Vol. 1

Strategies
and Concepts

HANDBOOK OF RESEARCH IN MASS CUSTOMIZATION AND PERSONALIZATION

edited by

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Volume 1

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Foreword & Acknowledgments

This book is the third in a series of publications that present the latest advancements in research on mass customization and personalization. Starting with Tseng & Piller (2003) and continuing with Piller, Reichwald & Tseng (2006), we again could collect the thinking of some of the leading scholars and practitioners in the field. In comparison to the previous editions, this is the most comprehensive collection of writings on mass customization ever. This inspired our publisher to name it the "Handbook of Research in Mass Customization & Personalization". The contributions in this handbook were inspired by the **4th World Conference on Mass Customization and Personalization (MCPC 2007)**, a biannual academic event that gathers the international research and practice community interested in mass customization, held in October 2007 at the Massachusetts Institute of Technology (MIT), hosted by the MIT Smart Customization Group (Mitchell et al. 2007). The conference also included a business seminar held at HEC Business School in Montreal, Canada. The participant roster of the conference represented the interdisciplinary nature of customization and personalization drawing from a wide range of interest from hard core engineering, fashion design, architecture, retail, business strategy to psychology. The papers in this book reflect this richness and scope. Our authors come from diverse schools in leading researech institutions as well as from business practice or consulting firms.

Such a voluminous work is not possible without the help from many individuals. At MIT, we sincerely want to acknowledge the support and help by Prof. **William Mitchell, Ryan Chin** and **Betty Lou McClanahan** from the MIT Design Lab and the MIT Smart Customization Group. As co-chairs and organizers, they were providing leadership for the MCPC 2007 at MIT, hence paving the way that the research presented in this book could be assembled in the first place. From more than 200 conference contributions, an editorial committee selected the papers included in this handbook. All papers were subject of an additional review process. Along with the feedback authors received in the conference, the manuscripts were modified and edited to the collection of papers presented here. There are too many reviewers to name them here individually, but we want to thank them all for their great service to our community.

At RWTH Aachen, **Frank Steiner** coordinated the editorial and publishing process of this large project as the executive editor and provided valuable assistance to us. Dealing with more than 100 authors and coordinating more than 50 papers is a very demanding and time-consuming task. In addition, we thank our

publisher for their patience and continuous support for this project. It was a real pleasure working with **World Scientific Co**. on this book.

Our final thank, however, deserve the authors and contributors to this handbook. Only due to their willingness to contribute their latest research and thinking, this project has been possible. We thank them for their patience and compliance in addressing all the numerous demands and requests that such a book project demands. We believe that the research presented here provides a comprehensive and rich introduction into the various aspects that make mass customization one of the most promising business strategies for this century.

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&

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Introduction: Mass Customization Thinking: Moving from Pilot Stage to an Established Business Strategy

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Mass customization regards heterogeneities of demand among different customers not as a threat, but as a new opportunity for profits. To capture this value, however, a firm has to obtain a specific set of capabilities to address the challenges of such a business. In this chapter, we first define the core concepts of mass customization and personalization and briefly discuss their background and state of implementation in industry. We also present a set of challenges that many companies are facing when entering a mass customization business. We argue that companies have to obtain competences along three sets of distinctive capabilities to address these challenges. The term 'mass customization thinking' is introduced to denote practices in companies that follow these capabilities in order to profit from customer heterogeneities. In the second part of this chapter, we provide a comprehensive overview of the research presented in this handbook.

The Way Towards Mass Customization

Along with Joseph Pine (1993), we define mass customization as "developing, producing, marketing and delivering affordable goods, and services with enough variety and customization that nearly everyone finds exactly what they want." What one needs, when one needs it. Or, to say it in a different way, mass customization aims at producing goods and services catering to individual customers' needs with near mass production efficiency (Tseng and Jiao 2001). To apply this apparently simple statement in practice however is quite complex. As a business paradigm, mass customization provides an attractive business proposition to add value by directly addressing customer needs and in the mean time utilizing resources efficiently without incurring excessive cost. This is particularly significant at a time where competition is no longer just based on price and

conformance of dimensional quality. Today, customization has been well accepted in several key industries such as agriculture harvesting machines, trucks, commercial airplanes, elevators, computer hardware, buildings and others. For examples, in the machine tool industry, every machining center is equipped with different options and features to fit into the production requirements of the companies that make the purchase.

For years, we could observe a similar patter in this industry that guided the way of companies towards mass customization:

- It starts with a segment of the market that has not been served well. Certain types of products are needed to fulfill this market gap.
- Companies then design not a single product, but a platform that can be configured to address the requirements of this potential market
- The marketing department will then come up with a campaign to communicate the unique differentiation of the products that have been perceived as market needs.
- The sales department interacts with customers to translate customers' needs with machine specification and to configure a product that fits well with the customers' requirements and can be delivered when the customers need it. At the same time, and often more importantly, the total cost has to be within the budgets available to the customer.
- Next, production and distribution have to figure out a way to produce and to manage the logistics for the necessary components and assemblies and to complete machine efficiently. However, uniqueness of components often translates into set up time and additional cost. This may run against the required budget limitation and lead time. To address these challenges, techniques like flexible scheduling, modularity, commonality and others are applied to counterbalance the additional cost.
- In a final step, often years after product modularity and flexible processes in manufacturing and logistics have been established, the firm starts to increase the efficiency of the customer interaction process when taking the order. A product configuration system is introduced to better communicate to customers what is available and to match customer requirements with existing solutions of the manufacturer.

This sequence of events presents several challenges to accomplish the seemingly conflicting goals of mass customization: on the one hand to satisfy divergent needs of customers and on the other to accomplish efficiency comparable to

volume production without the economies of scale. Similar issues in trading cost and time with uniqueness also apply to downstream operations such as outbound logistics, installation, service, maintenance, and recovery. These challenges include tasks along all stages of the value chain. The characteristic of a good ("smart") mass customization system is that it addresses these challenges in a meaningful way. This is where the three capabilities of successful mass customization, which we will describe in the next section, come into place. But let's first have a closer look on the challenges when addressing diverse customer needs individually.

Speed and lead time: Products produced in a mass production system are manufactured in batches with sufficient quantity to justify the fixed cost such as money spent for set up. They often come with inventory in warehouses in different nodes of a supply chain, including the shelves at the point of sales. Thus, products are readily available from off the shelf. The actual net lead time for these products spanning from product design, material acquisition to product delivery is often in months if not years. However, customers finding the most "tolerable" products from off the shelf in retail stores often perceive the lead time between perceiving a need and its fulfillment relatively short. For custom products, it is however not practical to follow the same approach by building up inventory along the supply chain. But still, customers may expect to have the same order of magnitude in short lead time by extrapolating the expectation from standard items onto the custom goods. In many industries (especially in consumer markets), this gap between the customers' expectation and the physical limit of time required by a customized production often is significant.

Customers' needs: Contrary to the traditional belief, customers often do not know exactly what they want. They lack specific knowledge regarding what is available or feasible from manufacturers or suppliers in the value chain, let alone the relationships among product features and variables. For instances, a buyer of a price of customized furniture may not know what is the standard size of plywood and hence she may not select the proper width of a table that is more economical to produce. Such implicit domain knowledge is not easy to be made explicit in a customization system. This is very different in mass production. Here, manufacturers design and produce a set of products in quantity according to the perceived needs of customers. Customers then make their own selection among this set of products from the manufacturers and their competitors. Customers have to live with their choices and designs made by the manufacturers.

Economies of scale: Customization to individual customers' needs intuitively leads to small quantities and higher varieties; hence it becomes difficult to reach

the necessary scale of economy. Various techniques have been developed to counter such natural tendency. For examples, although the finished products can be vastly different, they may contain components or subassemblies that are identical for volume production. Customers can then configure to their needs with components that are produced with efficiency in the back end. Another approach is to sequence the products or subsystems in such a way that similar or identical materials can be accomplished with scale economies. Postponement is one of techniques that have been deployed to address this challenge. The idea is to place variety as late as possible in the fulfillment cycle. But how to postpone and where to set the decoupling point is a major challenge for many firms.

Value: Offering choices may not automatically be of value to customers. Previously, some manufacturers boasted billions of selections to customers. But most users do not appreciate the choices that are not of their interest. Additional choices often create confusion. In consequence, customers need longer to understand the differences among these choices. This additional mental load can discourage commitment of sales, impose extra sales effort or even chase customers away. Thus, it is important that the product variety offered to the customer matches the perceived value. Synchronizing choice between features, product attributes and options with customer appreciation and willingness to pay is a major challenge in the customization business.

Complexity: With high variety and small lot sizes, the tasks of scheduling, organizing, and managing categories, schedules, and division of work can become daunting. Complexity drives additional cost (particularly in the overhead) that could defeat the efficiency goal set by mass customization. Various algorithms and IT solutions have been introduced to manage complexity and to make a customization system more manageable. However, understanding and implementing these methods still is a large challenge for many companies.

The Capabilities of Mass Customization

Companies that master mass customization successfully have found an integrated way to address these challenges. This requires them to gain competences around a set of three core capabilities that are driving a sustainable mass customization business. The key to profiting from mass customization is to see it as a set of organizational capabilities that can supplement and enrich an existing system. While specific answers on the nature and characteristics of these capabilities are clearly dependent from industry context or product characteristics, three fundamental groups of capabilities determine the ability of a firm to mass customize. Following Salvador et al. (2009), we call them *Solution Space Development,*

Robust Value Chain Design, and *Choice Simplification*. The methods behind these capabilities are often not new. Some of them have been around for years. But successful mass customization demands to assemble these methods to capabilities in a meaningful and integrated way.

- *Solution Space Development.* First and foremost, a company seeking to adopt mass customization has to be able to understand what the idiosyncratic needs of its customers are. This is in contrast to the approach of a mass producer, where the company focuses on identifying "central tendencies" among its customers' needs, and targets them with a limited number of standard products. Conversely, a mass customizer has to identify the product attributes along which customer needs diverge the most. Once this is understood, the firm knows what is needed to properly cover the needs of its customers. It can draw up the "boundaries of its playground", clearly defining what it is going to offer and what it is not – the firm's solution space is defined. Mass customization implies by necessity the development of vast solution spaces, thus escalating the cost and complexity of understanding customer needs, in terms of spotting differentiating attributes, validating product concepts, and collecting customer feedback.
- *Robust Process Design.* A second critical requirement for mass customization is related to the relative performance of the value chain. Specifically, it is crucial that the increased variability in customers' requirements does not lead to significant deterioration in the firm's operations and supply chain (Pine et al. 2003). This can be achieved through robust value chain design – defined as the capability to reuse or re-combine existing organizational and value chain resources to fulfill differentiated customers needs. With robust process design customized solutions can be delivered with near mass production efficiency and reliability.
- *Choice Navigation.* Finally, the firm must be able to support customers in identifying their own problems and solutions, while minimizing complexity and burden of choice. When a customer is exposed to too many choices, the cognitive cost of evaluation can easily outweigh the increased utility from having more choices, creating the "paradox of choice": too many choices reduce customer value instead of increasing it (Huffman and Kahn 1998; Piller 2005). As such, offering more product choices can easily prompt customers to postpone or suspend their buying decisions, and, even more worryingly, to classify the vendor as difficult to deal with and hence undesirable. Therefore, the third requirement needed to ensure successful adoption of mass customiza-

tion is the organizational capability to simplify the navigation of the company's product assortment. We call that choice simplification.

Table 1: Three capabilities to make mass customization work.

Mass customization capability	**Examples of approaches to develop Mass customization capabilities**
Solution Space Development: *Capability to identify the product attributes along which customer needs mostly diverge*	**Innovation toolkits:** Software applications that can empower large pools of customers to translate their preferences into unique product variants by themselves, enabling each of them to highlight possibly unsatisfied needs **Outcome-driven innovation:** Methods to identify latent customer needs in an analytic way and to transfer those into product functionalities. **Customers experience intelligence:** Definition of adequate processes to continuously collect data on past customer transactions/ behaviors/ experiences and to translate this data into information on customer preferences
Robust Process Design: *Capability to reuse or re-combine existing organizational and value chain resources to fulfill a stream of differentiated customers needs*	**Flexible automation:** Using modern "digital" manufacturing technologies that enable high variance in operations at low switching cost. **Process modularity:** Reusing and recombining existing organizational and value-chain resources to fulfill differentiated customers' needs **Adaptive human capital:** People are a necessary element of a mass customization strategy, especially for their capacity to deal with new and ambiguous task.
Choice Navigation: *Support the customers in identifying their own solutions, while minimizing complexity and burden of choice*	**Assortment matching:** Negotiating the characteristics of an existing assortment with a model of the customers' needs in order to propose possible solutions to the customers without requiring significant effort and time in the search process **Fast-cycle trial-and-error learning in co-design toolkits:** Empower customers to build models of their own needs and to learn about appropriate solutions to their needs by interactively testing the match between these models and the available options. **Embedded configuration:** Developing smart products that "understand" how they should adapt to usage conditions and re-configure itself accordingly to a user profile.

Table 1 summarizes some of the methods companies can apply when building these capabilities (for a more detailed discussion, refer to Salvador et al. 2009). We find that companies that have found individual means to implement methods and approaches to match these three capabilities are succeeding in their mass customization endeavor. Other companies are just working along one of these capabilities. This is a good strategy as well. Mass customization has to be seen as

a process rather than a destination. It is not about achieving a “perfect” state of mass customization. What matters to most companies instead is to continuously increase their overall capabilities to define the solutions space, to design robust processes, and to help customers navigate available choices. A company may already profit tremendously from just implementing better, say, choice navigation capabilities to match diverse requests of customers not familiar with the product category. We call this understanding *"mass customization thinking"*. It provides a way to profit from heterogeneities of a firm's customers. Mass customization thinking means to build the three capabilities outlined before and to apply them for designing a value chain that creates value from serving different customers differently.

The contributors to this handbook provide a much more detailed discussion of these capabilities. While the nature of such a handbook with multiple authors prevents us to provide an integrated framework among all the diverse papers presented in this here, we believe that our three-capability-framework will help the reader to see the larger picture between the different streams of research presented in this book.

Personalization versus Mass Customization

Before we provide an overview of this research, we want to comment on a long debate, apparently never-ending debate. What is the difference between mass customization and personalization? Kasanoff (2009) recently provided a good definition of personalization: "After years of trying to simplify [the definition of] personalization, I finally got it down to two words: *Personal = Smarter*. The more you customize, the smarter you get. The smarter you get, the more competitive you become. It really is that simple. Doing it, of course, takes a lot of work."

According to his definition, personalization is using technology to accommodate the differences between people. Done right, it's a win/win strategy for providing a better outcome for both the service provider and the individuals involved. For example, if a doctor gives a patient a test to determine which treatment will work best for her before the treatment starts, that's personalization. Likewise, if a company gives their clients the option to tell their service center when and how to contact them, that's also personalization. Mass customization is a process for implementing personalization. In some respects, personalization is a goal and mass customization is the way to accomplish that goal. But we need to be careful about defining or debating semantics. Both personalization and mass customization push a company towards being more responsive to the marketplace and thus being more nimble. Both result in a firm that can react faster and more effectively

to volatility. Both enable a company to build defendable competitive advantages, because both require a firm to track, understand and accommodate the needs of its customers. In the end, it is not the term, but the result and value created by applying these concepts. However you are going to define these concepts, making them work is what matters in the end. And this is exactly where the chapters in this handbook start.

An Overview of Volume 1 of this Handbook: Strategies & Concepts

Volume 1 of this handbook is structured along the value chain. After a broader discussion of the mass customization concept and its implementation in industry, Chapters 2 to 5 follow the value chain by looking on mass customization from the perspective of marketing, product creation and design, and manufacturing. The latter aspect is extended by a special focus on rapid manufacturing (3D printing), a technology that is seen as a key enabler of new solutions for mass customization manufacturing.

Chapter 1: Strategic aspects of managing mass customization & personalization

The book opens with a number of conceptual and empirical contributions that discuss mass customization as a business strategy and its implementation in practice. The first papers address the inertia of companies and markets alike to move towards mass customization – starting the book with one of the largest present challenges in making mass customization work.

In Section 1.1, *Fabrizio Salvador* and *Manus Johnny Rungtusanatham* review the factors why the state of practical implementation of mass customization does not match the extent of its discussion in the literature. The authors discuss hindrance factors and structural inertia that make the transition from mass production to mass customization difficult. Doing so, this section also addresses many of the characteristics of a mass customization system. The authors build on an extensive case study of a manufacturing facility as it seeks to transition from mass production to mass customization. They propose five factors hindering the move towards mass customization.

This theme is continued in Section 1.2 by *Erlend Alfnes* and *Lars Skjelstad* who study a number of mass customization implementations in industrial organizations in Scandinavia. They identify three performance objectives, low cost, short delivery time and the degree of customization, and show how companies moving towards mass customization manage to balance these objectives.

While the previous sections have argued from the perspective of the company, Section 1.3 looks on the market inertia which become a potential threat to the success of mass customization. *Detlef Schoder, Johannes Putzke* and *Kai Fischbach* use the media market to explain why customers and users may not adopt mass customization to an extent as previously predicted. Based on entrepreneurial experience by the authors in setting up an individualized printed newspaper, the rich prospects of mass customization in content-related industries are contrasted with the lack of market take-off. They share an inside story of this venture and derive a number of exploratory explanations for the market inertia of mass customization adoption.

Section 1.4 extends the arguments in this section by proposing an integrated conceptual model to operationalized mass customization. Using the example of furniture manufacturing, a leading industry in mass customization, *Emmanuel Kodzi Jr.* and *Rado Gazo* synthesize insights from previous research to conceptualize a value-delivery framework for making mass customization work. This section also provides an insight how mass customization can improve the competitiveness of an entire industry. As the authors argue for the furniture sector, this industry has traditionally pursued a concept of competitiveness based on either price or on high-quality differentiation in a craft-business sense. They show how mass customization can provide a new value preposition that seems to be more applicable for the majority of the US market. We believe that this argumentation holds true for many other sectors in developed economies as well.

The final sections of this chapter extend the perspective and look beyond mass customization. *Nicola Morelli* and *Louise Møller Nielsen* argue in Section 1.5 that mass customization is just one of many strategies of a new paradigm of customer co-creation. Technological and organizational developments are stretching the capabilities of industrial systems, which are now able to address the needs of smaller and more diversified target groups. At the same time though, substantial transformations in the social and economic conditions of our societies are challenging the basic assumption of the existing production systems. This is creating extreme differentiations in demand patterns and is changing the role of customers in the production process fundamentally. The section outlines the characteristics of a new integrated value paradigm and explores methodological directions for addressing the new perspectives by further research.

"Is the best product a unique product," asks *Adam Fletcher* in Section 1.6. He presents the results of study undertaken with the online t-shirt manufacturer Threadless and its virtual community. The aim of this study was to look at an industry where it is technically possible to deliver a "pure" mass customization

experience and then to look at different approaches to see what they offer the consumer. Threadless' business model aggregates opinions of user submitted designs and manufacturers the most popular into limited t-shirts (following a mass production model). Fletcher investigates why this model is an attractive proposition for customers and the company. His results challenge a number of assumptions which can be found in the wider mass customization literature. They also remind us that mass customization is not *the* ultimate business strategy, but (just) one of several strategies that can provide a viable response to today's changing business environment (Ogawa and Piller 2006).

Section 1.7 concludes the chapter with a more general and broader discussion of the foundations of the mass customization concept. *William Mitchell* and *Ryan Chin* argue that long before Pine and Dell, mass customization thinking has been present in architectural and urban design. Long before B. Joseph Pine II presented a viable economic strategy around the concept of mass customization and Dell executed its custom build-to-order strategy, combinatorial theory and generative systems have been employed in biological systems, grammatical sentence structure in linguistics, and architecture and urban design. The paper traces the conceptual roots of mass customization through the examination of its historical precedents, citing work of Aristotle, Mitchell, Durand, Newell, and Simon. It applies this thinking on the grammar of culinary arts and discusses the limitations of such combinatorial methods. To overcome these limitations, the authors lay out a conceptual framework for achieving high levels of customization.

Chapter 2: Consumer studies & marketing aspects

Chapter 2 provides a deeper investigation of the customer perspective of mass customization and personalization. It addresses both the capabilities of choice navigation (selling systems for MCP) and solution space design (factors driving customer value in MCP). *Hans Bauer, Anja Düll* and *Dennis W. Jeffery* propose in Section 2.1 a typology to structure the potential benefits of mass customization for the customer. Based on an extensive review of the literature and twenty in-depth expert interviews, they suggest that style (form) customization especially is capable of generating symbolic, emotional, hedonic and epistemic benefits. Customizing a product with regard to its fit and functionality mainly offers possibilities for the generation of functional benefits, such as quality and comfort, but also has positive effects on the physical health. Furthermore, personal and economical benefits are of importance. Using a focus group methodology, the authors also derive additional insight into moderating factors of a purchasing decision of a mass customization offering.

The co-design process of a user defining her custom product in a toolkit is a central element of any mass customization offering. *Kate Herd, Andy Bardill* and *Mehmet Karamanoglu* address this process in Section 2.2 and discuss conceptual models and design tools for mass customization. The authors find that the notion of designing for co-design is still relatively under-researched. Co-design can be seen to consist not only of specific activities during product creation, but also include the entire purchasing experience for the customer co-designer (see also Müller and Piller 2004). This section presents a conceptual model and an approach to support design for co-design, encompassing issues of increased emotional connection and positive customer experience.

In Section 2.3, *Aurelie Merle, Jean-Louis Chandon* and *Elyette Roux* also investigate the additional value generated by mass customization from the consumer perspective. This value can be expressed by the willingness of consumers to pay a premium for mass customized products. In line with the previous sections, the authors conceptualize the perceived value of mass customization into two clusters, the product value and the mass customization experience. In an empirical experiment, they test their integrated model.

This quantitative research perspective is supplemented by a qualitative study of customer perception of customization, using the extreme case of Sneakerheads, an online community of sneaker enthusiasts. The study by *Michael Giebelhausen* and *Stephanie Lawson* (Section 2.4) provides deep exploratory insight into the symbolic value of mass customization. Members of the "Sneakerheads" community demonstrate their infatuation with sneakers via activities ranging from creating catalogs of custom shoes to buying and selling rare athletic footwear online. A series of in-depth interviews utilizing the Zaltman Metaphor Elicitation Technique (ZMET) provides a better understanding of how issues such as art, self-expression, exclusivity, peer recognition, and counterfeit goods interact with the mass customization of symbolic products by category experts.

The remaining sections of this chapter provide a focused view on selected marketing topics. *Muhammad Aljukhadar* introduces cognitive learning theory as a concept to model and explain mass customization in online markets. Whereas consumers are heterogeneous with regard to cognitive learning styles and strategies, cognitive learning theory proposes several high levels categories that can be used to segment consumers for different customization applications. The findings suggest a positive effect for the congruency between consumer learning styles (strategies) and online message format (content) on communication efficiency, recall, attitude, and decision making. The section proposes a number of

applications of cognitive learning theory in the domain, including online consumer segmentation, information content and format customization.

In Section 2.6, *Florian Siems* and *Dominik Walcher* show how the concept of (product) modularity, a key feature of a mass customization system, can also serve at the base for efficient life cycle management. The authors introduce the idea of "life event cycles" in order to enable a long term relationship between companies and their customers. The final section (Section 2.7) of this chapter represents some of the recent research on formal modeling of mass customization in the marketing sciences. *Luca Petruzzellis* and *Ernesto Somma* develop a mathematical model to explain when mass customization is superior to a conventional bundling strategy within a duopoly of differentiated goods and consumer uncertainty. The focus of this section is on information goods, i.e. products with large amount of digital content, which facilitates the customizability of the products.

Chapter 3: Building the solution space: Product & process design for MCP

A core capability of mass customization is to define a solution space, consisting of the product architectures and corresponding process structures that allow the firm to meet the heterogeneities in the target market in an efficient and effective way. This solution space has to be stable during the execution of a mass customization process – a core characteristic to achieve mass production efficiency – but at the same time flexible enough to address the diverse needs and demands of the customer base.

The first paper in this chapter (Section 3.1) develops a knowledge support system that can enable a better design of product families for mass customization. *Seung Ki Moon, Xiaomeng Chang, Janis Terpenny, Timothy Simpson* and *Soundar Kumara* describe how such a system supports the knowledge representation, knowledge discovery, and recommendation for product family design. The authors define an ontology to represent products as functional-based hierarchical structures and to describe cost information related to product design. Fuzzy clustering is employed to partition product functions into subsets for identifying a platform and modules within a given product family. Using a case of a family of power tools, the authors demonstrate the application of their method in practice.

Section 3.2 continues on the theme of product family design for mass customization. *Kaj Jørgensen* introduces a method for product family modeling that observes multiple abstraction levels. He argues that customer driven product configuration is concentrated on decisions, which are relatively invariant throughout order processing. Higher abstraction levels are typically related to the identification of basic functionalities of the product and to considerations about

the ability to perform functions demanded by the customer. With the modeling approach introduced in this section, the focus of product configuration can be shifted to identification and definition of attributes instead of modules and components.

Section 3.3 proposes a methodology for strategic platform design in a product family. The idea of *Seung Ki Moon*, *Timothy Simpson* and *Soundar Kumara* is that game theory allows for better modeling of situations of uncertain market environments. A Bayesian game is used to decide strategic equilibrium solutions for selecting modules in a product family design. To demonstrate the implementation of the proposed approach, the authors continue the case study of power tools introduced already in Section 3.1.

Hans Johannesson and *Stellan Gedell* present a knowledge-based model for configurable product platforms (Section 3.4). In a research project in the automotive industry, a modeling procedure and a new fully configurable platform model concept have been developed. It consists of a set of linked sub-systems which are configurable, generic, and autonomous. The authors describe the development and implementation of this model and comment on its performance achievements in platform design.

The final paper of this chapter (Section 3.5), written by *René Keller*, *Claudia Eckert* and *P. John Clarkson*, introduces a model and method to predict the changes for a product (component) over the live time of this product. Using the automotive industry as an example, they discuss how change requests from new customer requirements, coming often late into the process, can be analyzed for potential costly knock-on effects on other components. The authors introduce the Change Prediction Method (CPM) to assess knock-on change risks to support companies in evaluating proposed changes. The method allows for an improved solution space planning in mass customization systems.

Chapter 4: Making manufacturing & supply chain management for MCP work

Following the value chain structure of this part of the book, Chapter 4 and 5 are dedicated to selected methods and tools of manufacturing and supply chain planning in mass customization companies, addressing the capability of "robust value chain design" (Salvador et al. 2009). Chapter 4 is primarily discussing planning issues, while Chapter 5 will look on advancements in manufacturing technologies.

To start the chapter with a general perspective on mass customization manufacturing, *Riadh Azouzi, Sophie D'Amours* and *Robert Beauregard* connect the idea of agile manufacturing with mass customization in Section 4.1. Using again an

example of the furniture industry (see Section 1.4), their paper proposes an agility reference model to represent the specific capabilities required by along the value chain. Agility is described along three perspectives: flexibility, responsiveness, and autonomy. It is shown that each perspective addresses a distinct set of competences, which required the application of technologies with specific properties. In two case studies, the authors analyze the agility properties of manufacturing technologies in use and the corresponding customization strategies.

Section 4.2 addresses the issue of complexity in mass customization manufacturing. *Erik Oestreich* and *Tobias Teich* introduce a flexible configuration model that supports the generation of free definable descriptions and configuration dialogues, which can be used to identify individual components instead of using unique item numbers. Their method, developed and tested in the German automotive industry, also considers the fact that in many situations there is additional demand for standard parts, needed for the final assembling of an individual component.

Flexible manufacturing in the automotive industry also is the field of study in Section 4.3. Here, *Ulrich Berger, Ralf Kretzschmann, Veronica Vergas* and *Sarfraz Ul Haque Minhas* present an approach for flexible assembly of custom components. They argue that present solutions for production control at the manufacturing cell level as well as the plant level have certain disadvantages, such as manufacturer dependent programming of industrial robots and difficulties in implementing synchronized robot simulation and program execution. The authors discuss different approaches to overcome these limitations.

In Section 4.4, *Ashok Kumar* and *Frank Piller* introduce a prioritization algorithm for scheduling the production of an arbitrary number of product configurations when production budgets and time are limited. The authors first develop three measures of the value associated with each configuration of the product. Using these measures, a linear programming model is developed to find the optimal sequence of configurations to maximize the total value of the production over a given period. Given the dynamic nature of configuration demands and a constantly evolving system state, two efficient heuristic solutions are developed to solve this problem.

The final section of this chapter extends the perspective and takes a supply chain management view (Section 4.5). *Songlin Chen* and *Mitchell Tseng* address an issue that has not been covered in the existing literature on mass customization in a larger extent, procurement strategies for customized products. The authors develop a conceptual framework based on contract theory and axiomatic design theory to characterize the essential decisions involved in procuring customized products. Based on the framework, they identify key barriers that prevent

customers from effectively tapping into the value of customization. To overcome these barriers, the authors explore alternative procurement mechanisms.

Chapter 5: Rapid manufacturing for mass customization

Chapter 5 provides a detailed view on an advanced topic of manufacturing for mass customization: rapid manufacturing. This term represents a family of new production technologies (also called "3D printing") that can revolutionize the way how mass customization products are delivered by fast, flexible, and cost-effective production directly from electronic data. On the one hand, rapid manufacturing promises a design freedom for customized products that cannot be reached with conventional technologies. At the same time, rapid manufacturing can also achieve lower costs. Saving on molds reduces time and costs. Economies of scale are fading thus liberating manufacturing decisions from lot size optimization, forecast accuracy, and break even points. Rapid manufacturing promises to overcome these constraints of present manufacturing systems, but also introduces new challenges.

In Section 5.1, *Christopher Tuck, Min-Huey Ong, Helen Wagner* and *Richard Hague* provide a detailed introduction into rapid manufacturing and its applications in the mass customization domain. Combining results from several research projects, the authors present an integrated process view of generating a customized product using rapid manufacturing techniques. Their sample case is that of a customized motorcycle seat that is adapted to the driver's body. Methods and issues associated with manufacturing personalized seating are explored and the service requirements for motorcycle seat consumers are identified.

Christof Stotko and *Andy Snow* present in Section 5.2 a practitioner-focused view on the applications and technologies of laser-sintering as one example of rapid manufacturing technologies. The article provides an introduction into the technologies behind laser-sintering and shares results from a number of use cases in various industries. The authors also discuss potential future applications that can extend the present state of customization.

While the technologies discussed in the two previous sections demand rather advanced machinery with high machine cost, *Ed Sells, Sebastien Bailard, Zach Smith, Adrian Bowyer* and *Vik Olliver* argue in their paper that rapid manufacturing technology also can be provided at very low cost, even meeting DIY applications in the home (Section 5.3). The authors present insights from the RepRap project, a "replicating rapid prototyper". This is a filament-deposition rapid prototyping machine that has been designed to manufacture the majority of its own parts. All other parts of the machine are standard materials easily available.

RepRap is intended to maximize the customizability of both the products that it makes and also itself. While this machine may not yet be used for manufacturing of components in industrial settings, it is a great tool to educate future users about the opportunities of customization.

In Section 5.4, another extreme case of mass customization based on rapid manufacturing technologies is presented. *Marc van der Zande, Sjors Bergmans, Nico Kamperman* and *Bart van de Vorst* show how rapid manufacturing can be used to produce a fully customizable ladies' shoe – in one single manufacturing process. Such an application requires deep knowledge of footwear requirements, production processes, material properties, and design opportunities. The article summarizes the main achievements of the project and opportunities to transfer this learning onto other product categories.

Volume 2 of this Handbook: Applications & Cases

Volume 2 of the handbook provides a focused view on applications of mass customization & personalization in diverse industry settings. It contains a number of extensive case studies of specific mass customization implementations. These case studies discuss the findings presented in Volume 1 in an integrated way and discuss how the three bundles of capabilities of a sustainable mass customization system have been applied in different companies. But beyond just demonstrating "best practices" and learning from case studies, the papers in this part of the handbook also provide new conceptual, methodological and theoretical contributions with a distinctive industry focus.

While the fashion industry (Volume 2, Chapter 2) has been the focus of research in mass customization since a long period of time, the construction industry (Chapter 3) has only recently become an object of study. The same holds true for the vast area of services and intangible products (Chapter 1). This chapter provides insights into specific challenges and methods required to customize services efficiently for a larger customer segment. But also furniture, optical lenses, industrial machinery, or high-end home entertainment are fields of mass customization application discussed in this volume (Chapter 4). The final chapter of this book then bridges the topic of mass customization & personalization with a closely related topic, open innovation and customer co-creation in the new product development process (Chapter 5). For a more comprehensive overview about the content of Volume 2, please refer to the introduction in that volume.

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Vol. 2

Applications and Cases

HANDBOOK OF RESEARCH IN MASS CUSTOMIZATION AND PERSONALIZATION

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Introduction and Overview

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Continuing the introduction and overview provided in Volume 1 of this handbook, this chapter provides a comprehensive overview of the research presented in this volume of the handbook.

Structure of the Book

Volume 1 of this handbook was structured along the value chain. After a broader discussion of the mass customization concept and its implementation in industry, the chapters of Volume 1 followed the value chain by looking on mass customization from the perspective of marketing, product creation and design, and manufacturing. The latter aspect was extended by a special focus on rapid manufacturing (3D printing), a technology that can be seen as a key enabler of new solutions for mass customization manufacturing.

Volume 2 of the handbook provides a more focused view on applications of mass customization & personalization in diverse industry settings. It contains a number of extensive case studies of specific mass customization implementations. These case studies discuss the findings presented in Volume 1 in an integrated way and discuss how the three bundles of capabilities of a sustainable mass customization system have been applied in different companies. But beyond just demonstrating "best practices" and learning from case studies, the papers in this part of the handbook also provide new conceptual, methodological and theoretical contributions with a distinctive industry focus.

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of services and intangible products (Chapter 1). This chapter provides insights into specific challenges and methods required to customize services efficiently for a larger customer segment. But also furniture, optical lenses, industrial machinery, or high-end home entertainment are fields of mass customization application discussed in this part (Chapter 4). The final chapter of this book then bridges the topic of mass customization & personalization with a closely related topic, open innovation and customer co-creation in the new product development process (Chapter 5).

Chapter 1: Customization & personalization of services

Mass customization originated in the manufacturing domain. This origin still dominates the research landscape. But mass customization thinking also is increasingly relevant for providers of intangible goods such as software and services. There is, however, relatively little work on mass customization in the service context until today, despite the dominant role of this sector in the modern society. The papers in this chapter want to close this gap. They include case studies of specific company examples of successful service customization and conceptual or empirical papers addressing particular challenges of customizing a service offering. These challenges effect all three core capabilities of mass customization (Salvador et al. 2009): the requirements towards the design of the service architecture (*solution space design*), the design of the service production and delivery processes (*robust value chain design*), and the design of the interaction system with the customer, including an appropriate education of service employees (*choice navigation*).

One key challenge for service customization is to translate information about consumer preferences gained through market research into a format that can be easily used for service modularization decisions and customer-contact personnel training. *Michael Haas* and *Werner H. Kunz* address this aspect of solution space design for service mass customization in Section 1.1. The authors propose narrative descriptions of archetype service customers (called 'personas') as a tool for transferring complex market research data into a solution design for service customization.

In Section 1.2, *Hong Chen* and *L-F Pau* provide a detailed insight into a core application of service customization, the configuration of individual services and tariffs for wireless communication services. Their chapter advocates a user-centric view of wireless service configuration and pricing as opposed to present-day service catalogue options. The focus of the paper is on the design methodology and tools for such individual services and tariffs, using information compression,

negotiation algorithms, and risk port-folio analysis. The implications of this approach are discussed based on an end-user survey and model-based calculation. The authors show that users can achieve desired service bundle cost reduction while suppliers can improve significantly their risk-profit equilibrium points, reduce churn as well as marketing costs, and simplify provisioning.

Introducing service mass customization always is a major innovation from the perspective of suppliers and customers alike. In Section 1.3, *Ikenna S. Uzuegbunam, Satish Nambisan*, and *Manli Chen*, discuss the specifics of the service innovation process. They identify network approaches through which firms engage the "service innovation dilemma"— the problem of diseconomies of scale in a world of increasing demand for services. The authors argue that firms can develop sustainable competitive advantage in services through "real" and "virtual" embedded inter-firm and customer co-creation mechanisms. Section 1.4 provides an in-depth insight in such a service innovation process. Here, *X. Hernández* and his co-authors from the *Universidad Politécnica de Valencia* describe the use of emotional design techniques for service personalization. They show how these techniques can improve the design of the point of sale of habitat-related products. The authors share findings from a user experiment and show to which extent a retail store's background has influence on the willingness to purchase a product.

The remaining three sections of this chapter describe three specific applications of service customization. In Section 1.5, *Hans Björkman* discusses the special case of customization at *Unionen*, a major white-collar trade union in Sweden. He builds on the dilemma that only "bespoke" services can deliver ultimate customer value, but that these services often come at a cost. The section demonstrates how Unionen managed to provide a broad and attractive service portfolio consisting of standardized, mass customized, and individually customized services. Each individual member creates an individual service portfolio through personal choice of information, activities, and services. Linkages between standardized, mass customized, and individually customized services are well defined. Section 1.6 describes a field of service customization that has received a lot of attention recently, mass customization of education. *Hermann Klinger* and *Alexander Benz* propose to replace the paradigm of traditional education with its idea of an "economy of scarcity" by an "economy of self-generation". Mass customization provides the conceptual and operational framework for analyzing participants' needs. *Andrew Watson* finally discusses the WordPress software ecosystem, which is both software and service (Section 1.7). The chapter presents WordPress as a blogging software that is widely distributed and deeply customizable, as a family of products built on a common platform, and as the focus of a vibrant community and a thriving ecosystem. Analyzing these layers, the author provides

implications for service customization at WordPress and for mass-customized software more generally.

Chapter 2: Beyond bespoke tailoring: Mass customization in the apparel industry

While customization in the service sector still is in an emerging stage, mass customization in the apparel industry today can be regarded as an established field. Plenty of research and a wide array of business applications exist in this domain. Accordingly, the papers in this chapter address advanced topics. They often build on the combination of services and tangible product features, providing an integrated experience from the customer's perspective. The first three papers in this chapter (Sections 2.1, 2.2, and 2.3) focus on personalization in fashion retail. Rather then discussing aspects of the customized production of garments for an individual consumer, their perspective is on personalizing fashion retail. A fundamental approach here is technology to match an *existing assortment* of garments to an individual profile of one consumer, helping customers to better navigate the existing choice. The remaining papers in this chapter (Sections 2.4, 2.5, and 2.6) discuss advancements of the customized manufacture of clothing, i.e. of creating a *new assortment* for each consumer. The focus is on new manufacturing technologies like digital printing or 3D knitting which translate the promises of rapid manufacturing ("3D printing") for the fashion industry.

Section 2.1 is a good example for this new stream of research. *Susan Ashdown, Emily Calhoun* and *Lindsay Lyman-Clarke* address personalization in fashion retail over the internet, comparing a match-to-order system, where a standard good is matched to the personal profile of a consumer, with a make-to-order system where the product is produced on demand based on the personal consumer profile. They compare different technologies to support this matching process. Overall, the paper reveals how personalized online recommendation systems can improve consumer confidence in purchasing, and ultimately boosts sales.

While *Asdown et al.* focus on personalizing the online experience, *Sanchit Tiwarie* and *Suzanne Loker* cover personalization in an offline retail setting. Here, RFID technology is regarded as a core technique to enable a personalized retail experience in stores. Previously, this research was dominated by technical aspects of making RFID work. In this chapter, however, the crucial question is answered whether consumers will accept these technologies. The authors present results from an empirical study about consumer perceptions of body scanning and RFID technologies and applications.

"Discard 'one size fits all' Labels," demand *Marie-Eve Faust* and *Serge Carrier* in Section 2.3. While this sounds like a natural claim in a book on mass customization and personalization, the authors provide detailed evidence that this easy statement is not heard in today's fashion industry. They propose a new size labeling system to support order givers, manufacturers, retailers, and consumers. Such a system may become a cornerstone of personalization in fashion retail, providing consumers with fundamental information for matching an existing garment to an individual preference profile.

With Section 2.4, the perspective turns back to more conventional mass customization applications. Firsr, *Jing-Jing Fang* and *Chia-Hsin Tien* propose an application of computer-aided techniques to customize garment creation. Different from traditional CAD tools on planar pattern design, the authors show how a 3D-body scan of an individual consumer can be transferred into basic body shapes. The authors also propose an innovative tailoring method to generate a flare sagging style.

In Section 2.5*, Sandy Black, Claudia M Eckert* and *Philip Delamore* address "The Fashion Paradox" – the economic importance of the fashion industry set against its inherent obsolescence and waste through constant change. They present a new methodology for designers to approach these complex problems and to evaluate the impact of design decisions through the development of personalized fashion products. The approach positions the user at the centre of the design process by applying rapid manufacturing technologies (see Chapter 5 in Part I of this handbook) in the textile industry.

Section 2.6 discusses a further case of digital technologies in manufacturing. *Philip Delamore* and *Jennifer Bougourd* present a detailed look onto the digitization of the clothing product development process incorporating 3D body scanning, automatic pattern generation, visualization, digital printing, and embroidery. The aim of this project was to introduce custom printing and embroidery into an existing line of mass customized fashion, provided by Bodymetrics Digital Couture of London at Selfridge's and Harrods, two leading UK department stores.

Chapter 3: Mass customization in architecture and construction

Only very recently, the large field of architecture and construction has seen a systematic discussion of mass customization. As *Amir E. Piroozfar* and *Olga Popovic Larsen* observe in Section 3.1, mass customization has been used inadvertently in the building industry since a long time. But only very little and scattered systematic attempts have been made to apply it within the field knowingly. Almost none of these attempts have successfully avoided the

predicament imposed by the dominance of either (craft) manufacture interpretation or its predecessor, mass-production. In this section, the authors provide a review of the literature and current attempts to mass customization in the building industry. They investigate a series of projects where mass customization thinking has been successfully applied to the design and fabrication of building envelopes.

One reason that mass customization has received more attention in the field of architecture is the recent focus on sustainability and eco-efficiency in housing. Accordingly, Sections 3.2 and 3.3 address this issue. *Masa Noguchi* and *Karim Hadjri* discuss how mass customized design can lead to more sustainable housing development. Homes today need to be socially, economically, and environmentally sustainable in response to the wants and needs of individual homebuyers as well as the society. However, existing approaches to housing design in the residential market barely lead to any accomplishment of the sustainability agenda. In their paper, the authors discuss how mass customization thinking can support sustainability in the housing market. This also includes the idea to mass-personalize a home after its first occupancy to meet diverse market demands over the lifetime of a building. In Section 3.3, *Amir E. Piroozfar, Olga Popovic Larsen* and *Hasim Altan* extend this discussion. Their paper proposes "modern methods of construction" (MMC), a set of approaches and methods in the building industry in which the notion of customization can potentially be embedded. Findings of a comparative study of two building projects are used to demonstrate how the benefits of a mass-customization based modern construction method may increase sustainability in the built environment.

Chapter 4: Applications of MCP in various contexts

Chapter 4 is devoted to applications of mass customization in diverse contexts. The papers assembled here provide an insight into the scope and scale of mass customization thinking in different industries.

Section 4.1 starts this review with an in-depth view into the state of mass customization practices in Finland. *Marko Mäkipää* and his co-authors present the results of a multiple-case study conducted in 37 industrial companies. They show that mass customization practices are widely used in Finnish technology industries. Product qualities and production processes are managed well, but still numerous challenges remain, especially with regard to cross-functional cooperation, the deployment of configuration systems, and the integration of different information systems.

In Section 4.2, *Torsten Lihra, Urs Buehlmann* and *Robert Beauregard* discuss opportunities and challenges of North American furniture companies implement-

ing mass customization. Their study sheds light on manufacturers' perception of mass customization as a strategy to react on the growing competition from Asian manufacturers. A survey of furniture manufacturers in Canada, the USA, and Germany showed that developing modularity and agility, integrating the supply chain and pursuing a competitive cost structure are critical elements of a furniture customization system. But while these elements were mastered well by many respondents, limited capabilities of end users when designing their individual product were regarded as the true limit of mass customization in this industry.

Section 4.3 changes from a macro to micro perspective and provides an in-depth study of one particular company and its mass customization strategy. *Begoña Mateo, Rosa Porcar-Seder* and their team of co-authors show how INDO, a Spanish provider of ophthalmic lenses, designed and implemented a new generation of customization in the lenses industry. Traditionally, users have been asked to adapt to progressive lenses that are designed to fit an average wearer. INDO's proposal is that a customized progressive lens that mimics the natural vision can be obtained by measuring the visual strategy of each individual user, defined as the coordination of eyes and head movements. The result represents a major scientific advance and has positioned INDO at the head of the progressive lens' field.

An even more specialized application of mass customization is presented in a paper by *Richard So, John Au* and *K.L. Leung* (Section 4.4). They discuss how personalization technology can resemble the experience of listening to music played on a theater stage in a consumer's home. Using personalized filtering technology, it is possible to simulate the acoustics effects of a concert-theater for music presented on a pair of earphones. However, such a personalized solution can cost over $2000 and may not be feasible for consumer products. Non-personalized solutions, on the other hands, do not work well. This paper discusses the challenges and opportunities of mass-customized solutions in this industry.

In Section 4.5, *Fazleena Bardurdeen, Haritha Metta* and *Brandon Stump* present an approach to teach mass customization and to educate students about the elements of this strategy. The authors have developed a simulation model to incorporate practical demonstrations of mass customization in order to engage students in active/experiential learning. Their paper presents a simple but versatile simulation that can be used in classroom environments to help participants to understand the concept of mass customization and challenges to implementing the strategy.

Chapter 5: From mass customization to open innovation

Chapter 5 extends the perspective presented in the previous chapters by connecting mass customization with the concept of open innovation. The term characterizes a system where innovation is not solely performed internally within a firm, but in a cooperative mode with other external actors (Fredberg et al. 2008; Reichwald and Piller 2009). Open innovation is opposed to closed innovation, in which companies use only ideas generated within their boundaries, characterized by big corporate research labs and closely managed networks of vertically integrated partners (Chesbrough 2003). Sources of external information for the innovation process are plentiful, including customers, suppliers, competitors, university labs, and research institutions. In the papers in this chapter, the focus is on the users' or customers' contribution to an innovation project.

Integrating the customer into the firm's value chain is a dominating perspective in both mass customization and open innovation. In mass customization, customers are being integrated to utilize an existing solution space, i.e. to configure a product or service by selecting options from this existing assortment of choices. In open innovation, on the contrary, customers are being integrated to create a new solution space or modify an existing one, i.e. to co-create a general product or service offering that then is offered to a larger customer base. While the context of customer integration is different, customer integration in mass customization and in open innovation share a number of common characteristics, as the papers in this chapter reveal.

In Section 5.1, *Philine Warnke, Karl-Heinz Leitner, François Jégou* and *Wolfram Rhomberg* provide a good macro-level overview on the state of customer innovation in Europe and its relevance for the European manufacturing industry. In times of increasing relocation of manufacturing to low wage production sites, production strategies that place a large part of the value chain close to the customer are becoming increasingly attractive to keep jobs within the country. As a result, many governments recently have launched initiatives to explore how to benefit from user innovation and to support companies in their adoption. However, the authors show that to achieve this goal, tailored and efficient actions are required that can align research and innovation policy with measures from other realms such as IPR and regulation.

In Section 5.2, *Philippe Duverger* and *Salah Hassan* provide a micro-level analysis of contributing customers. They start with their analysis with leading-edge users in a market that are ahead of the general trend and have a high motivation (and ability) to solve an existing problem on their own. But lead users only correspond to a very small segment of customers in a market segment. Thus,

the authors look further how firms can bridge this "innovation gap" between leading-edge users and the mass market. Building on the lead user and customer co-creation literature, their paper demonstrates the strategic pertinence of involving a firm's users and defectors in generating new innovative ideas.

Peter R. Magnusson, Per Kristensson and *Christiane Hipp* extend this perspective in Section 5.3. They look whether the contributions of ordinary users to a firm's innovation process foster radical or incremental innovation. Their paper provides a better understanding of how users contribute in ideation, using the example of mobile telephony services. They conduct a quasi-experimental study to evaluate the innovation potential of ordinary users. Based on the results of this study, the authors derive a number of managerial implications how to obtain ideas from ordinary customers.

The final section of this chapter provides an integrated framework and methodology to perform open innovation (Section 5.4). Building on a large literature background, *Jouni Similä, Mikko Järvilehto, Kari Leppälä, Harri Haapasalo* and *Pasi Kuvaja* propose a facilitated innovation process model which links a company's internal and external innovation process, including also the role of an external intermediary brokering the interaction between the company and external actors. Empirical evidence from three cases of SMEs in an early idea generation phase is used to evaluate the proposed method.

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