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MASS CUSTOMIZATION CAPABILITIES IN PRACTICE – INTRODUCING THE MASS INTO CUSTOMIZED TECH-TEXTILES IN AN SME NETWORK

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Abstract: *The German textile industry is dominated by small and medium-sized enterprises (SMEs), which are characterized by limited resources and highly specialized skills. To expand their skills, SMEs organize in business networks, working closely with other local SMEs, which complement their skill set. The development of custom technical textiles is highly complex, and the outcome depends on many input and process parameters (e.g., if a spinner changes his supplier for cotton, this impacts the processes of all firms downstream of the value chain). The textile value chain's distributed character, with each firm of a network, specialized in certain processes, adds complexity to the development and production of custom technical textiles. The coordination effort in the network is high and results in inefficient and ineffective information flow. The difficulties in coordination result in long development periods, making it difficult to compete with foreign companies. Following a case study approach, we accompany an SME network over three years as they develop, design, and implement a digital platform for collaboration on the development of custom textiles. We derived and validated implemented micro-foundations of Mass Customization capabilities for customer integration, solution space development, and robust processes. Thus, we present results on how an SME network in the textile industry leverages Mass Customization capabilities to increase efficiency via a digital collaboration platform.*

Key Words: ***Mass Customization Capabilities, Digital Platform, Collaboration, SME, Network, Technical Textiles, Product Development***

1. INTRODUCTION

As a result of globalization and the removal of trade protections, the textile industry experienced a disruption. The changes led to a decline in the sector in developed countries, while developing countries strengthened their textile industry [1]. Forced by the competitive pressure, the textile industry shifted towards value-adding production steps (e.g., design, fabric testing, or quality control) and knowledge-intense production, especially of technical textiles [2]. Today, technical textile production represents over 30% of the European textile industry output [3]. Even though the textile industry in Europe experienced a sharp decline, by shifting towards technical textiles, the traditional sector still holds an important position in the global market as the second-largest textile and apparel exporter after China [4].

Technical textiles are designed to perform specific functions (e.g., in the automotive and aerospace industry) and require research and development for highly customized solutions [5]. Technical textiles do not contain any parts or components, which makes the technical textile industry a process industry similar to the chemical and metal-processing industry, where the production knowledge is not about modular products but procedures and techniques [6].

The development and production of customized technical textiles require high coordination efforts along the textile value chain. The fragmented nature of the textile value chain, with SMEs organized in production networks, each firm performing essential production steps, makes coordination of textile production highly complex. Inefficient and ineffective coordination results in long development and production times, which weakens the competitive advantage of geographical proximity and short delivery times of European textile firms against Asian competitors.

In this paper, we focus on a production network of four textile firms producing custom technical textiles. The firms rely on an engineer-to-order approach and aim to increase their efficiency and effectiveness in coordinating their textile production. In the engineer-to-order approach, the decoupling point where the customer can intervene in the design and manufacture of individual products lies upstream in the value chain [7]. By placing the customer decoupling point in the design and development stage of the value chain, the degree of customer integration is higher, and the solution space is more open [8]. Our embedded case study presents how firms can leverage Mass Customization (MC) principles to increase the efficiency of an engineer-to-order approach.

The investigated firms introduce a collaboration platform for textile product configuration to realize IT-supported development and production of customized technical textiles. Configurators are a common approach among firms striving towards an MC-strategy [9, 10]. However, the introduction of such technology does not automatically result in a firm's ability to execute an MC-strategy. Firms need to develop specialized capabilities to align new technologies with their goal of improved efficiency. Literature provides three MC-capabilities: solution space development, robust process design, and customer integration [11]. Those capabilities are high-order capabilities [12], far away from actionable suggestions for firms. Hence, the question of which concrete and actionable capabilities do small and medium-sized textile enterprises with an engineer-to-order approach need to move towards MC-efficiency arises.

The literature highlights the integration of MC-capabilities of incumbents moving from mass production to Mass Customization [11]. However, on the other side of the continuum, we find SMEs with an engineer-to-order approach, manufacturing individual unstandardized products. In our study, we highlight the latter path towards the ideal state of Mass Customization [11] (Figure 1).

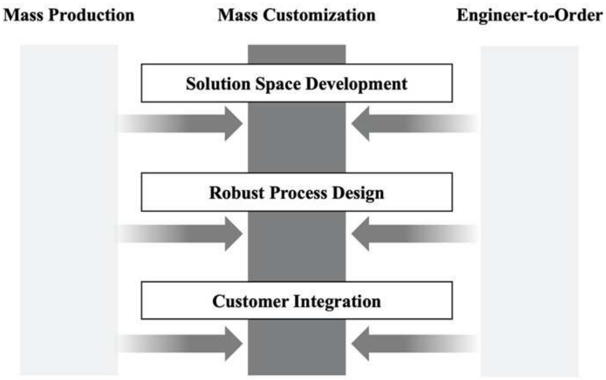

Fig. 1. *Continuum from mass production to engineer-to-order production*

We derived micro-foundations of MC-capabilities, which are closer to a firm's operational capabilities and, therefore, more actionable for firms to address our research question. Micro-foundations are defined as 'the underlying individual-level and group actions that shape strategy, organisation, and, more broadly, dynamic capabilities' [13]. In this paper, we present a framework of micro-foundations of MC-capabilities supporting the high-order MC-capabilities for business-to-business (B2B) firms. More specifically, we derived a subset of micro-foundations for networked engineer-to-order collaborations in the process industry from the real-world case of a textile network with four SMEs.

2. BACKGROUND

2.1. Mass Customization Capabilities

Mass Customization is defined as "producing goods and services to meet individual customer's needs with near mass production efficiency" [14]. However, as Salvador et al. [11] argue, Mass Customization is not a state where a firm knows each customer's needs precisely and fulfills those needs at mass production cost. Mass Customization is rather a process towards that ideal state, which is impossible to achieve [11]. However, firms can get closer to the ideal state by incorporating three core capabilities: solution space development, robust process design, and customer integration.

A firm's solution space clearly defines what product variations it offers and what it does not. Therefore, firms need to identify product attributes among which customer needs diverge significantly [11]. Addressing those heterogeneities generates the most value for customers. In contrast, expanding the solution space further by customizing attributes where customer needs do not fall too far apart, adds little value. At some point, adding more options reduces customer value. Theory suggests an inverted u-shape of product variety and customer value [15]. Hence, it is crucial not only to identify where customer needs diverge but also where customer needs are similar. Thus, a clearly defined solution space allows to address heterogeneous customer needs and improve efficiency simultaneously [8] . Understanding customer needs is a crucial part of the solution space development. As customer needs can change over time, firms need to analyze those constantly and adjust the solution space if highly heterogenous needs regarding product attributes emerge.

To deliver products within the developed solution space, firms need to integrate a robust process design. Robust process design is a firm's "capability to reuse or recombine existing organizational and value-chain resources" [11]. Implementing a flexible and modular process design is a common way to design robust processes [16]. The key is to rearrange processes in a way that allows product variation while ensuring near-mass production efficiency and reliability.

The third capability that supports a firm's efforts to achieve Mass Customization is customer integration [8, 11]. This capability refers to a firm's ability to support customers in identifying the product attributes that meet their needs. Firms need to minimize the complexity of choice, as evaluation options come with costs for customers [15]. In extreme cases, the cost of choice can outweigh the additional benefit from having that choice [17]. Therefore, companies need to carefully navigate customers' choices in a way that supports the customer toward finding their custom product.

2.2. High-order Mass Customization Capabilities and Micro-Foundations

Teece, Pisano, & Shuen [18] present a firm's overall capabilities in a hierarchical structure, where high-order dynamic capabilities are underpinned by micro-foundations, which are based on operational capabilities [19]. Operational capabilities are organizational routines and managerial skills that lay the ground for business processes and keep the business running. Micro-foundations of dynamic capabilities enable firms to adapt and adjust their operational capabilities. High-order dynamic capabilities are the strategic modification of operational capabilities to address opportunities [e.g., 18]. These high-order dynamic capabilities include competencies for sensing, seizing, and transforming, which enables the firm to be innovative and responsive to the environment [e.g., 12, 20]. Firms that frequently adapt and adjust their operational capabilities develop micro-foundations through learned patterns that ultimately enable them to build high-order dynamic capabilities [19].

Similarly, Salvador et al. [11] present three MC-capabilities that are located at a strategic level, are rather abstract and, hence, represent high-order capabilities.

Firms might find it challenging to build high-order MC-capabilities as they lack concrete guidance on how to do so. Following Teece et al. [18], we structure MC-capabilities into high-order capabilities and their micro-foundations. Thus, we aim to introduce micro-foundations of MC-capabilities, which enable firms to adapt and adjust their operational capabilities. These micro-foundations enable firms to ultimately build three high-order MC-capabilities, namely solution space development, robust process design, and customer integration.

3. RESEARCH APPROACH

We examine the micro-foundations of MC-capabilities in the context of a firm network in the German textile industry in an embedded case study. The investigated case is the network, while the firms represent the embedded units of analysis [21].

3.1. Case Description

We investigated four SMEs that are positioned at different stages of the textile value chain. Our case includes one weaving firm, one knitting firm, one textile finishing firm, and one coating firm. The weaving firm and the knitting firm produce textile fabrics using different technologies. The produced textile is then passed on to the finishing firm who cuts, washes, fixes, dries, and irons textiles. For particular uses, the textiles need additional coating; this is where the coating firm engages.

The produced textiles are not based on components or parts which can be assembled on a modular basis. Instead, the processes are reconfigured to produce a textile, which supports the notion that the firms are actors in a process industry. Due to the fragmented nature of the value chain, the firms are heavily dependent on the other firms along the value chain. The investigated firms serve business customers with technical textiles (i.e., the firms operate in a B2B context). The firms have focused on serving a niche market demanding highly complex textiles with dedicated purposes requiring custom solutions. With a deep understanding of customer needs and great experience, the firms translate the needs into customized textile solutions. The firms engage in textile sampling and research and development activities if the customers need cannot be met by existing textiles in the market.

Customers value the firms' flexibility, reliability, speed, and geographical proximity. As the firms follow an engineer-to-order approach, customer requirements present a key resource, which enables the firms to develop and provide their products. The requirements also enable the firms to expand their repertoire of existing solutions, which can then be offered to other customers. This is a typical pattern for the engineer-to-order production approach, where the solution space is not fixed and evolves with each new customer instead. In this setting, the companies have decided to establish a digital collaboration platform based on MC-principles [22].

The collaboration platform implemented by the production network allows the firms to exchange information on production configurations, including customer requirements and production configuration (who is doing what to produce the textile) along the textile value chain. The platform offers various functions for this purpose. The existing knowledge about feasible products is available in the network in a standardized digital form and serves as a knowledge database. For this purpose, valid product developments are broken down into configurations at the production process level and are stored in the platform. Furthermore, the storage of valid solutions and the corresponding process steps allow the firms to re-produce valid textile solutions quickly by reusing the stored process steps.

The stored combination of process steps successfully carried out for the production of a textile can be used for textile development by re-configuration of existing solutions and also serves as a basis for recommendations for the development of new textiles. The use of the collaboration platform enables the firms to take a step towards Mass Customization and standardization in the area of complex engineer-to-order products in process industry (i.e., there is no component-based product platform and no product modules). Hence, process modularity reduces the complexity of the production of technical textiles.

The digital collaboration platform consists of four essential components: knowledge base, process configuration component, analytics component, and overarching platform that provides the components [22, 23]. The configuration via the platform is multi-level. First, a request for product development in the network is created using a requirement-based configuration. The network can then be configured (which partners are involved in a specific product development). Finally, the production process is configured (which production steps are carried out on which machines with which parameters by which company).

3.2. Data Collection and Analysis

To identify micro-foundations of MC-capabilities, we collected data from various sources. First, we searched the field and gathered information from existing product configurators. In a second step, we conducted ten semi-structured interviews with textile industry firms using product configurators and with developers of product configurators. We integrated the results from the field analysis into the expert interviews in order to validate the findings. We conducted a literature review to triangulate our results [24].

Identifying the micro-foundations of MC-capabilities, we followed an iterative approach. First, we analyzed the field data on product configurators. The analysis derived mainly micro-foundations of MC-capabilities for customer integration and solution space development. The expert interviews added valuable insights into robust processes underlying the micro-foundations of MC-capabilities. In the first iteration, we were able to identify 46 micro-foundations of MC-capabilities. Conducting interviews, we not only amained to derive additional micro-foundations from textile industry experts but also to validate the micro-foundations identified in the field study. In a second iteration, comparing interview data and field data, we dropped 26 micro-foundations as those were not suited for the B2B-context. Of the remaining twenty micro-foundations, nine have been implemented in the digital collaboration platform in our case setting. We will present the overall structure of the developed framework for the B2B-context and the nine implemented micro-foundations in detail.

4. RESULTS

4.1. The Mass Customization Micro-Foundation Framework for the Textile Industry

In this section, we present an overview and structure of the validated twenty micro-foundations of MC-capabilities for the textile industry. We identified three overarching themes (numbered I.-III.) structuring four micro-foundations (numbered 1-4) of the high-order MC-capability solution space development. Developing a solution space customer heterogeneity plays an important role and includes the analysis of past configurations, which enables firms to identify and account for customer heterogeneities. The solution space architecture determines how the solution is built. The third theme of solution space development is the solution space strategy, which determines how and under what circumstances a firm adjusts its solution space.

For the robust process design, we identified four themes (numbered IV-VII) structuring seven micro-foundations (5-11). Robust process design needs a flexible production system to enable the developed solution space. Many firms rely on modularity for robust process design. The concept of robust process design includes the postponement of customization to late production stages and modular processes, which can be reconfigured. Information processing presents an important theme for robust process design, as well as the integration of network partners.

We identified four themes (numbered VIII-XI) structuring nine micro-foundations (numbered 12-20). Capturing customer need presents a crucial step of customer integration, followed by matching the captured need to a product configuration. Furthermore, firms support customers in evaluating the product configuration. Firms also often support customers configuring products with help-functions and pre-configurations to find a product the fits their needs. Figure 2 illustrates the MC-micro-foundation framework.

4.2. Micro-Foundations in Practice

The firms of our case study identified nine micro-foundations as suited for the purpose to efficiently and effectively collaborate on developing and producing custom textiles. We present the validated micro-foundations and show how those correspond to features in the collaboration platform.

The production of textile products is complex, as it involves several firms, each performing a specific task along the value chain. Hence, the solution space of a textile depends on the limits of each of the firms involved. Configuring textiles in the early stages of the value chain allows for maximal variety. In contrast, in the late stages, the configuration is limited by the attributes set by the previous production processes. To provide customers with custom textiles that fit their needs, firms should be aware of the limits of firms upstream and downstream the value chain. The collaboration platform integrates the solution space of the partners, enabling users to configure textiles considering the solution space along the value chain. Three micro-foundations were found suitable to define the solution space of the textile production network: solution space layers, analysis of past configurations, and continuous adaption of solution space.

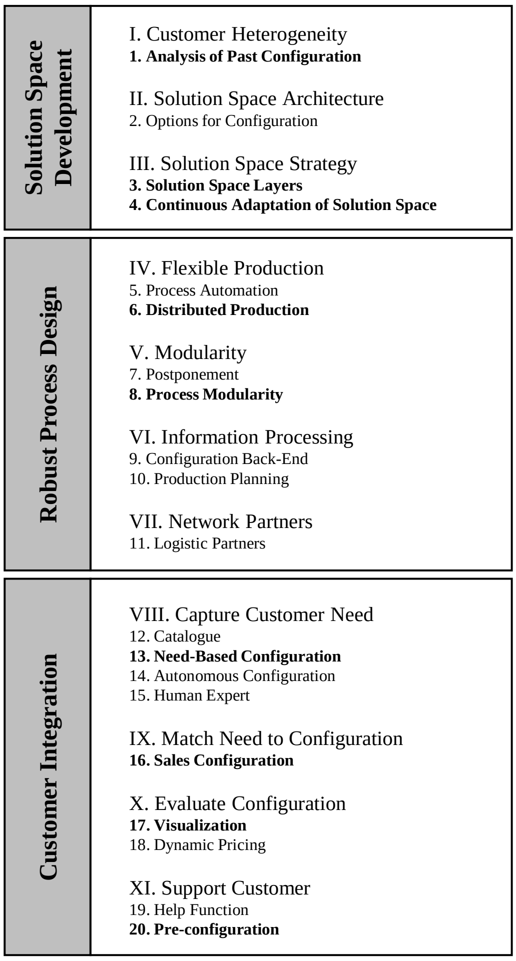

Fig. 2. *Overview of the Mass Customization micro-foundation framework (implemented and validated micro-foundations highlighted)*

Defining different *solution space* layers allows firms to vary the degree of customization. In our case, we identified four solution space layers in the platform. In the first layer, customers can choose from existing textile configurations. Those products can be easily produced, as the production parameters (i.e., inputs, machine setting) are known, and do not require textile sampling. The second layer also allows customers to choose from existing configurations but request simple changes (e.g., thickness of the textile, color of the textile). Simple changes can be implemented with little effort. In the third layer, customers can freely configure textiles within the solution space. The firms engage in textile sampling to find a suitable solution and deliver the product. If the samples do not satisfy, the firm and the customer can decide to engage in research and development activities to perfectly meet the customer's needs, which is the fourth layer of the solution space.

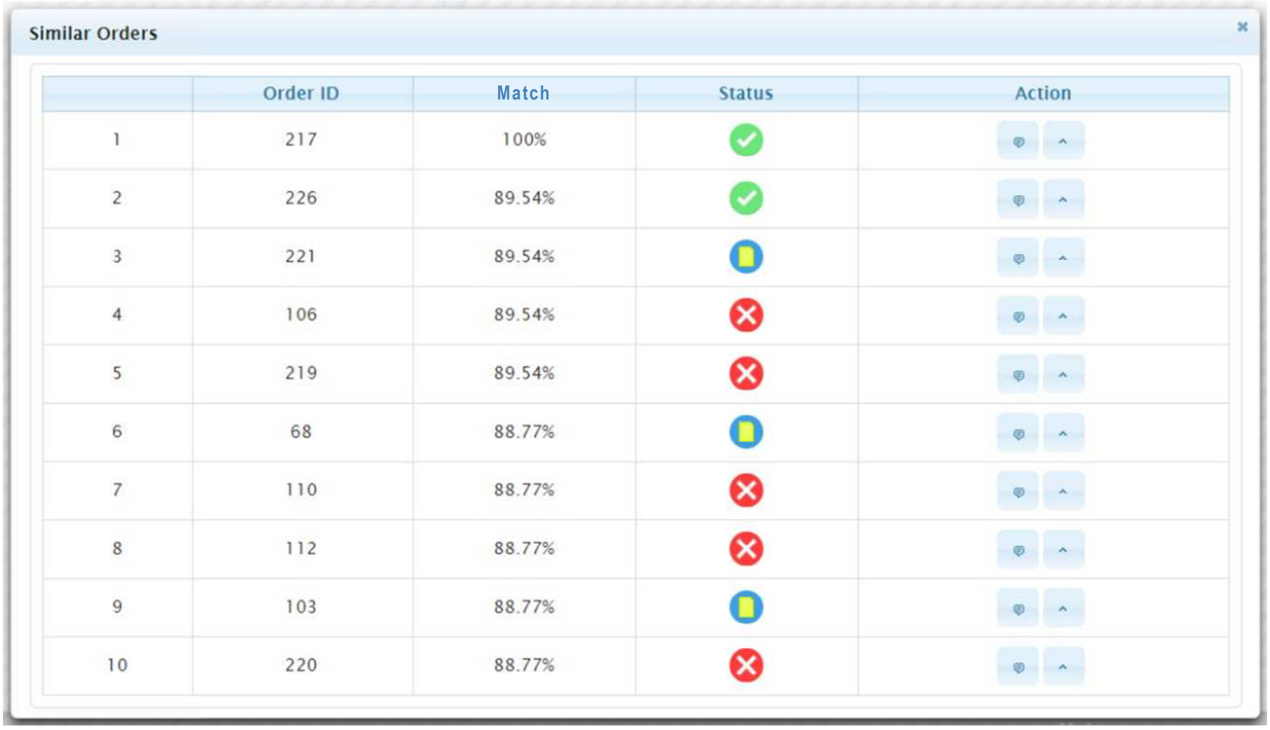

Fig. 3. *Analysis of past configurations on the collaboration platform*

The *analysis of past configurations* is found a micro-foundation of solution space development among mass customization firms. Firms analyze past configuration to understand customer needs better. Past configurations can provide favored configurations, which can be used as pre-configurations. Pre-configurations that meet many customers' needs are beneficial for customers and firms alike. Customers save time configuring a product. The firms benefit from economies of scale since the pre-configurations will be ordered more often as they meet many customers' needs. They can pass on the cost savings to the customers, which will make the product cheaper and even more attractive compared to going through a configuration process. Besides deriving pre-configurations from past configurations, the platform implements a matching algorithm. Users can configure a textile, but instead of requesting a custom product, they can request to compare their configuration with existing solutions. The algorithm lists past configurations similar to their request with information on the degree of similarity and where the differences are (Figure 3). In the "Status" column, the platform shows whether the development has been successfully completed (check symbol), is still being processed (form symbol) or has been aborted (X symbol). The "Status" and "Match" column help firms to estimate whether the feasibility of the new configuration is high (high similarity to successfully completed textile developments) or low (high similarity to failed textile developments).

Successful providers of custom products limit their solution space to reduce complexity. At the same time, they *continuously adapt their solution space* to changing customer needs. Those changes can be seasonal or follow long term trends. A long-term trend in the German textile industry is the focus on technical textiles as opposed to home and apparel textiles. The firms in our case study follow this trend. They constantly evaluate whether they need to adjust their solution space to emerging needs in the textile industry. Those considerations often take place when customers' needs cannot be met using existing resources. The limitations can be due to machine specifications or due to limited knowledge. Knowledge is regularly expanded through research and development activities, which constantly enlarges the solution space and feeds the platform with pre-configured products. Solution space limits based on machine specifications can be adjusted within the platform by the firms through an administration mechanism.

The investigated production network possesses capabilities to ensure a robust process design. The developed collaboration platform supports a robust process design by integrating distributed production and process modularity.

Distributed production – also known as cloud producing or local manufacturing – is a way to decentralize production by utilizing production resources that are geographically spread and coordinated through IT solutions. The firms of this case study rely on distributed production as each firm performs one step along the value chain. Even though each firm's production step is essential, none of the steps alone is sufficient to produce an entire textile. The platform enables the firms to coordinate their production and development of custom textiles in an integrated system.

Process modularity enables firms to reconfigure their processes to meet customer needs [25] and is established in the production of custom products. The firms of our case study make use of process modularity. The finishing firm's production line is conceptualized in a way that single process steps can effortlessly be skipped. If necessary and economically reasonable, the finishing firm temporally adjusts the production line beyond simply skipping process steps. Similarly, the coating firm can flexibly configure single production processes.

Furthermore, the network itself is a modular value chain, with each firm being a process stage and thus a link in the chain. The production of textiles does not necessarily involve every firm of the network. Hence, the firm's processes can be organized to meet the customers' needs.

Customer requirements constitute a key resource for the investigated firms. To capture the requirements, firms need to integrate the customer. Customer integration is enabled by the configuration front-end of the collaboration platform. The platform implements four micro-foundation of customer integration: need-based configuration, sales configuration, pre-configuration, and visualization.

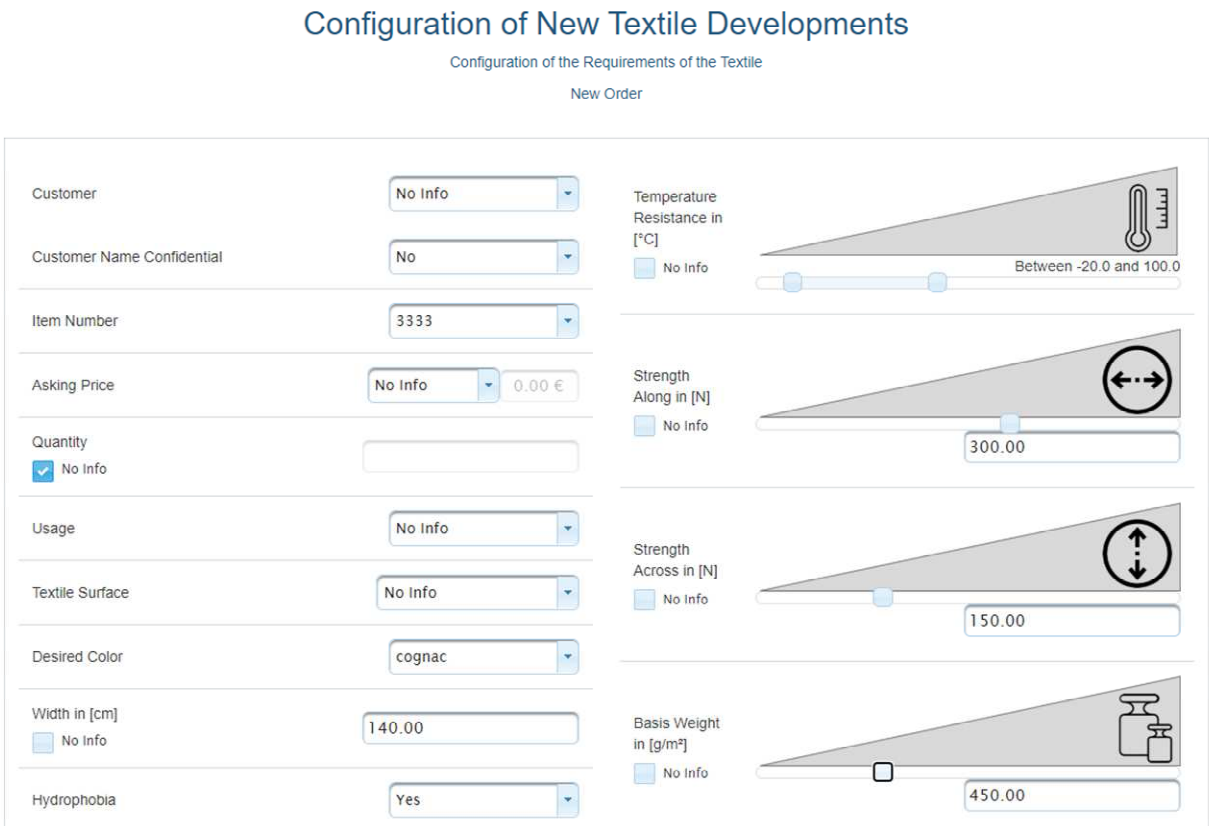

Fig. 4. *Need-based configuration on the collaboration platform*

A *need-based configuration* is an approach where customers are asked to state their needs, preferences, and expected outcomes, i.e., the textile's intended use, the characteristics the textile must have (e.g., waterproof, scratch-resistant). The need-based configuration is opposed to a parameter-based configuration, where customers are asked to state specific input parameters. The configurator implemented by the textile production network does not ask the customer to choose a yarn, a finishing chemical, and a coating, but rather asks what requirements the textile needs to fulfill (cf. Figure 4).

In B2C-contexts, we often find web-configurators for fast-moving consumer goods (e.g., food, cosmetics). Those configurators are operated by the customer to create their desired product and order it directly via the website. For highly complex products, where specific know-how is necessary to operate the configurator, *sales configuration* is a common approach. In a sales configuration, a sales employee is operating the configurator to capture the customers' requirements. Configuring textiles is highly complex. Therefore, the primary use of the configurator is the sales configuration. However, firms can give access to the configurator to knowledgeable customers.

Pre-configuration is a thriving practice for integrating customers. Instead of starting from scratch, customers are offered pre-configured products, which they can adjust to their needs. In the investigated case, the firms add configured textiles continuously to the collaboration platform contributing to a growing base of pre-configurations. Users of the configurator (customers or sales employees) can access the order history to re-order products or use past products as pre-configurations, which they can adjust to their specific needs.

The *visualization* of configured products is an established practice for consumer goods. Visualizing configured textiles, however, is rather difficult and often does not add essential value. Finishing a textile, for example, does not change its visual appearance. However, it is possible to visualize some key features of the textile to show these important characteristics at a glance and for easy comparison. Figure 5 illustrates how the visualization of the textile configuration is now realized in the collaboration platform. The cake chart indicates to what extent each listed feature is pronounced; the bigger the cake piece, the more the characteristic is pronounced. The cake chart in Figure 5 presents a thin (yellow piece), medium weight (green piece) textile with a medium strength crosswise (dark blue piece), and a high strength lengthwise (orange piece).

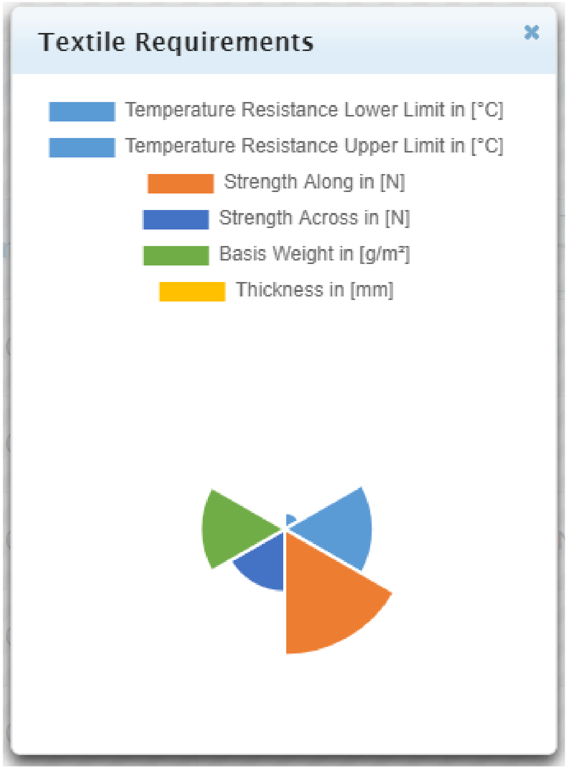

Fig. 5. *Visualization of the textile configuration on the collaboration platform*

5. DISCUSSION

The Mass Customization literature provides high-order MC-capabilities, which are necessary for a firm's success in pursuing an MC-strategy [11]. However, those capabilities are rather abstract and especially for SMEs with limited time and resources difficult to grasp [26]. Following the capability hierarchy of Teece et al. [18], we derived micro-foundations which provide actionable guidance for textile SMEs on how to build high-order MC-capabilities (i.e., solution space development, robust process design, and customer integration). Our study contributes to the Mass Customization literature by introducing an integrated framework of micro-foundation of high-order MC-capabilities. Our research fills a gap between the high-order MC-capabilities of firms [11] and operational capabilities that managers in Mass Customization firms need to have [27]. An example of this interconnection of the hierarchical MC-capabilities may be as follows: At a high order, firms need the capability of robust process design, as micro-foundation they may rely on distributed production, and their employees, therefore, need negotiation capabilities at an operational level [27] to coordinate distributed production between companies efficiently.

In our case study, the firms put nine micro-foundations into practice by integrating them into the digital collaboration platform. Hence, our study provides a set of nine validated micro-foundations of MC-capabilities. We contribute to the literature by highlighting the path of SMEs in fragmented process industries with an engineer-to-order approach moving towards an MC-approach (Figure 1).

At the same time, the validated micro-foundations can be applied in practice, as they can serve textile networks striving for MC-efficiency to develop high-order MC-capabilities. Furthermore, the nine validated micro-foundations can also be transferred to other process industries (e.g., chemical and metal-processing industry) following an engineer-to-order approach. The overall framework can be used to identify additional suitable micro-foundations for other B2B-contexts. The actionable micro-foundations can help firms to develop high-order MC-capabilities.

Our study is not free of limitations. We present micro-foundations of MC-capabilities based on a single case study. The transferability of the micro-foundations to other industries is therefore not necessarily given. By carefully mapping out the characteristics of our case (i.e., engineer-to-order approach, SMEs, fragmented network production, process industry), we defined the borders of the transferability of our results. However, we aim – and also encourage other researchers – to empirically validate the overall micro-foundation framework.

6. CONCLUSION

In our case study, we present a framework structuring the micro-foundations of MC-capabilities. More specifically, we presented nine validated micro-foundations in detail, which provide fragmented process industries with an engineer-to-order approach with actionable insights on how to leverage MC-principles and develop high-order MC-capabilities. The firms of our case study developed a collaboration platform for textile product configuration entailing the nine presented micro-foundations. The collaboration platform and the implemented micro-foundations helped the firms to break down their complex processes and define their solution space. Furthermore, the customer integration is standardized using the developed platform, and customer requirements can be shared along the textile value chain. Overall, the developed platform allows the firms to exchange information on product development and production more efficiently and more effectively in the production network. By developing MC-capabilities through the implementation of micro-foundations, the firms were able to leverage MC-principles to introduce efficiency into an engineer-to-order approach for custom textiles. The use of the digital collaboration platform reduces development and production times, a crucial competitive advantage in the textile industry [28]. Hence, the micro-foundations of MC-capabilities embedded in the digital collaboration platform strengthen the firms' competitive advantage and ensures their survival.

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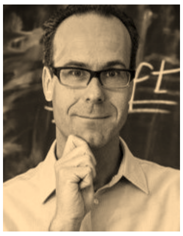

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