



A Framework for Solution Space Development in Mass Customization

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Abstract. A critical success factor in mass customization is offering the right level of variety. However, solution space development as one of the three core capabilities for mass customization is often overlooked and under-researched in current literature. This is surprising, as the solution space design is a critical factor in developing products and services, combining the customer requirements in the external marketplace with the capacities of the internal production system. Motivated by the gap in existing research, this paper presents a holistic framework, aiming to encompass the critical steps required to develop a dynamic, smart solution space. The framework aims to increase the understanding of how solution space decisions should be managed, emphasizing that these decisions must carefully balance different, often opposing, considerations. The framework establishes two central axes for the companies to manage: the dichotomy of front-end and back-end focus, and the role of switching between learning (understanding) and doing (developing). Combined, these axes create a cyclical development process comprised of four modules: Outlook, Insight, Develop, and Co-create. Each module is presented with accompanying core questions, obstacles, opportunities, and tools.

Keywords: Mass customization · Solution space · Framework

1 Introduction

Mass customization is a business strategy that combines the benefits of custom-made products with the efficiency of mass production [1, 2]. One of the three core capabilities for mass customization is solution space development [3], which is the process of managing the range of products and services offered to customers. Salvador et al. [3] describe solution space development as the capability to learn about customers' idiosyncratic needs in order to define customizable and standardized attributes. This capability enables companies to balance diverging customer requirements with efficiency and economies of scale [4]. Developing the solution space is a complex process that requires balancing different, often opposing, considerations. Therefore, a framework for solution space development is needed to provide a structured approach to creating and managing a dynamic solution space.

Despite its importance, solution space development has been overlooked and understudied within research, and few tools and methodologies exist [5, 6]. There is a lack of knowledge on evaluating and developing a dynamic solution space [7]. This paper addresses this literature gap by presenting a holistic framework for solution space development.

The overall research question guiding this study is: *what are the main elements in a framework for solution space development in mass customization?* Investigating what the processes of solutions space development mean in practice for companies has been a goal for this research. The main contribution of this paper is a holistic framework for solution space development, describing *what* the main elements of solution space development processes are and *how* solution space decisions should be managed. The study's findings show that companies can benefit from a structured approach to solution space development. The framework can support companies in balancing a range of decisions needed when developing a dynamic, smart solution space.

2 Theoretical Background: Solution Space Development

Mass customization is defined as the technologies and systems to deliver “goods and services that meet individual customer needs with near mass production efficiency” [2]. Three core capabilities for performing mass customization have been identified: robust process design, choice navigation, and solution space development. The first two capabilities have received much attention within the literature. However, there has been less attention to developing the solution space of a company [7]. Solution space development aims at answering what the firm will offer to its customers—and what it will not. It links the front-end (customers) with the back-office process of manufacturing [7].

There is a lack of awareness and methodical development for creating and maintaining a dynamic solution space [8, 9]. Some studies [6, 10] have addressed the design challenges associated with product development in mass customization, but there are few models to analyze an existing solution space. A solution space should easily adapt to the current customer demand and still be economically sound for the company to produce. Existing research has primarily focused on technical methodologies for product modularization (e.g., [11]). Kumar [5] has formulated criteria for module-based product development within mass customization but does not consider whether the solution space is in sync with what customers actually demand. There is also a lack of knowledge on evaluating and developing a dynamic solution space [7]. A key challenge is identifying how companies can systematically gather, analyze, and utilize customer data to adapt their solution space. A notable exception is a recent study of solution space, separating between *continuous solution space* as a knowledge-based approach and the *discrete solution space* as a rule-based approach to customization [12].

Close collaboration with customers is vital in solution space development. Customer-centricity, co-creation, and open innovation [13] provide valuable avenues to guide solution space development. Salvador et al. [3] pointed to three valuable tools: innovation tool kits, virtual concept testing, and customer experience intelligence.

3 Methodology

The purpose of the research has been to develop a framework for solution space development seen from a practitioner’s perspective. The research methodology has followed three main steps: a literature study on solution space development, conceptual framework development, and interaction with the practice field for verification. The framework development followed the approach of Meredith [14], with multiple iterations and cycles with description, explanation, and testing, both with industry practitioners and fellow colleagues. The framework aims to develop an understanding of the process steps, tools, and considerations needed for companies to develop their solutions space.

The study is part of four-year research and innovation addressing solution space design in collaboration with the Norwegian Mass Customization Cluster. Five manufacturing companies are part of the research project, all delivering customized products for domestic and international markets. The case companies all share the crucial challenge of managing their solution space.

4 Results: The Framework for Solution Space Development

A crucial role of solution space development is linking customer requirements (*front-end*) with the capabilities of the production system (*back-end*). Developing the solution space involves a shift between two different modes of operating: learning and creating. *Learning* involves a better understanding of customer preferences and internal capabilities. *Creating* involves an in-house product development process and collaboration with customers and partners. The framework for solution space development is built upon these two axes. Combining these axes, we have developed a framework addressing each combination into the following four modules: Outlook, Insight, Develop, and Co-create, as shown in Fig. 1.

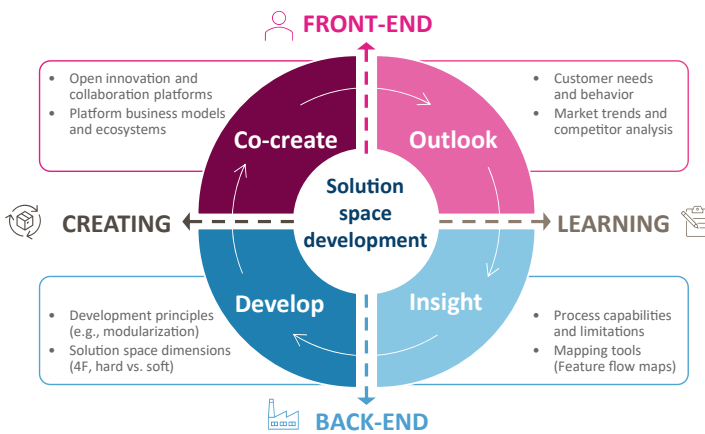


Fig. 1. Framework for solution space development.

Two of the modules are directed toward learning. The *Outlook* module looks outward toward customers, competitors, and market trends. The *Insight* module looks inside the factory to study the internal process capabilities of the company. The other two modules are directed toward the specific creation and development of the solution space. The *Develop* module encompasses back-end product and service development processes. Last, the *Co-create* module consists of mechanisms to work collaboratively with customers and users to shape the current and future solution space. Each of the modules is presented in more detail in the following sections.

4.1 Outlook: Understanding the Customer

The *Outlook* module focuses on learning about customers and competitors. In mass customization, each customer is viewed as a 'separate market' with individual needs, which should be understood and analyzed. Systematic mapping of customer behavior contributes to a solid foundation for adjusting the solution space to cover more of the customers' different needs. The core questions to address within this module are:

- What are the real customer needs, and how can we gather data on their behavior?
- How much of the current solution space is used? What do our competitors offer?

Customer Needs and Behavior. Understanding customer needs and behavior is crucial in mass customization. Customer behavior data can be gathered through data from online interactions with the company, such as subscription data, social media insights, product usage reports, and consumer reviews. This way, companies can gain insights into how customers make purchasing decisions, what motivates them to choose certain products or services, and what obstacles they face in the buying process. Customer data can be used to identify trends, determine what customers are willing to pay for, and tailor products and services accordingly. This information is invaluable in helping companies design products and services that meet their customers' specific needs and preferences. Additionally, understanding customer behavior can help companies identify areas for improvement in the customer experience.

Market Trends and Competitor Analysis. Data on market trends and the competitive landscape can be derived from internal and external sources to ensure a complete picture of micro and macro consumer trends. Companies should gather data on competitors and analyze market trends to inform decision-making and meet customers' evolving needs. Market trend analysis helps companies identify growth areas, emerging market segments, and trends, allowing them to tailor their products and services accordingly. Competitor analysis helps companies identify potential weaknesses, opportunities, and improvement areas. By understanding the market context, companies can develop better products, services, and marketing strategies that meet the unique needs of their customers.

4.2 Insight: Understanding Internal Capabilities

In this module, one looks at internal processes to identify physical limitations in production to avoid inefficient processes. This step considers opportunities and constraints for

product dimensions, capacity, supplier network, and competence requirements. The company's *capabilities* should not be seen as static and should be adapted to the customers' needs. Core questions to answer within this module are:

- How can we analyze and communicate internal process capabilities?
- How quickly can we adapt our capabilities to meet new customer requirements?

Mapping Process Capabilities and Limitations. An important starting point for developing the solution space of the company is to get a clear understanding of the current physical limitations of the production process. A *Capability Matrix* can help analyze current production processes and physical limitations, such as product size and dimensions, colors, process time, and change-over time. A *Mass versus Custom Cost Map* helps analyze typical cost elements of producing standard variants versus custom variants outside the current solution space [8]. The tool is similar to a Value Stream Map, but two factors of mass versus custom features are added to each step of the VSM [8].

Tools for Analyzing and Communicating the Solution Space. For product families with many possible variants, it can be challenging to have an overview of a large number of possible variations and the relationship between them. Our studies of current literature and case company collaboration have identified three tools that would assist in further analyzing process capabilities for the solution space: A *Product Family Master Plan* [15] can help to visualize the product tree structure from the perspectives of customer, engineering, and production. Second, a *Tree of External Variety* [16] can help convey product variation and customer options visually. The tool is based on the principle of modularization and supports communication between production and marketing. Third, a *Feature Flow Map* focuses on functionality and product attributes and gives a good overview of connections between product options [17]. It provides a visual overview of the final attributes of a product variant.

4.3 Develop: Internal Processes for Creating the Solution Space

A critical success factor in solution space development is defining the right level of variety to offer. The development module focus on limiting or expanding the solution space to improve the match between what customers need and what the factory can make. The knowledge gained in the Outlook and Insight phase is vital for such considerations. Key questions to answer within this module are:

- Which product development principles and -processes are we using?
- How can we customize our offerings through different solution space dimensions?

Development principles. Developing new products and services and managing the existing portfolio of offerings is essential to creating a dynamic solution space. Product development should follow a user-centric design philosophy that prioritizes the end user's needs, wants, and desires in the design process. A core principle guiding development is *modularization*, which refers to organizing products and services into modular components or building blocks. This approach allows companies to create and adapt a wide range of product components with standard interfaces, providing a flexible and scalable framework for solution space development.

Solution space dimensions. Customization can be achieved through four dimensions: adaptation of form, fit, function, and format. *Form* refers to the product's appearance and design and includes elements such as look, shape, color, materials, and user interface. *Fit* describes the physical dimensions of products and involves adapting size to the usage context or body measures. *Function* refers to a product's specific features and attributes, such as performance, durability, and efficiency. *Format*, sometimes called modality [18], refers to specific customer criteria for the production and delivery of goods and services. Customers may want to select specific output targets (e.g., energy efficiency), delivery modes (specific person completing the order), or delivery criteria (time and location).

One can also differentiate between hard and soft customization. *Hard customization* is physical product adaptation, whereas *soft customization* is achieved with software to personalize products and services [19]. New sensor technologies and smart product features can contribute to new value propositions and business models. Smart products can sense, communicate, and adjust according to their surroundings, providing the customer with personalized features at a fraction of the cost of hard customization [20].

4.4 Co-create: Collaborative Solution Space Development with Customers

Co-creation refers to the collaborative process of designing and developing products and services in close partnership with customers. Companies can better understand and meet their needs and preferences by actively engaging customers. Core questions to answer in this module include:

- How can customers contribute to the innovation process and propose new ideas?
- Does the company have the right collaboration platforms to involve customers?

Open innovation and collaboration platforms. Open innovation refers to the process of inviting and utilizing external ideas. By embracing open innovation, companies can gather customer insights and feedback more effectively, co-create with customers, and develop a solution space that better aligns with customer needs. Collaboration platforms play an essential role in open innovation. These digital spaces allow companies to interact with their customers to develop products and services jointly. Such platforms enable customers to share their ideas and preferences, while companies can facilitate the co-creation process. Examples of such collaboration platforms are SPICE (Philips) and AgroStart (BASF).

Platform business models and ecosystems. Platform business models can expand the solution space in mass customization. Such platforms enable multiple businesses to interact and offer customized products and services to their customers through an interactive platform. This model leverages vast amounts of customer data and information to co-create new products and services. Such models enable companies to provide customers with a wide range of customizable services. Platform business models provide a way for companies to create and manage a dynamic solution space in which they can continuously adapt and evolve their offerings in response to changing customer preferences.

5 Discussion

The framework for Solution Space Development aims to provide a holistic overview of the necessary aspects involved in developing a dynamic solution space. The Outlook, Insight, Develop, and Co-create modules aim to guide companies through a set of activities to manage their solution space. The development should balance adding new features with keeping the solution space limited to options in demand by customers.

The framework can serve as a guide for managers in the industry that wants to get an overview of the aspects involved in managing their own solution space. Key questions are provided for each module, together with a set of proposed tools and methods supporting each module. In this way, the framework attempts to build and expand on the initial description of solution space development provided by Salvador et al. [3]. By establishing a comprehensive *Outlook* on customers and markets, combined with a clearer *Insight* into internal process capabilities and limitations, companies are better equipped to create and update their solution space. The solution space must be well communicated within the organization to discuss and align what the sales department offers with what the factory can produce efficiently. Embracing open innovation, companies can gather customer insights and feedback, co-create with customers, and develop a solution space better aligned with customer demands [13]. Modularity can support the reuse of parts, components, and materials to reduce production costs. The 4F dimensions of the solution space, with form, fit, function, and format, aids companies in identifying opportunities for customization. Smart products can be included to achieve personalization at scale.

Limitations and Future Research: Additional case studies and surveys could be used to further validate and refine the framework. The framework can be expanded by adding a more thorough overview of relevant tools and methods for each module. It should also be considered how SMEs can find resource-efficient ways to employ advanced systems, such as open innovation and platform business models, which might require high investments, skills, and resources. Further research is needed to verify if the framework should be adjusted to different industry settings.

6 Conclusion

The overall research question for this study has been to identify the main elements in a framework for solution space development in mass customization. The framework establishes two central axes for the companies to manage: front-end and back-end focus, and shifting between creating and learning. Combined, these axes create a cyclical development process. The four modules of *Outlook*, *Insight*, *Develop*, and *Co-Creat*e support unique aspects of solution space development. The main contribution of this paper is to present a holistic framework with a structured approach to solution space development. By utilizing the four dimensions of the solution space (form, fit, function, format), mass customization companies can create and manage a dynamic, smart solution space that provides added value for customers over time.

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