.6 Lacking Coverage of the Complete Lifecycle

Other than indicated by the notion, existing product lifecycle management approaches in the automotive supply industry lack in covering the complete product lifecycle. Rooted in computer-based support for product development, the focus lies on the beginning-of-life stage, middle-of-life and end-of-life phases are comparably neglected. On closer examination, automotive suppliers have very limited information about the actual usage of their products once they are sold to their customers (closed-loop PLM) – conditioned by lacking technological capabilities, but also missing access to their products.

"What does our customer really need? From our manufacturer perspective, we cannot occupy the customer viewpoint. Currently, we cover this through selected reference customers and experiences from the past. But there are scarcely data that effectively show how the customer usage looks like. Our product lifecycle management stretches from requirements management to production planning. It would be very useful to see how our product are used, however we have no access to the OEMs' data." (Head of innovation and technology management)

4.7 Assurance of Data Security and Protection of Intellectual Property

With all enterprise data, information, and knowledge integrated in product lifecycle management systems, automotive suppliers are confronted with the assurance of data security and protection of intellectual property. Against the backdrop of the pervasiveness of cyber- and non-cyber-attacks across all industries, manufacturing industries are one of the most critical branches. Accordingly, data security and rights management represent core elements of product lifecycle management. Thereby, requirements for protection are imposed by customers, suppliers, and own impetus.

"Data security is a big issue in our IT engineering department. Some weeks ago, we had an IT security audit by one of our main OEMs. Their requirements rise constantly. Examples are the need for a safeguarded door locking to computer workspaces and OEM-specific employees to handle OEM-specific engineering data. But also internally, the efforts to protect our product data strongly ascend. An important factor is that we relocate our development centers closer to the emerging and – from a data security perspective – more critical end markets." (Head of IT engineering)

4.8 Deficient Management and User Commitment

Deficient management and user commitment in product lifecycle management is a common issue across departments in the automotive supply industry. Product lifecycle management is often equaled with a central repository for product data. Although the significance of human factors has been emphasized, understanding the relevance of product lifecycle management as a holistic strategy deeply entrenched into the enterprise culture and strengthened by all employees is not established across-the-board.

"Being responsible for product lifecycle management in terms of trainings and education, I learned that users experience PLM – sometimes intensified by legacy IT – more as a burden than as an assistance in their daily business. From my viewpoint, I recommend to invest – for example by the aid of trainings – in a mind-set change to manifest product lifecycle management as holistic enterprise strategy, relevant to and supported by every colleague." (Project staff process management (a))

4.9 Missing Link between Product Lifecycle and Knowledge Management

Although efforts on both product lifecycle management and knowledge management are made, automotive suppliers are challenged by missing links in-between. Researchers and practitioners agree that the ability to manage knowledge is becoming decisive in today's information age. Especially in manufacturing industries expertise has become one of the most essential assets. Yet, no sufficient alignment between the tangible product data and intangible product-related knowledge is created.

"I mostly use product data for purposes of manufacturing concept development. Sometimes it is hard to find the currently valid version and as soon as found it can be difficult to work solely with the data available because a lot of communication and know-how in the engineering process is conducted "silently". Beside the convenience factor, such product-related knowledge is lost if the employee is on holiday or even leaves the company." (Head of manufacturing engineering)

5 Discussion

The subsequent discussion is organized as follows: In a first step, we discuss general findings. In a second step, automotive supply industry-specific results are debated. In a third step, we contemplate on necessary activities to solving the identified challenges.

Regarding the first part, we structure our discussion along the established product lifecycle management framework (Eigner and Stelzer 2008; Eigner and Roubanov 2014), spanned by three dimensions. A priori, it can be observed that automotive suppliers are confronted with obstacles across all dimensions. Along the product lifecycle axis, challenges #1 ("multiple occurrence of media breaks along the lifecycle") and #6 ("lacking coverage of the complete lifecycle") are evident. Along the supply chain axis, challenge #3 ("complex data management and collaboration with OEMs and suppliers") is apparent. Along the engineering disciplines axis, challenge #2 ("insufficient integration of mechanical, E/E, and software development") is obvious. Furthermore, challenge #4 ("isolated engineering change management") may have implications on all three dimensions. Beyond, we can find information technology-related challenges (#5 "heterogeneous and contrarious requirements for tool portfolio" and #7 "assurance of data security and protection of intellectual property"). Interestingly, several challenges can be assigned to organizational culture (#8 "deficient management and user commitment" and #9 "missing link between product lifecycle and knowledge management"). This finding goes in line with David and Rowe (2015) who emphasize that research on product lifecycle management is currently dominated by technical issues and propose to understand the human and managerial dimensions.

Regarding the second part, some identified challenges are familiar from related studies (Burr et al. 2003; Tang and Qian 2008; Hewett 2010; Pulkkinen et al. 2013), whereas other unveiled obstacles are very specific for the case automotive supply industry. At a first glance, challenges #3 ("complex data management and collaboration with OEMs and suppliers") and #5 ("heterogeneous and contrarious requirements for tool portfolio") are counted among these, yet on closer inspection considerably more influences exist. To illustrate these influences, Table 4 provides a stakeholder analysis of challenges in product lifecycle management. Thereby, the identified challenges are analyzed by parties concerned. For this purpose, we adapted the manufacturing ecosystem framework by Meier et al. (2010). We can observe that many stakeholders such as OEMs and subordinate suppliers, but also the affiliated group play an essential role. In contrast, solely few challenges exist that automotive suppliers are able to address by their own efforts without involving their ecosystem stakeholders. Referring back to the underlying research question of this paper, the findings reinforce that product lifecycle management in the automotive supply industry is highly specific and constrained by several boundary conditions.

No.	Challenge	OEM	Tier One	Tier n	Group
#1	Multiple occurrence of media breaks along the lifecycle		●		
#2	Insufficient integration of mechanical, E/E, and software development		●		
#3	Complex data management and collaboration with OEMs and suppliers	●	●	●	
#4	Isolated engineering change management	●	●	●	
#5	Heterogeneous and contrarious requirements for tool portfolio	●		●	●
#6	Lacking coverage of the complete lifecycle	●	●		
#7	Assurance of data security and protection of intellectual property	●	●	●	●
#8	Deficient management and user commitment		●		
#9	Missing link between product lifecycle and knowledge management		●		

Table 4. Stakeholder analysis of challenges in product lifecycle management

Regarding the third part, it must be initially stated that modifications in such complex environments like the design and supply chain of globally operating automotive suppliers ever represent a major change which needs to be designed, evaluated, and implemented diligently. As many technological, processual, and organizational steps have to be climbed, transformations in product lifecycle management may be realized in steps as proposed by Batenburg et al. (2006). With respect to the interwoven stakeholders in the automotive industry, product lifecycle management requires joint optimization by all involved actors: From a technological viewpoint, standardization efforts as attempted in different initiatives (Rachuri et al. 2008) may act as starting point. From a non-technological perspective, organizational change management (David and Rowe 2015) represents an essential activity as well.

6 Conclusion

Over the last decades, product lifecycle management has unfolded as established approach to handle issues related to the lifecycle of industrial products. This exploratory paper reports on challenges in product lifecycle management with focus on the rising automotive supply industry. Against the backdrop of the profound digitalization in manufacturing industries, our research was initiated by lack in understanding the current, specific situation as prerequisite to provide adequate solutions. Anchored in extensive empirical evidence from a typical and revelatory case study at a global leader for mechatronic assemblies, we identified, illustrated, and discussed nine obstacles.

For scholars, our work contributes to the academic discussion on product lifecycle management in four ways: First, in all conscience, this study is the first to investigate challenges focusing on the specific characteristics of the automotive supply industry. Through unique, in-depth access, the single-case study provides essential insights on stakeholder-related aspects which notwithstanding have certain general character. More formally, Urquhart et al. (2010) distinguish grounded theory studies by (1) degree of conceptualization and (2) theory scope. Utilizing this framework, our (1) degree of conceptualization is description and our (2) theory scope is bounded context. Second, by applying the concept product lifecycle management we confirm the relevance of its social component. Hence, we reinforce the further developed understanding as socio-technical system (Bostrom and Heinen 1977; David and Rowe 2015). Third, our research work may be regarded as empirically derived research agenda. Thus, we supply scholars with ideas and directions for future work. Fourth, information systems is an interdisciplinary research domain (Webster and Watson 2002; Hevner et al. 2004) and may look into other domains. With this paper, we strive to link the field of product lifecycle management with information systems. For practitioners in manufacturing industries, the obtained insights serve as solid foundation for future decisions on product lifecycle management. As source of technical, economic, social, and environmental value (Terzi et al. 2010), our findings offer decision makers from managing, operational, and supporting departments guidance on quintessential and business critical topics.

Yet, the study at hand has restrictions. The advantages of a single-case study go hand in hand with its limitations. First, although we immersed in a typical automotive supply company, our findings are not representative. Second, despite investigator triangulation, our data analysis is interpretive in nature. Third, this study stands out due to its exploratory character which cannot ensure exhaustiveness.

The work raised potential directions for further research. In the narrower sense, validating the identified challenges using a mixed method or quantitative research design will provide more insights. To capture a broader perspective, multiple-case studies may be conducted. In addition, studying the specifics of product lifecycle management in other manufacturing industries such as the aerospace branch seems valuable. In a broader sense, it is obvious to service the identified challenges with solutions. For these activities, the work at hand can act as point of origin.

7 References

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