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DEVELOPING COMPLEX, MASS-CUSTOMIZED PRODUCTS IN SME NETWORKS: A PROBLEM IDENTIFICATION FROM THREE PERSPECTIVES

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Abstract: *Especially for SMEs, collaborative networks are crucial to develop complex, mass-customized products as this allows for pooling several areas of expertise. However, leveraging mass customization efficiency in cross-organizational development poses challenges in manifold regards. To demonstrate the need for further research, we set up a network business process model, which has been developed with four SMEs from the German high-tech textile industry. To give a deeper insight and underpin the identified need for research, we detail the conceptual study of such network-based scenarios along our process model for the three focal areas: (1) co-creation, (2) solution space development, and (3) information systems. Particularly, our discussion focuses on a problem definition from three perspectives. We construe the need for further research and derive implications for both academia and practice.*

Key Words: ***Complexity, new product development, SME, solution space, co-creation, information systems***

1. INTRODUCTION

After decades of mass customization (MC) research, the topic has yielded results from multiple perspectives. As MC offers a strategy to provide products which are both inexpensive and customized [1], it has been researched extensively and gained heavy interest in both research and practice [2, 3]. MC research suggests several capabilities for its realization. Typically, the three capabilities of solution space development, robust process design as well as choice navigation are emphasized [4]. While solution space development refers to the capability to define the attributes which need to be customizable by the customers, robust process design denotes the capability to fulfill differentiated customer needs by reusing or recombining organizational resources. Lastly, choice navigation describes customer enabling and supporting as the customer gets a customized product [4].

Considering these well-acknowledged capabilities, their sufficiency appears questionable when looking at SMEs that aim for developing complex, mass-customized products within a network for three reasons. First, extant research mainly touches upon comparably low product complexity [5]. Second, although early studies focus on MC in SMEs [6], it does not shed light on what capabilities such MC networks require to successfully develop their complex offering. Third, research stresses barriers that hinder successful co-creation in B2B networks [7, 8].

We argue for the need of further research in this regard as current literature highlights the success of collaborative networks among SMEs [9–12]. The goal of this study is to tackle the topic of complex MC product development in an SME network. In doing so, we set up a network business process model using the Business Process Model Notation (BPMN), which has been developed with four SMEs from the German high-tech textile industry. To give a deeper insight and underpin the identified need for research, we detail the conceptual study of such network-based scenarios along our process model for three focal areas: (1) co-creation, (2) solution space development, and (3) information systems.

We advocate for the specific relevance of these areas because (1) the co-creation process is a central element to successfully develop the customized offering. Co-creation denotes the active, creative and social collaboration between providers and customers that target a joint development [13]. Considering extant MC literature, it appears that the dyad between customer and mass customizer has typically been at the heart of the research [e. g. 3]. But it appears that this dyadic consideration is insufficient when adding the network factor. A MC network increases complexity and comes with major implications for the co-creation process. Such processes distinguish external (customer side) and internal (network side) collaboration. In this regard, current B2B research is

heavily concerned with cross-organizational, joint value creation processes in B2B networks [7, 14, 15]. However, it has not focused on the MC context. Therefore, the paper at hand derives implications on a conceptual level. Similar internal coordination challenges arise with regard to determining the MC offering of the SME network: the solution space that comprises standardized and customizable product or service components. According to 16 [16], (2) defining the solution space is one of the greatest challenges for MC companies already on a single-company level. Offering customized products does not mean to offer unlimited choice, but to find the right extent of customization to meet customer demands, while ensuring that every individually defined product is actually producible [17]. For SMEs it is particularly difficult to define this customization threshold, determining standard components on the one hand and open windows for adapting the solution space continuously on the other hand. Hence, the paper at hand explores challenges for SMEs in a network to determine boundaries of the solution space for both the initial offering and its continuous adaption.

The last of the three MC capabilities is the robust process design, which can be defined as the capability of a company to reuse or combine the existing organizational and value chain resources to fulfill differentiated customer needs [4]. These robust processes pose a new complexity through their specific requirements, especially, when they are carried out in a network of SMEs. To handle these requirements, information systems are used [18]. Information systems are a kind of system, in which humans and or machines perform work along a business process using information technology among other resources to produce a specific product or service [19]. The main usage of information systems in the MC context are the customer integration for value creation and also the successful combination of manufacturing technology, information flow, and product design [20]. The paper at hand focuses on the challenges SME networks face by gaining the ability of robust process design from an (3) information systems perspective.

Particularly, our discussion focuses on a problem definition from three perspectives and derives recommendations for a future research agenda. We also derive implications for both academia and practice.

2. THEORETICAL UNDERPINNINGS

In the last three decades, the concept of MC has been subject to research from different management disciplines, such as marketing, operations management, and information systems [3, 21]. The introduction of the term MC dates back to 1987 and Stan Davis's visionary book "Future Perfect". According to 22 [22] MC is present when "the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously […] be treated individually as in the customized markets of preindustrial economies". In the early 1990s, MC has been further popularized and developed adding a more operational understanding [e. g. 1, 23]. Since the 2000s, there has been an exponential growth of research [2, 3]. Today, MC is a broadly accepted economically sustainable concept [4] to deliver affordable products, which better fit the needs of the customers than standard goods and services [24].

In the evolutionary history of manufacturing, MC is seen as the fifths contingent stage following (1) manual manufacturing, (2) manufactories, (3) industrial mass production, and (4) flexible production of many variants [27]. Depending of the context in which MC is implemented, companies move to MC from the customization side (increasing the "mass"-aspect) or from the mass production side (increasing the "customization" aspect). For previous mass producers, customization can increase costs for the complex coordination of producing and marketing goods according to diverging customer needs [29]. For previous craft producers, instead, finding ways to standardize the individual offering, is the core focus [25].

Comparing the introduction of MC in SMEs to large corporations, this reveals a number of additional challenges but also advantages for SMEs. 26 [26] highlight that the implementation of MC is "more important in small and medium enterprises than in larger ones" [26]. 28 [28] found that SMEs, besides their lack of resources [30], achieve greater success in implementing the MC approach than large companies. Thanks to their smaller sizes, SMEs have faster and more flexible processes enhancing information exchange between customer and company. Ad-hoc processes at SMEs allow being more flexible with regard to the changes in customer demand. Moreover, the closer relationship to their customers enables SMEs to establish the co-creation elements of MC [26]. However, the lack of financial resources and technical competencies [e. g. 31] are key challenges for SMEs, which hinder the successful implementation of MC.

3. RESEARCH APPROACH

3.1 BPMN & conceptual approach

In order to understand and analyze the status quo in the studied SME-network, the process of interaction along the value chain was captured on a conceptual level. To do so, the business process was recorded and modeled using BPMN, as a standard language especially at the level of domain analysis [32]. Process modeling is used to reduce the complexity of the real world and to focus the effort on the relevant part of the analyzed process. Furthermore, it provides a common base for the communication between all involved stakeholders [33]. The BPMN diagram is used to study the development of complex MC products and allows identifying the characteristics of the process from different perspectives. Therefore the graphical notation is vital to examine: (i) the interaction between different process participants, shown as messages between process-lanes, (ii) the information flow through the whole process, shown by information objects and (iii) the impact on the overall solution-space-perspective, shown by the complex interaction in the supply chain.

3.2 Field setting

The BPMN diagram was developed in cooperation with four companies of the German textile industry. This branch is characterized by small batches, niche specialization and

especially complex textile applications. The four companies are SMEs at different levels of the value chain, forming a textile network already. Their current challenge is to better manage the cross-organizational development of their mass-customized offering, which makes them particularly interesting for our purposes.

In a joint research project, the four companies collaborate with an interdisciplinary research team, aiming to develop approaches to that multi-layered task. During six workshops, the BPMN diagram was set up and discussed as a basis for future work. The main task was to detail the current process as nuanced as possible, which has been established informally in this network. Particularly, we involved the sales departments, the development departments as well as CEOs since they are also in touch with developing new offerings.

4. PROCESS OF COMPLEX PRODUCT DEVELOPMENT IN SME NETWORK

The *Figure 1* shows the entire value creation process in the SME network the paper at hand examines. The process starts with the need expression of the (end) customers and ends with the acceptance of the produced textile by the business customer. To illustrate the interaction between the various actors in the process in more detail, three stakeholder groups are presented across three different pools, not just the SME network itself. The first pool at the bottom of the diagram represents the network with two lanes, with one lane representing the company accepting the order request from the business customer (contractor) and the other lane representing the value chain forming to fulfill the order (value chain). This distinction is important because the contractor bears special responsibilities in the network and plays a steering role for the specific process iteration. The role of the contractor can be assumed by another company in the network for each order and thus for each iteration of the process. The second pool shows the business customer of the network, who is closely connected to this by the co-creational nature of the process. The third pool is the customer of this business customer, who also has to be involved to accommodate its requirements in certain cases.

The value creation process can be segmented into six subsequent phases: (1) Customer Contact, (2) Requirements Analysis, (3) Build Value Chain and Calculation, (4) Prototyping and Feedback, (5) Order and Production, and (6) Outbound Logistics and Project Closure. In the (1) Customer Contact phase the business customer contacts the contractor and the first feasibility check is performed. At this stage there are three possible outcomes: First, it is a known product and can be produced, second, it is a new or modified product that needs to be developed, or third, it is not feasible and the request is rejected and the process ends. In case that the product is known, the process shortens and moves on to phase (5) and (6), but in case the product needs to be developed, phase (2) follows next. This phase is characterized by intense communication to perform the requirements analysis with the business customer and ends with consolidated requirements. These requirements are used in the (3) Build-Value-Chain-and-Calculation-phase to check the feasibility in the network. An example for a requirement could be that the textile should be fireproof and waterproof at the same time. The contractor needs to check, if a combination of companies and their machines and services exist, which would be able to develop this fire- and waterproof textile. In case a stable network could have been built, the financial calculation can be carried out and communicated to the business customer. In the following phase (4) Prototyping and Feedback the - until now - purely conceptual prototype can be physically built. When the contractor decides that the requirements are met, in our example fire- and waterproof, the valid prototype is presented to the business customer for feedback, who possibly checks the results with his (end) customer. This phase can lead to iterations to improve the prototype further (Phase 2) or to an order (Phase 5). If the order is placed the (5) Order-and-Production-phase follows, in which the production network is build and the textile is produced. The process ends in the final phase (6) Outbound Logistics and Project Closure, where the business customer receives the textile.

5. A PROBLEM IDENTIFICATION FROM THREE PERSPECTIVES

5.1 A co-creation perspective

As one central element of developing MC products in a network, the co-creation process denotes the active, creative and social collaboration between providers and customers that target a joint development [13]. When looking at extant MC literature, it appears that typically the dyad between customer and mass customizer has been at the topic of interest [e. g. 3]. However, this dyadic consideration is arguably insufficient when a major part of the development also takes place internally in a network. A MC network increases complexity and comes with major implications for the co-creation process. Such processes distinguish external (customer side) and internal (network side) collaboration. In this regard, current B2B research is heavily concerned with cross-organizational, joint value creation processes in B2B networks [7, 14, 15]. Especially, the proper management of such processes is considered crucial for successfully developing [7, 14, 34].

However, it has not focused on the MC context with its peculiarities. Therefore, the process shown in *Figure 1* is analyzed in the following through the lens of co-creation. The center of interest is put on the first three phases described, namely (1) Customer Contact, (2) Requirements Analysis and (3) Build Value Chain. These phases are particularly interesting because the topic of co-creation is most intense during these interactions, because they serve to specify the customized offering. Looking at the (1) Customer Contact in the given context, we find manifold literature-based indications how to design the co-creation process. For instance, it is known that customers are likely to be confused when given too many options [35], or we are able to draw a fine grained picture how configurators can be used to enhance customer's perceived benefit in the customization process [36].

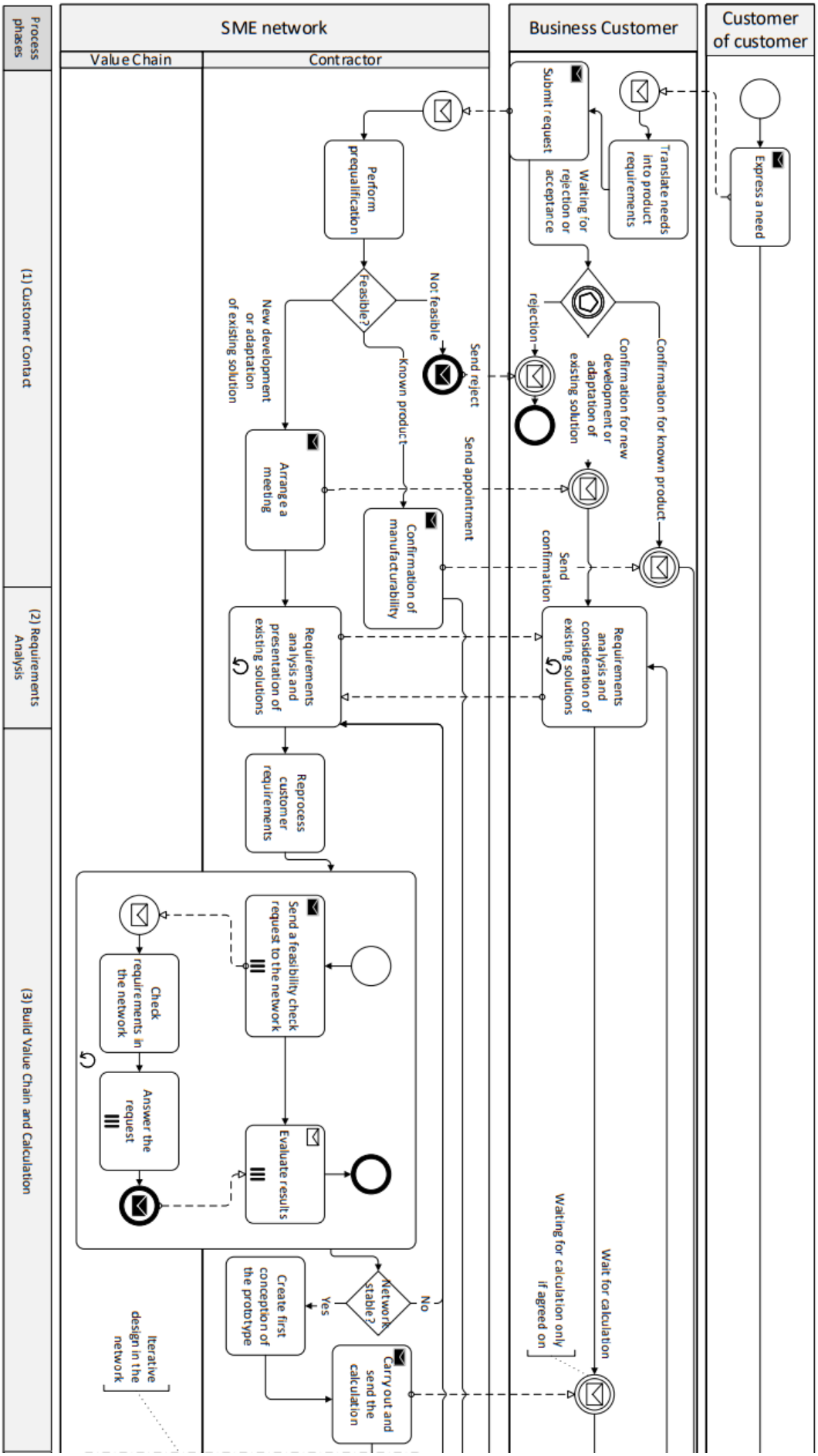

Fig. 1. *Network business process model for MC in SME*

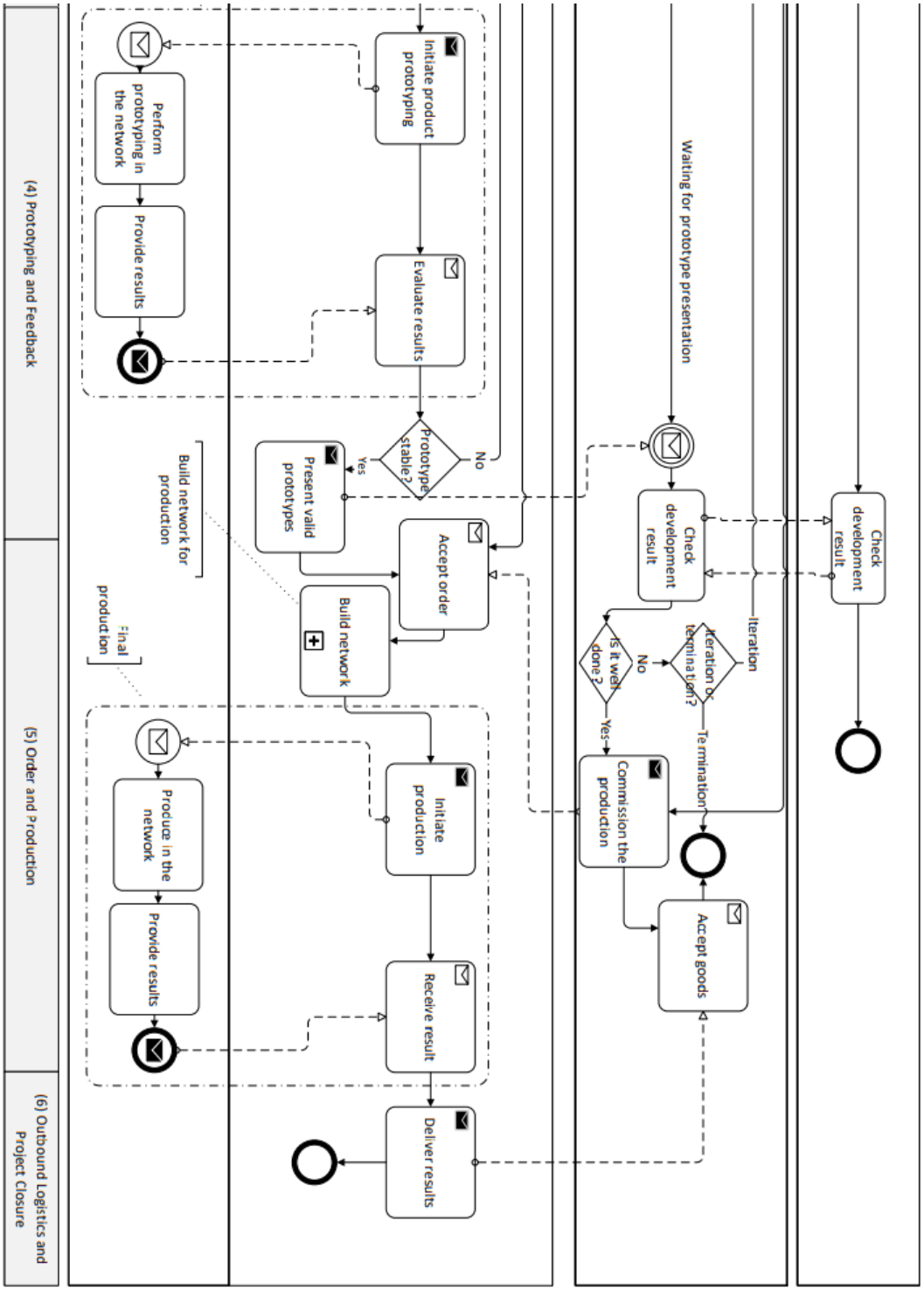

Fig. 2. *Network business process model for MC in SME (continued)*

In addition, several studies deliver precise insights of the value components unfolded by the MC offering [37, 38]. However, most of the studies in the MC area are grounded in the consumer context [3], paying far less attention to business customers [25]. We argue that the major difference regarding the co-creation process relates to its value to the customers: while consumers value enjoyment, creativity and product uniqueness, business customers buy for economic rather than emotional reasons [39]. Therefore, for redesigning the customer contact to co-create the MC offering, it is crucial to adapt to those different value components of business customers. In line with recent research from the marketing domain [40, 41], we advocate for a call for research in this regard. Moreover, we argue that these findings are likely to come with major implications for the overall process and, e. g. require adaptations of configurator designs.

The (2) Requirements Analysis with the customer is particularly challenging when product complexity is high, because it often lacks efficiency. A complex product is characterized by several customized components, a high number of components, different expertise and experts required as well as the skill needed to develop it [42]. During the requirement analysis, the customer needs to be explained product details, typically in face-to-face settings [43, 44]. Several studies stress time-consuming and costly processes [22, 43, 44],

thereby challenging one premise of MC. Therefore, for complex MC products, the customer integration into a joint requirement analysis is particularly challenging. Because of the strong need for face-to-face, configurator approaches are rather insufficient, as a high degree of offline interaction is best to face complexity [45]. These processes need to be appropriately designed, for which extant MC research does not hold sufficient results.

Moving to the phase to (3) Build Value Chain, we see the most urgent implication as extant MC research neglects the development within networks. For that, two research directions appear fruitful that we integrate with the subsequent phases of the (1) Customer Contact and the (2) Requirements Analysis, as follows. First, *Figure 1* suggests that one of the companies is in charge of managing and handling the overall process both externally with the customer and internally with the network. A deeper understanding of the co-creation process, best practices and organizational structures seems highly promising of how this leading company conciliates the interests and expertise of the different stakeholders, taking into consideration that often this company is the only stakeholder knowing all the parties involved. Second, although possibilities to use configurators seem limited during the phase of requirement analysis [e. g. 45], configurators or other toolkits are talented to facilitate the co-creation process within the network, targeting a smooth, network-internal development process. To the author's knowledge, research on such toolkit approaches is scant.

5.2 A solution space perspective

The second perspective relates to shortcomings of existing literature with regard to developing and using a solution space for mass customized offerings in a network of SMEs. Already on a single-company level, the successful implementation of MC is often hindered, because companies "lack the capability to define and set an appropriate solution space" [17]. A solution space is "the pre-existing capability and degrees of freedom built into a given manufacturer's production system" [46]. The task of developing such a solution space is "clearly a managerial decision" [47] and a prerequisite for any SME network which jointly develops an MC approach. MC literature stresses that the other two capabilities, robust process design and choice navigation, depend on the previously defined solution space [48]. Thus, also the outcome of the co-creation process with every single customer modeled in the BPMN diagram fundamentally depends on the previous definition of the solution space.

While existing literature clearly underlines the importance of solution space development, research on this core capability is very limited [49]. Thus, our call for further research on solution space development in SME networks also includes research on this capability in general. According to 49 [49], solution space development is divided into two phases, which differ according to the progress in the product development process: the initial solution space development and the adaptive solution space development.

The initial development describes the period before market launch, in which a company defines all the product and service possibilities or variations that it would like to offer at the time of its market launch [47]. The definition of the initial solution space requires great care, because the heterogeneity of customer needs produces a large range of product variations whose implementation is not economically feasible [46]. In an SME network, it is not only one company that needs to determine its offering, but several companies with several mutually dependent processes. How SMEs can be supported to jointly develop an initial solution space is not yet described in literature.

This is a difficult task, because the job of each company is not only to define what it *is able* to produce and which product characteristics work well together, but also what each company *wants* to produce. All companies in the network must *limit* the solution space and carefully determine which product variations it wishes to offer the customer. At this point, the decision is also made, which product properties remain constant as standard offers, and which can be varied according to customer needs [50]. Especially in B2C-markets, the solution space can be understood as a selection menu of options from which customers can choose to create a product according to their individual needs [51]. However, for SMEs in a B2B network with highly complex products, transferring the solution space into simple selection menus is not feasible. Instead, other forms of simplifying the representation of the solution space to the sales manager need to be developed.

The adaptive solution space development describes the period after the market launch and the competence to continuously adapt or improve an existing solution space to current customer requirements and market conditions [49]. For leveraging MC efficiency in cross-organizational development, it is important that the network does not develop a product or service offering for a new customer from scratch but instead explores whether and how the individual product can be developed based on existing product architectures and corresponding production and sales processes [27]. In a network such as a service-oriented textile network it is rather a combination of existing modular processes of the network partners than a product architecture. The BPMN diagram helps to clarify when and how the solution space development capability is needed. Already in the (1) Customer Contact phase, the first feasibility check is performed with the main aim to discover whether the desired product is within the range of the existing solution space (production is directly feasible) or at least within the scope of previously-defined spots for adaptation (production is not immediately feasible, but the solution space can be easily adapted). If the desired product is outside the scope of the solution space (and outside the previously defined area of adaption) the request must be rejected and the process ends. Also at the later stage (4), the results of the feasibility checks need to be used in the definition and adaptation of the solution space. It is important to notice that the current processes of the SME network reveals that companies focus on "known products" instead of "known feasible configuration of a solution space" (see (1)). For complex products it, thus, seems to be rather difficult for SMEs to strictly follow the solution space logic. Further research

is needed to explore barriers for consequently using the solution space logic.

Finally, solution space development always contains a market research perspective [4]. Only when a company understands the specific needs of each individual customer, it is able to develop a suitable solution space and to assess the costs and complexity of this solution space [52]. Thus, finding out what customers want and then collecting all this information to form the solution space is a continuous job of all members of an SME network. In research, recommendations for researching individual needs within a network of different value partners have not been described yet.

5.3 An information systems perspective

The third perspective focuses on the critical requirement called robust process design, which describes the capability of a company to reuse or combine the existing organizational and value chain resources to fulfill differentiated customer needs [4]. This capability can be further divided into process modularity, flexible automation and adaptive human capital.

Customer needs cannot be directly translated to process variations. (Jiao & Tseng 2004) use a domain framework to illustrate that in order to meet customer needs, a product platform provides functionality and has a corresponding process platform, which in turn provides technical feasibility for design changes through process variations. These variations can be realized by treating the value chain processes as segments, which provide variability through recombination and thus create modular processes [4]. A clear definition of valid process inputs and outputs is needed to be able to recombine these process segments. This however is problematic in value chain networks, because by providing these concise conditions for modular processes, which can be seen as interfaces between different companies, information about a company's capabilities is shared. Companies need to walk a fine line by sharing just enough information to enable modular processes within their network, while not giving away their competitive advantage by oversharing information regarding to their individual capabilities. An example would be the width of a panel of fabric which the machinery at a company can handle. The importance of standardized interfaces for process segments can be seen in *Figure 1*, where the contractor selects companies for the value chain depending on their capabilities and the individual compatibilities of the segments during the building of the value chain.

In the past automation was synonymous with rigidity, but nowadays modern technologies allow for more flexibility while still providing automation. This is realized through adaptive systems, which can react on environmental changes or accommodate for personalized experience in the case of the entertainment industry [4]. Information systems are the enablers for modern MC, because they can share information automatically or analyze data and react accordingly [18]. Their capabilities in the context of MC are vast, they can be used by both customers and companies, they provide customer decision support but also assist in pricing, design, production planning and the gathering of production process information [3]. Leveraging the possibilities of information systems is complicated by the number of participants in the value chain network. The more companies exist in the network, the more effort is required to unify the IT landscape required for information exchange. Most SME companies use different and incompatible systems, partly because they rely on individual software solutions, have lots of internal media discontinuities or even base their workflows on paper and telephones. These circumstances pose a big problem, especially during periods of higher interaction between the companies of the value chain network discussed in this paper. These interaction-intensive periods are characterized by complex communication patterns and occur in the process in the phases (3) Build Value Chain and Calculation, (4) Prototyping and Feedback and (5) Order and Production. Examples for problems emerging from the heterogeneity of employed information systems are incomplete information transfer from the requirements analysis to the production stage or inefficient communication during collaborative prototyping.

Automation has its limits though; it fortunately does not make human involvement unnecessary, on the contrary. The automated, modular processes of a well operating MC company still need humans, which need the appropriate skills to make mass customization work. [53] portrays an early successful attempt of a company leveraging mass customization by describing the approach of the National Industrial Bicycle Company of Japan. That company established a rotation of workers in order to broaden the knowledge and skill base to enable the company to develop new manufacturing capabilities for their MC approach. In our case this aspect is complicated by the field setting, where four independent companies interact to achieve competitive advantages against their competition. They serve different roles in this constellation, some are suppliers, some are service providers and some partly offer identical contributions within the value chain. A rotation of workers is not ideal for these companies because that would provide valuable insight into their individual competitive advantages - albeit it would possibly strengthen the value chain networks competitive advantage.

Looking at the ability of robust process design from an information system perspective, there are three promising research directions. (1) In order to be able to ensure modular processes in an SME network effectively and efficiently, an IT-based implementation of the value creation process and its process steps should be examined. A conceptual information model describing process and process steps with clean interfaces and input-output relationships seems to be a promising next step. (2) To be able to use automation and the associated advantages in SME networks, continuous information flows should be created. In the opinion of the authors, this can be achieved by reducing media discontinuity and increasing the general degree of digitization. As digitization progresses, large amounts of data are created in the value creation process. These provide an opportunity to conduct subsequent data analysis within the network, which leads to new research perspectives.

(3) From an information system perspective the task of involving humans into the value creation can be facilitated in many ways. Especially in the discussed highly specialized SME network which develops complex products, the knowledge transfer between employees across companies is vital. Research on IT supported concepts for sharing data, information, and knowledge in an appropriate way seems to be a promising starting point to reach an inter-organizational platform for cooperation and knowledge transfer in SME networks. Although collaboration platforms are discussed in general, to the best of the author's knowledge there is no concept to address this inter-organizational integration in the domain of MC to this extent.

6. CONCLUSION

In this paper, we derived a model that describes the current processes of an SME network that jointly targets individual need satisfaction of B2B customers. We used this descriptive model to derive key areas of MC research that need to be extended to the perspective of SME networks. Additionally, we also detected other focal points that require further attention in MC research such as highly complex products, and process-oriented companies with a solution space based on modular process instead of modular product architectures. Based on the analysis of the BPMN diagram of the SME network processes for MC offerings, we argue that there is a strong need to tackle the topic of MC networks with an interdisciplinary approach, because the three focal topics are highly interwoven.

From the co-creation perspective, we showed with the process model that there is one leading company of the network. Given that, this company is in charge of handling both the customer and the internal network. One the one hand, we argue for a study on how this company manages the MC network on an organizational level, shedding light on drivers and barriers. On the other hand, the co-creation process needs enrichment by both the solution space and information systems perspective. Especially, the leading company is likely to face challenges when co-creating the solution space, as it requires to deeply understanding the capabilities of each network party. Furthermore, we see great potential to support the co-creation processes within the network with toolkits.

Also from a solution space perspective, we argue that SME networks need to be supported with tools and methods to explore not only what their customers want, but also what they do not want. For exploiting the benefits of MC, companies need to define clear boundaries for their offerings, but also well-selected spots for continuously enabling adaptation of the solution space. Transparency about the offerings of each network partner is thus one of the core challenges for MC networks. Research should support such networks with developing guidelines in the sense of "modular construction kits". Moreover, we revealed that SMEs have difficulties in strictly following the solution space logic. Instead, the SMEs think within the frames of "known products" instead of "known configurations within a solution space". Future research needs to propose comprehensive approaches to enable SMEs to introduce the MC logic consistently.

For the information system perspective focusing on the robust process design we described three main research areas. In the first area, we advocate an IT-supported mapping of the modular processes across the entire network in order to enable an efficient process configuration of short-term value chains. In the second area we emphasized the importance of the general digitalization in the SME network to enable the companies to use automation and data analytics. Finally in the third area we argue, that an inter-organizational knowledge transfer platform addresses the challenges of developing products in highly specialized industries.

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