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Defining Archetypes of E-Collaboration for Product Development in The Automotive Industry

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DEFINING ARCHETYPES OF E-COLLABORATION FOR PRODUCT DEVELOPMENT IN THE AUTOMOTIVE INDUSTRY

Research paper

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Abstract

The automotive industry represents one of the most relevant industrial sectors of the global economy. In response to a plethora of challenges, e-collaboration for product development has become a nexus of competitive advantage in the automotive world. Since new dynamics in organizational forms on the one hand and advancements in engineering information systems on the other hand have led to increased complexity, a classification model to organize and structure the manifold manifestations seems analytically useful. Hence, the paper at hand (1) proposes, (2) describes, and (3) validates archetypes of e-collaboration for product development in the automotive industry. Anchored in (1) a structured literature review and (2) rich empirical evidence from a multiple-case study in the automotive ecosystem, we organize our research study along a well-established, two-stage research method on archetypes adopting a socio-technical systems perspective. Key findings include the archetypes (1) mechanical development-dominant, (2) software development-dominant, (3) systems engineering-oriented, and (4) non-development-focused e-collaborations for product development as basic patterns. Thereby, "importance of mechanical development" and "importance of software development" act as essential classification dimensions. Keeping the inherent limitations of the qualitative research tradition in mind, this paper offers theoretical, methodological, managerial, and cross-disciplinary contributions.

Keywords: Archetypes, Types, Classification, e-Collaboration, Product development, Product lifecycle management, Automotive industry.

1 Introduction

With a forecasted market size of 6,700 billion US-Dollar in 2030 (McKinsey & Company, 2016), the automotive industry represents one of the most relevant industrial sectors of the global economy. Fueled by digital technologies (Yoo et al., 2010; Yoo et al., 2012; Fichman et al., 2014), this economic branch is exposed to a plethora of challenges: On the one hand, non-traditional product innovations such as autonomous vehicles and business model innovations such as mobility on demand emerge. On the other hand, traditional forces on cost- and time-to-market reduction and quality enhancement remain (Ebel and Hofer, 2016). In this demanding milieu, the ability to launch innovative products in an effective and efficient manner is more pivotal than ever for today's automotive product development departments (Clark and Fujimoto, 1991; Brown and Eisenhardt, 1995; Nambisan, 2013).

In response to this competitive pressure, stakeholders in the automotive industry increasingly organize in more open, global, and collaborative forms such as customer-supplier networks, strategic alliances, and joint ventures (Chesbrough, 2003; von Hippel, 2005; Büyüközkan and Arsenyan, 2012) to enable value co-creation (Vargo et al., 2008; Lusch and Nambisan, 2015). Comprehensively conceptualized as "collaboration among individuals engaged in a common task using electronic technologies" (Kock et al., 2001, p.1), e-collaboration occupies an essential role in these decentralized product development and innovation activities. In the highly interwoven automotive ecosystems, different stakeholders ranging from original equipment manufacturers (OEMs), suppliers, and research centers of any kind collaborate in many different forms utilizing a variety of information systems (Howells, 2008; Büyüközkan and Arsenyan, 2012; Kalluri and Kodali, 2014).

Reinforced by this (1) heterogeneity of organizational forms and the (2) complexity and diversity of systems, scholars as well as practitioners are challenged by the manifold manifestations of e-collaboration for product development (Howells, 2008; Terzi al., 2010; Büyüközkan and Arsenyan, 2012). Thus, against the backdrop of understanding the phenomenon, a classification model to organize and structure these e-collaborations seems analytically useful. Although product development and e-collaboration in knowledge-intensive industries are established areas of research, little efforts have been made from a classification perspective. Moreover, a review of literature unveiled that despite this urgent need (1) automotive peculiarities, (2) the socio-technical nature, and (3) the real-world character of e-collaboration for product development are understudied. With e-collaboration understood as socio-technical system (Bostrom und Heinen, 1977; Rutkowski et al., 2002; Alter, 2008), the information systems domain seems well eligible to address this research gap.

Hence, we follow recent calls for research (Howells, 2008; Büyüközkan and Arsenyan, 2012; Nambisan, 2013; David and Rowe, 2015) and propose archetypes of e-collaboration for product development in the automotive industry. Rooted in (1) a structured literature review (vom Brocke et al., 2009) and (2) rich empirical evidence from a multiple-case study (Yin, 2003) in the automotive ecosystem, we organize our research study along the well-established research method by Greenwood and Hinings (1993). More precisely, this paper intends to tackle the following research questions:

[RQ1] *"What are potential archetypes of e-collaboration for product development in the automotive industry?"*

[RQ2] *"What are socio-technical characteristics of the proposed archetypes of e-collaboration for product development in the automotive industry?"*

[RQ3] *"How can the proposed archetypes of e-collaboration for product development in the automotive industry be leveraged for the classification of real-world cases?"*

In order to address these research questions, the study at hand is organized as follows: Section two provides an overview on the theoretical background (i.e. product lifecycle management and e-collaboration) and reviews related work. Section three introduces the applied research methodology in terms of structured literature review and case study research. Section four (1) presents the archetypes, (2) describes them with characteristics, and (3) maps them with the accomplished case studies. Section five critically discusses the findings. Lastly, section six closes the study with a summary, contributions, limitations, and avenues for further research.

2 Theoretical Background

2.1 Product lifecycle management and product development

Inspired by the biological lifecycle of organisms, lifecycle theory culminated in two climaxes (Sundin, 2009; Cao and Folan, 2012). In the 1960s, the holistic, sales-oriented perspective emerged. The sales-oriented view distinguishes the stages market development, market growth, market maturity, and market decline (Cao and Folan, 2012). Addressing the criticism that the market as unit of analysis may be too imprecise, the more fine-grained and product-individual, engineering-oriented perspective appeared in the 1970s. The engineering-oriented view proposes the segmentation into beginning-of-life (BOL), middle-of-life (MOL), and end-of-life (EOL) phases (Cao and Folan, 2012). Thereby, BOL includes product conceptualization, definition, and realization. MOL contains product usage, service, and maintenance. EOL comprises a spectrum of options from refurbishing to disposal (Terzi et al., 2010; Stark, 2015). Against this backdrop, product lifecycle management can be regarded as a comprehensive business strategy of managing a company's products all the way across their lifecycles, supported by a broad range of underlying information systems (Terzi et al., 2010; Stark, 2015).

Building on this logic, product development can be assigned to the initial stages of the product lifecycle. Broadly speaking, product development comprises “all tasks beginning with the perception of a market opportunity and ending in the production, sales, and delivery” (Ulrich and Eppinger, 2008, p.2). More precisely, paraphrasing Eigner and Roubanov (2014, p.7), product development includes “all activities and disciplines that describe the product and its production, operations, and disposal over the product lifecycle, engineering disciplines, and supply chain”. As central business process, management (e.g., Clark and Fujimoto, 1991; Brown and Eisenhardt, 1995) as well as engineering disciplines (e.g., Andreasen and Hein, 1987; Pahl and Beitz, 2007) have made fruitful contributions (Kalluri and Kodali, 2014). For this paper, two aspects should be emphasized: First, after a stepwise evolution with influences from R&D management, marketing, organization, strategy, and operations research within the last half a century, product development is nowadays conceived as IT-enabled innovation process (Nambisan, 2003). Second, in their literature review, Büyüközkan and Arsenyan (2012) highlight the collaborative, integrative, and strategic nature of product development.

2.2 e-Collaboration information systems for product development

When it comes to describing computer-supported collaboration among individuals, groups, and organizations, a vast amount of concepts can be encountered in literature. Among others, the notions computer-supported cooperative work (e.g., Kock et al., 2001), engineering collaboration (e.g., Molina et al., 2005), and e-collaboration for product development (e.g., Lefebvre et al., 2006) become evident. For the study at hand, we selected the nomenclature of e-collaboration as it fulfils several criteria: First, as powerful and fundamental concept, the umbrella term enables us to grasp the manifold manifestations of product development as demonstrated by Lefebvre et al. (2006). Second, understood as socio-technical system (Bostrom und Heinen, 1977), we are able to take both social and technical aspects into account which goes in line with our research objective. Finally, the concept is well-established in the information systems domain (Kock et al., 2001), where we ground our research in and aim to contribute to. Thereby, e-collaboration encompasses aspects of communication, cooperation, and coordination (Leimeister, 2014). In sum, e-collaboration for product development enables team members to jointly work on product-related information and to be seamlessly integrated in the development (Lefebvre et al., 2006).

Each stage of the product development process is empowered by a wide range of engineering information systems and e-collaboration tools (e.g., computer-aided design, engineering, and software engineering) (Molina et al., 2005; Li and Qiu, 2006; Eigner and Roubanov, 2014). Indicated by the diverse concepts, there exists no general consensus on tools for e-collaboration for product development. In line with Eigner and Roubanov (2014), product developers commonly operate and collaborate in five main areas: Product data management, production development, customer needs management, material sourcing, and management support. It should be accentuated that collaborative product development environments are intelligent combinations of specialized systems and may not be viewed as one singular tool (Molina et al., 2005; Li and Qiu, 2006). From an IT architecture perspective, four-layer models representing author systems, team data management, product lifecycle management backbone, and enterprise resource planning are prevalent. Thereby, e-collaboration is realized by specific collaboration tools and integrations respectively interfaces (Eigner and Roubanov, 2014). To optimize product characteristics at an early stage and to reduce resource-intensive physical prototypes, the subject model-based, virtual product development gains relevance (Eigner and Roubanov, 2014).

2.3 Related work

Upon the interdisciplinary character of the phenomenon of interest, we draw on prior research in relevant disparate research communities such as information systems, new product development, and computer science. A structured literature review (section “3.2 Literature review”) unveiled that studies addressing the interface of e-collaboration and product development in manufacturing industries, particularly studies related to classification, seem to be scarce and limited. Examples include: Bell and

Kozlowski (2002) developed a typology of virtual teams on the basis of conceptual research with the goal to derive implications for leadership. Thereby, virtual teams are initially distinguished from conventional teams (dimensions: spatial distance and communication) and then, types of virtual teams are differentiated (dimensions: member roles, boundaries, temporal distribution, and lifecycle). Gassmann and von Zedtwitz (2003) classed distinct forms of virtual team organizations for R&D projects anchored in empirical data. At that, the dimensions (1) type of innovation, (2) systemic nature of the project, (3) mode of knowledge involved, and (4) degree of resource bundling serve as basis for differentiation. Ostergaard and Summers (2009) developed a systematic classification of collaborative design activities grounded in an interdisciplinary literature review. Thereby, the design activities are classified by the dimensions (1) team composition, (2) communication, (3) distribution, (4) design approach, (5) information, and (6) nature of the problem with the superordinate objective to develop appropriate collaboration tools.

Synthesizing the extant body of literature (Kock et al., 2001; Orlikowski and Iacono, 2001; Büyüközkan and Arsenyan, 2012; Kalluri and Kodali, 2014): First, the characteristics and specificities of the automotive industry including stakeholder organization and supporting engineering information systems have not been taken into account in an adequate way. Second, the socio-technical nature of e-collaboration has been comparatively neglected, studying either pure technical or mere social aspects. Finally, extant studies frequently target narrow issues, often in a controlled setting, which seems applicable to the profoundly industry embedded phenomenon to a limited extent solely. Hereinafter, we address this research gap by a qualitative classification approach.

3 Research Methodology

3.1 Methodological foundations

The purpose of this paper is to classify the abundant forms of e-collaboration for product development in the automotive industry. In particular, we refer to the automotive business-to-business context with inter-organizational forms of e-collaboration as unit of analysis. Well-established models – "representations of how things are" (March and Smith, 1995, p.256) – to assist scholars and practitioners understand and analyze complex domains are classification models which organize objects of interest (Bailey, 1994; Nickerson et al., 2013). As common activity in sciences of any kind, even in our daily lives, the process of classification exhibits polymorphic facets. In the discourse on classification in social sciences, routinely (theoretically derived) typologies and (empirically derived) taxonomies are distinguished (Carper and Snizek, 1980; Doty and Glick, 1994). A useful approach to study organization design and change in a fundamental way with emerging interest are archetypical models which depict archetypes (Greenwood and Hinings, 1993).

In a simplified sense, archetypes may be regarded as basic patterns of organizing (Greenwood and Hinings, 1993). Following this, archetypical models are frequently regarded as antecedents of more advanced classifications. More precisely, archetypes are conceptualized as "a set of structures and systems that reflects a single interpretative scheme" (Greenwood and Hinings, 1993, p.1052). In line with Greenwood and Hinings (1993), we lay emphasis on two aspects: First, the analysis of overall patterns seems more suitable for understanding organizational structures and systems than the analysis of closely circumscribed properties. Second, these overall patterns are dependent of the underlying beliefs and values, hence, exhibit a strong interpretive character. In historical terms, archetypes are rooted in psychology literature. At a later time, the archetype concept has gained peculiar attention in strategy literature (Mintzberg, 1973; Miller and Friesen, 1978).

The selection of a research approach of this type is put forth along two lines: On the one hand, the derivation of overall patterns seems a proper method in consideration of our research objective of an initial classification. On the other hand, the proposition and validation of archetypes has been applied successfully for a variety of similar issues in contiguous scientific disciplines, such as open innovation (von Zedtwitz and Gassmann, 2002) or business model innovation (Bocken et al., 2014). Reviewing literature, several (arche-) typical models can be detected (e.g., Geiger et al., 2012; Haas et al., 2014).

However, there is no coincidence in terms of applied terminology (types, archetypes) and used methodologies (conceptual, empirical, combined methods). For the sake of scientific rigor and transparency, this study follows the well-established method introduced by Greenwood and Hinings (1993) and applied by Willner et al. (2016). In line with Greenwood and Hinings (1993), our research process encompasses two main stages:

[Stage 1] *Conceptualizing archetypes grounded on literature review and empirical evidence*
[Stage 2] *Empirically validating and iteratively refining the conceptualized archetypes*

Having formulated the proposition (Yin, 2003) that archetypes exist, we conceptualize archetypes grounded on literature review and empirical evidence in stage 1. Thereby, a structured literature review following vom Brocke et al. (2009) lays the groundwork. From an empirical viewpoint, exploratory case studies according to Yin (2003) and exploratory focus groups in line with Morgan (1988) are conducted to sensitize the conceptualization process. We neither follow a pure conceptual nor a pure empirical approach, but pursue a two-sided approach, as emphasized by Nickerson et al. (2013). In stage 2, we empirically validate and iteratively refine the conceptualized archetypes by classification of cases in an additional round of case studies and focus groups.

3.2 Literature review

Objectives and methods In order to ground our conceptual work in the body of knowledge, we performed a structured literature review following the established approach by vom Brocke et al. (2009). In addition, contributions from Cooper (1988) and Webster and Watson (2002) backed the review process from a methodological point of view. The purpose of this review is to (1) obtain an overview on related work (section “2.3 Related work”) and to (2) explore extant classifications and conceivable dimensions for the subsequent archetype conceptualization process.

Data collection Referring to Cooper’s framework (1988), our review exhibits the following boundary conditions: We focus on research outcomes. Our goal is the identification of central issues. The review findings are presented neutrally. The coverage has representative character. We target to inform general and specialized scholars as well as practitioners. Owing to the interdisciplinary nature of the review subject, the conceptualization of the topic was demanding. Hence, we carefully screened standard references and intensively discussed with senior scholars and professionals to carve out a graphic concept map. This concept map composed of synonyms, superordinate, infraordinate, and related terms ultimately resulted in the search string “(“classification” OR “taxonomy” OR “typology” OR “archetype”) AND (“product development” OR “product engineering” OR “R&D”) AND (“*collaborat*”)” which was applied for the literature key word search in major scientific databases. In brief, the rationale for the selection of this search string is based on our research objective, comprising (1) classification-related, (2) product development-related, and (3) collaboration-related constituents with manageable variation. Where available, database fields title, abstract, and key words were searched. With the objective to incorporate the most recent articles, we considered a publishing time frame from November 2001 to November 2016. In aggregate form, Table 1 illustrates the conducted literature search and results.

Publisher	Database	Net hits	Results
Association for Information Systems	AIS Electronic Library	0	0
EBSCO Information Services	EBSCOhost	228	10
Elsevier	Science Direct	15	1
Emerald	Emerald	238	3
ProQuest	ABI/INFORM Collection	215	9
Springer	SpringerLink	0	0
Thomson Reuters	Web of Science	206	12
Interim results (inclusion/exclusion)		Σ 902	Σ 35
- Duplicate removal		- 3	
- Forward/backward search		+ 12	
- Recommendations		+ 4	
Final results		Σ 48	

Table 1. Literature search and results

Data analysis To include all potentially relevant contributions and not to exclude pertinent ones in advance, a comprehensive initial search resulting in a large number of articles was conducted. Given this broad search, it was necessary to exclude a large amount of non-relevant publications during data analysis. The literature key word search initially equaled to 902 articles which were examined in a two-level approach reviewing title and abstract. On the basis of the review purpose and overarching research objective, inclusion/exclusion criteria were elaborated: Articles are included if the publication contains (1) content at the intersection of e-collaboration and product development in manufacturing industries, (2) a concrete classification, or (3) conceivable dimensions for the subsequent archetype conceptualization process. In contrast, we particularly excluded publications that (1) focalize on highly technical and mathematical issues, (2) lack in sufficient (explicit or implicit) statements, or (3) do not meet rigorous scientific requirements such as panel discussions and practice commentaries. From the remaining 35 articles we removed duplicates (3 articles), executed a forward/backward search process (12 articles), and integrated recommendations by senior scholars and skilled practitioners (4 articles). In total, the overall count of publications for in-depth full-text investigation equaled to 48 papers.

3.3 Case study research

Objectives and methods In order to ground our conceptual work in empirical data rich in content and for the purpose of triangulation (Yin, 2003), a pluralistic policy regarding data sources and collection methods was applied. More precisely, case study research following Yin (2003), Eisenhardt (1989), and Benbasat et al. (1987) complemented by focus group research following Morgan (1988), Nielsen (1997), and Tremblay et al. (2010) served as methodological guidance. 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" (Yin, 2003, p.13), which fits to the real-world phenomenon under investigation. The purpose of the qualitative research is to (1) explore potential dimensions and characteristics that may describe e-collaboration for product development for the subsequent archetype conceptualization process and to (2) identify concrete cases of e-collaboration (objects of interest) for classification and validation.

Data collection Primarily, semi-structured interviews and focus groups served as sources of evidence (Yin, 2003). As proposed by Lincoln and Guba (1989) and Coyne (1997), we applied purposeful theoretical sampling for the case organizations, focus group participants, and conversational partners. Thereby, one of the main organizational theories – stakeholder theory (Freeman, 1984; Donaldson and Preston, 1995) – acted as sensitizing device. The stakeholder model proposes that a firm has stakeholders such as investors, political groups, customers, communities, employees, trade associations, suppliers, and governments. Transferred to the research milieu of e-collaboration for automotive product development, the stakeholder model primarily includes OEMs, suppliers, research institutes, and start-ups of any kind (Sturgeon et al., 2008; Sturgeon et al., 2009). Although relationships increasingly evolve from hierarchical supply pyramids to interwoven networks, OEMs still represent the focal point as customer interface. In consideration of our research focus, we excluded non-development-related e-collaboration between stakeholders such as political groups and governments. Through a consortium research approach (Österle and Otto, 2010), we had the opportunity to study case organizations in an intensive way from an inside perspective. In addition, we had the chance to incorporate cases from automotive innovation hubs like Singapore and Silicon Valley (Ebel and Hofer, 2016).

In order to achieve an initial lucid picture, interview partners and workshop participants which held senior managerial and technical responsibilities from relevant R&D departments were selected. With the objective to understand the emerging issues better, snowball sampling (Lincoln and Guba, 1989; Coyne, 1997) was used to identify more specialized informants. These sampling strategies were applied until saturation and additional data unveiled only minimal further information. The utilized interview questionnaire was designed along recommendations by Schultze and Avital (2011), the employed guideline for the focus groups was developed along principles by Tremblay et al. (2010). Both guidelines were harnessed to explore the following e-collaboration topics: Background of the interviewee and case organization, strategic, processual, organizational, cultural, social, and information technology-related aspects. Auxiliaries were iteratively adapted over the course of the research process. In order to ensure a rigorous processing, all audio was recorded, anonymized, and transcribed. Interviews and focus groups were enriched by supplementary data (Yin, 2003) such as participation in company meetings, company presentations, and publicly available data. Qualitative and quantitative data were collected in a case study database (Yin, 2003) for subsequent analysis. Table 2 provides an overview on involved case organizations and sources of evidence.

Case organization	Description	Characteristics (HQ[1], EE[2])	Sources of evidence
OEM_{Alpha}	Traditional OEM (luxury segment)	Germany, 100,000+	2 interviews, supplementary data
OEM_{Beta}	Traditional OEM (mid-range segment)	Germany, 100,000+	2 interviews, supplementary data
OEM_{Gamma}	Non-traditional OEM (luxury segment)	United States, 1,500+	1 interview, supplementary data
$Supplier_{Alpha}$	Tier-one supplier (mechatronic modules)	Germany, 7,000+	4 interviews, 3 focus groups, suppl. data
$Supplier_{Beta}$	Tier-one supplier (mechanical modules)	Germany, 3,000+	2 interviews, 2 focus groups, suppl. data
Research $institute_{Alpha}$	Research institute (complete vehicle)	Singapore, 100+	1 interview, supplementary data
Research $institute_{Beta}$	Research institute (digital innovation)	Switzerland, 50+	2 workshops, supplementary data
$Start\text{-}up_{Alpha}$	Start-up (vehicle design and concepts)	Switzerland, 30+	1 interview, supplementary data
$Start\text{-}up_{Beta}$	Start-up (autonomous driving)	Switzerland, 10+	2 interviews, supplementary data
Car $sharing_{Alpha}$	Mobility provider (OEM-dependent)	Germany, 500+	1 interview, supplementary data
Car $sharing_{Beta}$	Mobility provider (independent)	Switzerland, 150+	1 interview, supplementary data
[1] HQ = Country of headquarters // [2] EE = Number of employees (approximate numbers of fiscal year 2015)			

Table 2. Case organizations and sources of evidence

Data analysis Congruent with the exploratory research strategy, we made use of grounded theory techniques (Strauss and Corbin, 1990; Strauss and Corbin, 1997) for data analysis. More precisely, open, axial, and selective coding procedures were performed. In the course of the open coding phase (1) the transcribed interviews were broken into codes, categories, and subcategories. During the axial coding phase (2) systematic connections between categories and subcategories were developed. Over the selective coding phase (3) core categories were chosen and categories and subcategories were reorganized (Strauss and Corbin, 1990; Strauss and Corbin, 1997). Thereby, the data analysis started as early as the first data were collected as recommended by Miles and Huberman (1994). For the coding processes, computer-assisted qualitative data analysis software (CAQDAS) NVIVO 10 was harnessed as advised by Alam (2005) and Sinkovics et al. (2005). During this systematic aggregation, several dominant themes emerged, among them "importance of mechanical development" with 322 open codes and "importance of software development" with 217 open codes.

In addition to comprehensive *ex post* validation activities (section "4.3 Empirical validation of archetypes"), ample *ex ante* efforts regarding quality assurance (Yin, 2003) were undertaken. First, we aimed to increase internal validity by comparing different sources and accomplishing cross-checks. Second, we strived to enhance external validity by involving diverse cases in terms of product portfolio and organization size. Finally, constantly seeking for scientific rigor across the whole study operations, we targeted reliability. Particularly, for investigator triangulation (Miles and Huberman, 1994), two researchers coded the data independently and discussed differences. Upon the diversity of data sources, we selected the basic measure "percent agreement" (Lombard et al., 2002) to calculate the intercoder reliability (intercoder agreement). The resulting coefficient of 78 percent seems acceptable within the frame of our exploratory research strategy (Lombard et al., 2002).

4 Archetypes of e-Collaboration for Product Development

4.1 Conceptualizing template structure and dimensions

In order to answer research question I ("What are potential archetypes of e-collaboration for product development in the automotive industry?"), we conceptualize (1) an archetype template and (2) the associated archetypes grounded on the previously introduced foundations. With the goal to make these conceptualization steps transparent and comprehensible, we stick to the guidelines for conceptual papers by Hirschheim (2008) in aspects such as presentation and structure and data analysis/interpretation/argumentation.

Apriori, we propose a two-dimensional archetype template where the archetypes are conceptualized. Such a parsimonious representation fits very well with our research objective of an initial classification and has been proven as suitable in similar research contexts (e.g., Kaufmann et al., 2000; von Zedtwitz and Gassmann, 2002; Willner et al., 2016). Regarding the dimensions of this archetype template, it became evident in various ways (Nickerson et al., 2013) that the dimensions "importance of mechanical development" and "importance of software development" are essential for classifying e-collaborations for product development in the automotive industry. The key rationale for the selection of these dimensions is put forth along the following line: On the one hand, mechanical development has represented the center in cost- and time-to-market-driven environments in the past. On the other hand, software development will become the focal area in innovation- and information technology-driven market environments in the future. In the template, the horizontal axis represents the "importance of mechanical development" and the vertical axis represents the "importance of software development", both dichotomized from low to high. Whereas a spectrum of quantitative metrics may be applicable, we decided not to apply a number-based scheme as we follow the tradition of qualitative research. Figure 1 depicts both template and herein situated archetypes.

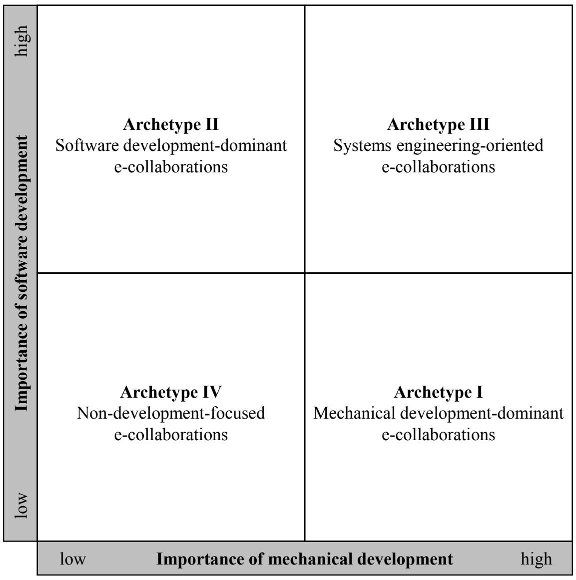

Figure 1. Towards archetypes of e-collaboration for product development

Evidence for this reasoning can be unkenneled in both approaches (Nickerson et al., 2013): First, in the literature review this argumentation is supported by Clark and Fujimoto (1991) and Ulrich and Eppinger (2008) from the mechanical development perspective and by Nambisan (2013) and Porter and Heppelmann (2014, 2015) from the software development perspective. For example, Porter and Heppelmann (2015, p.100) argue that *"at the most basic level, product development shifts from largely mechanical engineering to true interdisciplinary systems engineering."* Second, in the case study research the line of argument for the dimension "importance of mechanical development" is underpinned by 322 open codes, the line of argument for the dimension "importance of software development" is substantiated by 217 open codes. In order to illustrate these codes, we provide "thick" and context-rich data within the limited space available: *"Currently, we reorganize our supplier management and develop a group-wide supplier strategy. In the assessment process, you see this spectrum of rather traditional suppliers relying on the efficient development of physical components and rather new players leaning onto software-driven innovations – with anything in-between these extremes."* (Senior executive supplier management of OEM_{Beta}). In the introduced template, four archetypes were conceptualized which are subsequently elucidated in detail.

4.2 Conceptualizing and characterizing the archetypes

AI: Mechanical development-dominant e-collaborations Mechanical development-dominant e-collaborations are designated by a high importance of mechanical development and a low importance of software development. Illustrative examples for this archetype may be traditional OEM and tier-one supplier relationships which collaboratively design and manufacture pure physical components such as car body structures, powertrain components, or drivetrain assemblies.

AII: Software development-dominant e-collaborations Software development-dominant e-collaborations are characterized by a low importance of mechanical development and a high importance of software development. Exemplary instances for this archetype may be OEM and engineering office relationships jointly blueprinting and implementing control systems for car body, powertrain, or media applications for future vehicles.

AIII: Systems engineering-oriented e-collaborations Systems engineering-oriented e-collaborations are denoted by both – a high importance of mechanical development and software development. Exemplifying samples for this archetype may be relationships of large OEMs working together with equally powerful tier-one suppliers on highly complex mechatronic systems composed of mechanical components, electric/electronic elements, and software constituents such as digitally controllable, electro-mechanic power transmissions.

AIV: Non-development-focused e-collaborations Non-development-focused e-collaborations are described by a low importance of mechanical development and a low importance of software development. Clarifying cases for this archetype may be relationships between OEMs and market research institutes focusing on innovation management before technical realization with a generally low involvement in product development activities.

Characterization methodology With the objective to answer research question 2 ("What are socio-technical characteristics of the proposed archetypes of e-collaboration for product development in the automotive industry?"), Table 3 provides empirically derived and in literature grounded characteristics. In addition, these characteristics help to demarcate the individual archetypes more clearly as the archetype boundaries are fluent in a qualitatively described representation. In line with Greenwood and Hinings (1993), we selected set of suitable dimensions to specify the patterns. Following the understanding of e-collaboration as socio-technical system (Kock et al., 2001; Rutkowski et al., 2002), we employ the social-technical systems theory (Bostrom and Heinen, 1977; Alter, 2008) as theoretical lens. In this sense, e-collaboration encompasses a social subsystem (dimensions "people" and "structure") and a technical subsystem (dimensions "technology" and "task") which are closely interrelated (Bostrom and Heinen, 1977). The characteristics were derived from case study research and – engaging in existing theory – triangulated with literature (dimension "selected, supporting literature").

Characterization results Examining the characteristics of each archetype in terms people and structure, considerably different actors (ranging from automotive engineers to interdisciplinary roles) and divergent values, norms, and behaviors (ranging from "straight forward" to "systems-of-systems") become evident. Investigating the characteristics relating to technology and task, distinctly heterogeneous information technology (from mechanical computer-aided design tools to integrated development environments) and objectives (from cost-, time-, and quality-driven development to realization of system functions) become obvious. We did not include generally accepted characteristics of synchronous and asynchronous e-collaboration (Leimeister, 2014) as these can be found across all archetypes, but rather focus on characteristic features for the case of product development. Regarding the archetype "Non-development-focused e-collaborations", the dependency of the product lifecycle (early versus late stages) is conspicuous. An essential differentiation criterion seems related to materiality (Leonardi and Barley, 2008), distinguishing between digital and physical materiality. Empirically derived characteristics can be strengthened by discipline-specific literature such as Pahl and Beitz (2007) for "Mechanical development-dominant e-collaborations" or Porter and Heppelmann (2014) for "Systems engineering-oriented e-collaborations". In sum, the characteristics detail the proposed patterns and help delineating the archetypes from one another.

Dimensions		AI: Mechanical development-dominant e-collaborations	AII: Software development-dominant e-collaborations	AIII: Systems engineering-oriented e-collaborations	AIV: Non-development-focused e-collaborations
Social subsystem	People	Automotive engineers, mechanical engineers, manufacturing experts	Electrical engineers, computer scientists, data scientists	Interdisciplinary roles, R&D focus	Interdisciplinary roles, no R&D focus
	Structure	"Straight forward" (physical materiality)	"Agile, iterative" (digital materiality)	"Systems-of-systems" (digital and physical materiality)	Early lifecycle stages: innovation-driven culture Late lifecycle stages: efficiency-driven culture
Technical subsystem	Technology	Mechanical computer-aided design, computer aided-engineering and manufacturing tools, product data management systems	Electric/electronic computer-aided design, computer-aided software engineering tools, software management systems	Environments integrating mechanical, electric/ electronic, and software development and validation	Early lifecycle stages: office and project management tools Late lifecycle stages: enterprise resource planning tools
	Task	Cost-, time-, and quality-driven development and adaptation of products	Realization of innovative product functions	Realization of system functions incorporating adjacent systems	Early lifecycle stages: providing input for PD Late lifecycle stages: processing output of PD
Selected, supporting literature		Pahl and Beitz (2007); Ulrich and Eppinger (2008)	Broy (2006); Schäuffele and Zurawka (2013)	Porter and Heppelmann (2014); Porter and Heppelmann (2015)	Chesbrough (2003); von Hippel (2005)

Table 3. Socio-technical characteristics of archetypes of e-collaboration for product development

4.3 Empirical validation of archetypes

Validation methodology With the purpose to address research question 3 ("How can the proposed archetypes of e-collaboration for product development in the automotive industry be leveraged for the classification of real-world cases?"), a second round of case studies and focus groups was accomplished. Discussing the findings with interview partners and workshop participants which were (1) not involved in the initial evidence collection, yet (2) from the theoretically sampled case organizations (Table 2) contributed unbiased and broad perspectives for validation alike. Moreover, beyond the introduced organizations, one additional case (Engineering consultancy$_{Alpha}$, headquarters: Italy, employees: 4,000+) was added to bring in additional fresh insights. Both interviews and workshops were organized as follows: Introduction, participants' and company's background, archetype template and archetypes presentation, individual ideation, discussion, and conclusion. Beside the framework and archetypes, particularly the horizontal and vertical position of the e-collaborations of the present case organization were discussed and iteratively refined. Thereby, the advantages of interviews and focus groups in terms of flexibility and interactivity (Morgan, 1988; Yin, 2003) enabled us to scrutinize potential differences and reinforce consistencies among the estimations. This procedure contributed to an acceptable consensus regarding the horizontal and vertical positions despite the qualitative approach. In sum, a considerable amount of objects of interest was classified. Figure 2 depicts the empirical validation of archetypes of e-collaboration for product development.

Validation results Principally, the archetype approach was reinforced. The archetypical model in its current form was considered as descriptive for the automotive ecosystem. For example, Supplier coordination manager at OEM$_{Alpha}$ annotated: *"For our product lifecycle management harmonization project, we are collecting best practices from our suppliers. What we actually can see: The collaboration forms manifest in different schemes, different worlds."* Despite the inherently positive attitude, two major modifications were integrated in the course of the validation activities. First, the structure was adapted from an early four-quadrant representation in a 2x2 matrix to the current triangle representation, considered as more close to reality. In this context, Head of IT Engineering at Supplier$_{Alpha}$ brought in: *"The present dominance of mechanical or software development surfaces more clearly in such a representation. Horizontal and vertical shares of 0-100 and 0-33 percent resulting in triangles seem more adequate to express dominance than shares of 0-50 and 0-50 percent eventuating in quadrants."* Second, the horizontal and vertical position as well as the extent of the archetypes was modified. In that regard, Senior Consultant at Engineering consultancy$_{Alpha}$ reasoned: *"The spread of the archetype areas should not be equal for each archetype as systems engineering-*

oriented e-collaborations already originate with minor shares of mechanical and software development. Respectively, non-development-focused e-collaborations should occupy only little space with negligible relevance in development activities."

Essential quality criteria of classification models include that dimensions comprise (1) mutually exclusive and (2) collectively exhaustive characteristics (Bailey, 1994; Nickerson et al., 2013). Regarding the first criterion, each e-collaboration could be located in one archetype in an unambiguous way. Regarding the second criterion, the archetypical model was able to classify all e-collaborations in an entire way. Finally, we remark that the archetype template should be regarded as an initial illustrative model assisting the comprehension of the phenomenon e-collaboration.

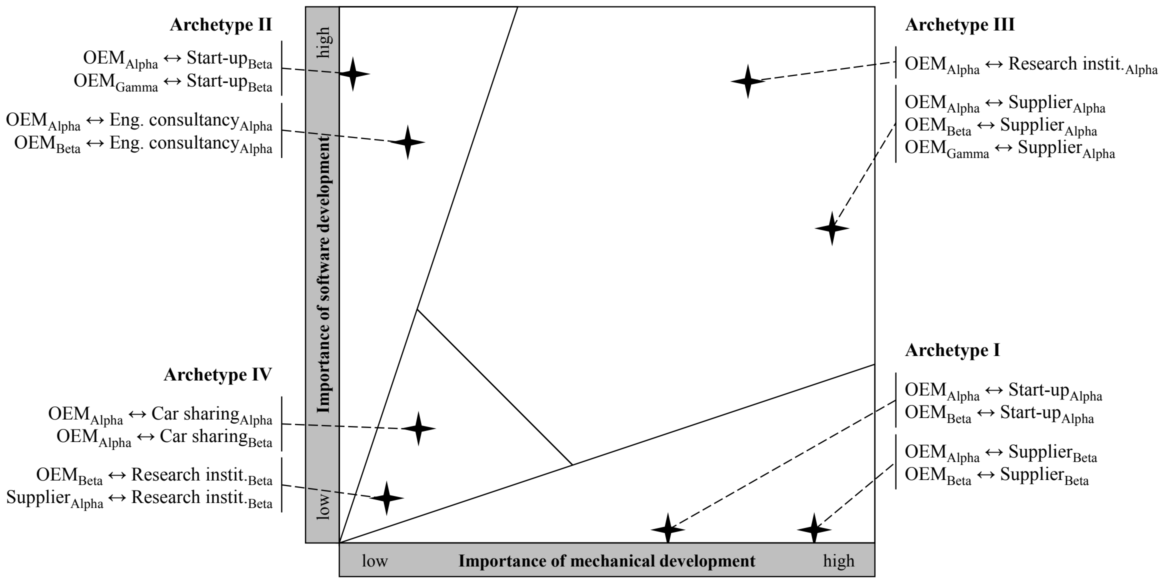

Figure 2. Empirical validation of archetypes of e-collaboration for product development

AI: Mechanical development-dominant e-collaborations In the field study, four cases of e-collaboration emerging in two clusters (cluster OEM$_{\text{Alpha}}$ ↔ Start-up$_{\text{Alpha}}$ and OEM$_{\text{Beta}}$ ↔ Start-up$_{\text{Alpha}}$; cluster OEM$_{\text{Alpha}}$ ↔ Supplier$_{\text{Beta}}$ and OEM$_{\text{Beta}}$ ↔ Supplier$_{\text{Beta}}$) matched with archetype I. Start-up$_{\text{Alpha}}$ focuses on vehicle product design and novel vehicle concepts. Being specialized on early development stages from conceptual design through to first physical prototypes, Start-up$_{\text{Alpha}}$ collaborates with major European automotive OEMs. Supplier$_{\text{Beta}}$ represents a tier-one automotive supply enterprise developing and manufacturing mechanical components and assemblies for combustion engines together with automotive OEMs in a global setting. All instances feature similar social (e.g., traditional automotive engineers) and technical (e.g., plain product data management systems) characteristics, yet minor differences in terms of collaboration complexity become visible as well.

AII: Software development-dominant e-collaborations In the empirical investigation, four cases of e-collaboration appearing in two clusters (cluster OEM$_{\text{Alpha}}$ ↔ Start-up$_{\text{Beta}}$ and OEM$_{\text{Gamma}}$ ↔ Start-up$_{\text{Beta}}$; cluster OEM$_{\text{Alpha}}$ ↔ Engineering consultancy$_{\text{Alpha}}$ and OEM$_{\text{Beta}}$ ↔ Engineering consultancy$_{\text{Alpha}}$) were in accordance with archetype II. Start-up$_{\text{Beta}}$ develops software platforms for autonomous vehicle fleets including smartphone and infrastructure applications in close collaboration with traditional and non-traditional OEMs worldwide. Key competences of Engineering consultancy$_{\text{Alpha}}$ include the development and validation of electronic control modules for a variety of automotive interior and exterior uses in conjunction with their customer OEMs. Despite different collaboration scopes, all studied forms show social (e.g., technology specialists) and technical (e.g., software management systems) characteristics at a comparable level.

AIII: Systems engineering-oriented e-collaborations In the validation stage, four cases of e-collaboration nascent in two clusters (cluster OEM$_{\text{Alpha}}$ ↔ Supplier$_{\text{Alpha}}$, OEM$_{\text{Beta}}$ ↔ Supplier$_{\text{Alpha}}$, and OEM$_{\text{Gamma}}$ ↔ Supplier$_{\text{Alpha}}$; cluster OEM$_{\text{Alpha}}$ ↔ Research institute$_{\text{Alpha}}$) corresponded with archetype

III. Similar to $Supplier_{Beta}$, $Supplier_{Alpha}$ also represents a tier-one automotive supply enterprise developing and manufacturing mechatronic assemblies for steering systems together with major traditional and non-traditional automotive OEMs at global-scale. Research $institute_{Alpha}$ aims to enhance roadways, vehicles, and public transportation in Singapore as pointer for Asian megacities. For this vision, both stakeholders Research $institute_{Alpha}$ and OEM_{Alpha} have collaboratively developed a function prototype for e-vehicles. Considering different system complexities (subsystem versus complete vehicle), comparable social (e.g., interdisciplinary nature of team members) and technical (e.g., integrated development environments) properties become ostensible.

AIV: Non-development-focused e-collaborations Lastly, in the validation phase, four cases of e-collaboration occurring in two clusters (cluster OEM_{Alpha} ↔ Car $sharing_{Alpha}$ and OEM_{Alpha} ↔ Car $sharing_{Beta}$; cluster OEM_{Beta} ↔ Research $institute_{Beta}$ and $Supplier_{Alpha}$ ↔ Research $institute_{Beta}$) met archetype IV. Both Car $sharing_{Alpha}$ and Car $sharing_{Beta}$ supply mobility services for private as well as business customers. With different levels of proximity and involvement, both stakeholders collaborate with OEM_{Alpha} regarding customer requirements for future mobility solutions. Research $institute_{Beta}$ supports manufacturing businesses (OEM_{Beta} and $Supplier_{Alpha}$) in the digital transformation and provides concepts for digital innovation for the industrial product and service business close-partnered. All e-collaborations are intensively involved in upstream (e.g., market studies) and downstream processes (e.g., marketing), but have no direct involvement in the actual development activities. The extent of social and technical properties is wide, yet common pattern can be detected.

5 Discussion

New dynamics in the automotive stakeholder ecosystem on the one hand and advancements in engineering information systems and e-collaboration tools on the other hand have led to an increased complexity of e-collaboration for product development in the global auto world. Prior research has not considered the (1) specificities of the automotive industry, (2) ties and dependencies of both social and technical subsystems, and (3) real-world mechanisms sufficiently. Adopting a socio-technical systems perspective, we conceptualized, described, and validated four archetypes. Three aspects seem particularly worthy of discussion: (1) Embedding findings in prior research, (2) debating effects owing to the archetype approach, and (3) discussing implications regarding the information systems domain.

First, the prejudice of “software development-intensive” and “mechanical development-intensive” product development relationships is widespread in the academic and practice-oriented discussion on manufacturing industries (Chu et al., 2006; Eigner and Roubanov, 2014). Grounded on a rigorous and transparent qualitative research process, we can corroborate this assumption and strengthen our initial proposition (Yin, 2003). However, findings demonstrate the subtle differences and characteristics of the classified e-collaborations within these rather approximate archetypes. Furthermore, findings indicate that the archetypes “Non-development-focused e-collaborations” and “Systems engineering-oriented e-collaborations” represent additional patterns beyond the two assumed ones. Although we solely can rely on evidence from the automotive industry, the results may be transferable to other manufacturing industries which develop innovative and knowledge-intensive products incorporating mechanical and software elements. In that regard, further research can establish clarity.

Second, archetypes are particularly suited to investigate organization design and change over time (Greenwood and Hinings, 1993). As electric/electronic elements and software constituents have become an emerging source of innovation for today’s product development departments with proportions up to 70 percent of implemented product functions (Eigner and Roubanov, 2014), the archetypes “Software development-dominant e-collaborations” and “Systems engineering-oriented e-collaborations” can be expected to gain relevance. On the one hand, with new stakeholders in the automotive innovation hubs predominantly working on software-intensive systems, new e-collaborations may be situated in the upper section of the template. On the other hand, traditional stakeholders – which increasingly evolve from the development of mechanical components to mechatronic systems – may also adopt their e-collaborations towards the upper section. Taking these aspects into account, a general vertical shift of e-collaboration for product development in the automotive industry is likely to occur. Yet, it should not be disregarded that findings also show the relevance of specific, non-software-development-involved forms of e-collaboration.

Finally, the information system discipline strives to assist managers to understand the potential of information technology with the objective to exploit its advantages at the best possible rate (Agarwal and Lucas, 2005; Chen et al., 2010). As this paper aims to contribute to this discipline, it seems valuable to discuss the role of the archetypes in the light of the design, implementation, and operations of e-collaboration. In this sense, the archetype template and archetypes support the understanding of current and the development of potential future e-collaborations. Managers can assess their actual situation and subsequently discuss and sharpen their strategic position. Referring to the selected socio-technical theoretical lens, findings demonstrate the tight connection and relevance of both social and technology-related aspects to successfully design e-collaboration. Accordingly, beside the evident technology-related implications such as information systems introduction, particularly social consequences and transformation processes such collaboration culture need to be derived. To further study the fit with the environment, contingency ("if-then") or configuration ("cause-effect") theory approaches (Meyer et al., 1993) seem well qualified.

6 Conclusion

The paper at hand presents the classification of e-collaboration for product development in the automotive industry. On the basis of (1) a structured literature review and (2) rich empirical evidence from a multiple-case study, four distinct archetypes were conceptualized, described, and validated: (1) Mechanical development-dominant, (2) software development-dominant, (3) systems engineering-oriented, and (4) non-development-focused e-collaborations for product development.

Our study offers four contributions: First – from a theoretical point of view – we identify archetypes and related characteristics and further empirically validate them. Hence, we contribute to a better understanding of the phenomenon e-collaboration in manufacturing industries. Considering the framework of Gregor (2006), classifications are equaled with "type one theories" affording analysis and description without prediction. Hence, we can specify our theoretical contribution as "theory for analysis". Second – from a methodological perspective – we transfer and apply the archetype concept in the field of information systems. Thus, we are able to strengthen the contemporary relevance of this methodological approach. Third – from a managerial point of view – we provide a useful analytical artifact for benchmarking enabling understanding and designing e-collaboration. Lastly – from a cross-disciplinary perspective – with the information systems domain being a scientific discipline at the intersection of other domains, we interlink the new product development community with the information systems discipline.

We are sensible that our research study faces limitations: One potential weakness is reasoned in the qualitative approach. On the one hand, this entails a restriction in sources of evidence and – thus – generalizability. On the other hand, this implies the referred fluent transition of archetype boundaries. Another potential limitation may arise from the snapshot approach in the dynamic automotive market environment. New momenta in the stakeholder ecosystem and advancements in information systems may lead to novel archetypes of e-collaboration in the future. Lastly, but certainly not the last constraint is raised by the non-exhaustive literature review.

Our study opens the door for several conceivable research directions: On the one hand, the introduced work may benefit from additional qualitative and quantitative research to expand, specify, and revise the archetypes and their characteristics. In this context, potential metrics and indicators to quantify the dimensions may be of value. On the other hand, from a social point of view organizational transformation processes and from a technical point of view the integration of distributed development environments seem fruitful research areas. Furthermore, e-collaborations for product development may be studied in other industrial contexts (e.g., aerospace or plant construction and engineering) to assess the generalizability of the archetypes beyond the automotive industry. We hope that our work serves as a necessary foundation for the introduced avenues.

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