Value Creation Through Mass Customization: 
An Empirical Analysis of the Requisite Strategic Capabilities

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<tr>
<td>AC</td>
<td>Acquisition costs</td>
</tr>
<tr>
<td>AGFI</td>
<td>Adjusted goodness-of-fit index</td>
</tr>
<tr>
<td>AVE</td>
<td>Average variance extracted</td>
</tr>
<tr>
<td>B2B</td>
<td>Business-to-business</td>
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<tr>
<td>B2C</td>
<td>Business-to-consumer</td>
</tr>
<tr>
<td>CFA</td>
<td>Confirmatory factor analysis</td>
</tr>
<tr>
<td>CFI</td>
<td>Comparative fit index</td>
</tr>
<tr>
<td>CI</td>
<td>Competitive intensity</td>
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<td>CIP</td>
<td>Continual improvement process</td>
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<td>CN</td>
<td>Choice navigation</td>
</tr>
<tr>
<td>CNC</td>
<td>Computerized numerical control</td>
</tr>
<tr>
<td>CS</td>
<td>Customer success</td>
</tr>
<tr>
<td>DIY</td>
<td>Do-it-yourself</td>
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<tr>
<td>FTE</td>
<td>Full-time equivalent</td>
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<tr>
<td>GFI</td>
<td>Goodness-of-fit index</td>
</tr>
<tr>
<td>GU</td>
<td>Gross utility</td>
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<tr>
<td>HOQ</td>
<td>House of quality</td>
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<td>IPO</td>
<td>Initial public offering</td>
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<td>KPI</td>
<td>Key performance indicator</td>
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<td>MC</td>
<td>Mass customization</td>
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<td>MCC</td>
<td>Mass customization capability</td>
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<td>MCC direct</td>
<td>Mass customization capability (direct measure)</td>
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<tr>
<td>MCC second-order</td>
<td>Mass customization capability (second-order construct)</td>
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<td>MCCAP</td>
<td>Mass customization capability (calculated measure)</td>
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<td>MG</td>
<td>Market growth</td>
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<td>MT</td>
<td>Market turbulence</td>
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<td>MTO</td>
<td>Make-to-order</td>
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<td>NV</td>
<td>Net value</td>
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<tr>
<td>PCM</td>
<td>Process modularity</td>
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<tr>
<td>PDM</td>
<td>Product modularity</td>
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<td>QFD</td>
<td>Quality function deployment</td>
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<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>RBV</td>
<td>Resource-based view</td>
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<td>RMSEA</td>
<td>Root mean square error of approximation</td>
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<td>ROI</td>
<td>Return on investment</td>
</tr>
<tr>
<td>ROS</td>
<td>Return on sales</td>
</tr>
<tr>
<td>RPD</td>
<td>Robust process design</td>
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<tr>
<td>SBU</td>
<td>Strategic business unit</td>
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<tr>
<td>SEC</td>
<td>Search and evaluation costs</td>
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<td>SEM</td>
<td>Structural equation modeling</td>
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<td>SF</td>
<td>Skill flexibility</td>
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<td>SME</td>
<td>Small to medium-sized enterprises</td>
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<td>SSD</td>
<td>Solution space development</td>
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<tr>
<td>TLI</td>
<td>Tucker-Lewis index</td>
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<tr>
<td>TQM</td>
<td>Total quality management</td>
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<tr>
<td>TT</td>
<td>Technological turbulence</td>
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<tr>
<td>VIF</td>
<td>Variance inflation factor</td>
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<tr>
<td>VRIN</td>
<td>Valuable, rare, in-imitable, non-substitutable</td>
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<tr>
<td>VTO</td>
<td>Virtual try-on</td>
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<tr>
<td>WTP</td>
<td>Willingness to pay</td>
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1 Introduction, Research Motivation, and Research Questions

1.1 Problem Setting

The term “mass customization” appears at first glance to be an oxymoron that links two opposing concepts—namely, mass production and customization—yet this contrasting notion is very much a reality today (Selladurai 2004). It can be defined as producing “goods and services to meet individual customers’ needs with near mass production efficiency” (Tseng and Jiao 2001, p. 685).\(^1\) Start-ups in this field are exploding, offering customized products ranging from cereals to pet food to novels to handbags, perfume, and jewelry—all enthusiastically covered by the press (Piller 2009).\(^2\)

It thus should come as no surprise that major brands are trying to jump on the customization bandwagon. In particular, food and beverage manufacturers are searching for any avenue to halt strong declines in brand loyalty while also cashing in on consumers’ desire for customized objects (Baertlein 2009). For example, Mars U.S. introduced its product line My M&M’s in 2004, allowing customers to upload personal images online and then create personalized candies.\(^3\) In 2010, Coca-Cola invested $100 million in a plant in its hometown of Atlanta, Georgia, to churn out concentrates for its Freestyle soda dispensers, which offer more than 100 drink choices to mix and mash up (McWilliams 2010).\(^4\) And Kraft just launched its first new major brand in 16 years in one of the biggest ever rollouts: MiO, a liquid water enhancer, touted as a way to make beverages more personal.\(^5\) This megatrend toward individualization is growing more and more pronounced, with a “just-for-me” ethos driving customers’ desire for products and services that cater to their heterogeneous needs and personalities. Especially the Millennial Generation (Howe and Strauss 2000), with its massive purchasing power and frequently cited sense of entitlement, has transformed the role of customers to demand product offerings that enable them to co-create, self-design, and gain control over their consumption experience (Prahalad and Ramaswamy 2004). This development is further fueled by the recent growth in social media, like Facebook and Twitter, that fosters company–customer interactions and collaboration among customers. In turn, it seems safe to say that after several

\(^1\) For a more comprehensive definition of mass customization refer to Chapter 1.2.3.
\(^2\) Websites such as www.milkorsugar.com and www.egoo.de provide an overview of the fast growing range of customizable products.
\(^3\) See www.mymms.com
\(^4\) See www.coca-colafreestyle.com
\(^5\) See www.kraftbrands.com/mio.
false starts, mass customization has grown beyond the niche (Gownder et al. 2011). Once considered a new frontier in business competition, mass customization has evolved into an imperative for many companies (Pine 2009).

Despite widespread agreement that it represents a viable business strategy, many companies have soured on their attempts to implement profitable mass customization (Salvador et al. 2009). Understanding what constitutes a mass customization strategy and effectively putting it into practice are two different issues (McCarthy 2004). Achieving mass customization takes more than just “fine tuning” a company’s operations and supply chains (Brown and Bessant 2003, p. 715); it involves developing multidimensional strategic capabilities in an evolutionary process (van Hoek et al. 1999). Strategic capabilities refer to the managerial ability of an organization to utilize its existing resources in order to create value and gain competitive advantage (Prahalad and Hamel 1990; Amit and Schoemaker 1993). Developing and strengthening these capabilities should thus be at the core of every company’s strategy process (Hayes and Pisano 1996). However, academic research provides managers with little guidance on which strategic capabilities firms need to realize mass customization (Salvador et al. 2008). Most current research instead focuses on individual phenomena within specific disciplinary domains, such as operations management (e.g., Duray et al. 2000), innovation management (e.g., Franke and von Hippel 2003), strategic management (e.g., Kotha 1995), or marketing (e.g., Dellaert and Stremersch 2005). Many works still rely on case descriptions and concept development; few of the field’s propositions have been empirically tested (Kaplan and Haenlein 2006). This has led to mass customization’s continued perception as a fuzzy buzzword and has even prompted claims that it is no more than an unsustainable business fad (Piller 2005a). A notable exception is the comprehensive framework of Salvador et al. (2009) that synthesizes the essential capabilities a mass customization firm should develop to turn customers’ heterogeneous needs into opportunities to create value.

This thesis thus aims to operationalize the strategic capabilities framework of Salvador et al. (2009) for empirical research and derive sources of competitive advantage associated with these capabilities. The research is part of “The Customization 500,” a global benchmarking study of more than 500 online providers of mass customized goods initiated by the MIT Smart Customization Group, the Technology and Innovation Management Group of RWTH Aachen
University, and the University of Applied Sciences in Salzburg. This multi-stage study comprises expert evaluations of online mass customization configuration systems, customer surveys, and a survey of vendors and manufacturers. The objective is to provide a comprehensive picture of the state of the art of customization and personalization on the Internet.

To test the propositions developed in this thesis, we draw on a sub-sample of 115 mass customization firms. Analyzing the data, we can supplement the state of the literature on mass customization with a number of theoretical, methodological, and managerial contributions. In terms of theory, this study synthesizes the resource-based view (RBV) and the economic theory of complementarities to examine how multiple core elements of a mass customization strategy enhance company performance, either independently or collectively. We find that the three strategic capabilities for mass customization do not improve corporate performance on their own. However, by modeling their complementarity using a second-order construct, we discover super-additive synergies arising from the simultaneous implementation of the strategic capabilities. Thus, the results confirm that competitive advantage cannot be explained by a single strategic resource or capability; it is based on a successful integration of various different organizational elements.

Methodologically, this study makes two important contributions. First, it develops a set of valid and reliable instruments to measure the three sub-dimensions of mass customization capability, namely solution space development, robust process design, and choice navigation. Second, this study returns to the intellectual foundations of mass customization by enforcing strict criteria in terms of the selection of respondents. This allows us to investigate synergies arising from the complementarity of the three strategic capabilities in a relevant sample of pure-play mass customizers.

From a managerial perspective, to attain strategic differentiation and competitive advantage, firms pursuing mass customization as their core business must have all three capabilities in place due to the complementarity of their effects on company performance. The empirical results also provide valuable information for firms as to which specific activities are effective for implementing these capabilities in practice. Furthermore, concrete recommendations are
derived for financial investors regarding how to assess the competitiveness and sustainability of mass customization business models.

In summary, this thesis makes an attempt to advance the research on mass customization capabilities from anecdotal and case study evidence to a relatively large-sample study. It demonstrates that the strategic capabilities for mass customization are likely “dynamic capabilities” (Teece et al. 1997) in the sense that they enable firms to effectively adapt and integrate their resources and skills in order to more efficiently respond to customers’ heterogeneous needs and changing business environments. Furthermore, the results add to the body of accumulated work on the importance of complementarities and internal fit (e.g., Siggelkow 2002; Carmeli and Tishler 2004; Peteraf and Reed 2007).

1.2 Conceptualizing Mass Customization

This section introduces the phenomenon of long-tail markets, outlines the development of the mass customization concept, and provides a working definition. It also explains why studying strategic capabilities in the context of mass customization is important and formulates concrete research questions. The main objective of this section is to create a common understanding of mass customization as the underlying concept for this thesis.

1.2.1 Individualization of Demand and Long-Tail Markets

Before the Industrial Revolution products were made to order and per the specifications of the customer by craftsmen. Each customer was a segment of one, and the products were only available to select groups of wealthy individuals (Pine 1993). With the advent of mass production, standardized products and operations allowed companies to leverage economies of scale and division of labor, which drastically reduced production costs. A new generation of mass consumers grew up satisfied with standardized products at reasonable prices, even if that meant sacrificing some of their preferences (Sheth et al. 2000). This era is best characterized by Henry Ford’s famous statement: “Any customer can have a car painted any color that he wants so long as it is black” (Ford and Crowther 1922, p. 72). Companies focused on promoting, pricing, and distributing products for the mass market, based on the assumption that supply would create its own demand. However, in the 1950s, when markets in many industries began to mature and saturate, firms gradually began shifting their attention to
markets rather than products. Following the argumentation that creating a satisfied customer should be the primary objective of business (Drucker 1954; Keith 1960), *market orientation* emerged as a new organizational form for firms. The concept was popularized by Kotler (1967; 1977) and soon became the philosophical foundation for marketing academics and practitioners alike. With an increasing emphasis on markets, *market segmentation* was the logical next step. Smith (1956) suggested that market demand can be broken down into segments with distinct demand functions, requiring products and marketing efforts to be adjusted to cater to these differences. Firms thus began to organize around market segments and offer a number of focused product variants. As competition intensified, marketers began defining smaller and smaller segments, resulting in a proliferation of brands and distribution channels (Sheth et al. 2000). In the course of the continuous refinement of the segmentation approach, market segmentation evolved into a *customer orientation*. Customer-oriented organizations (1) put the customers’ interests first, (2) are able to generate, disseminate, and use superior information about customers and competitors, and (3) apply inter-functional resources in a coordinated manner to create superior customer value (Day 1994). This perspective was enforced by the emergence of *customer relationship management*, a holistic approach to creating shareholder value by managing customer relationships through information technology (Payne and Frow 2005, p. 168). With increasingly individualized customer requirements (Porter 1996; Prahalad and Ramaswamy 2004), the next natural progression was then from market niches to mass customized markets, or *markets of one*, in which each individual customer is his or her own market (Gilmore and Pine 2000).

As a consequence of this individualization of demand, our culture and economy is increasingly shifting away from a focus on a relatively small number of “hits” (mainstream products and markets) at the head of the demand curve and toward a huge number of niches in the tail (Anderson 2006). This transition is also vividly illustrated in the sales statistics of many companies. Whereas previously the majority of profits came from selling a handful of hit products to a lot of people, now millions of unique products can be sold in relatively small quantities to niche markets. However, these niche markets have emerged only recently, as a result of advances in information technology, as aptly exemplified by Amazon, iTunes, and Netflix. For these companies, the marginal cost of storing or making available a vast range of products in a category converges to zero, because supply is no longer limited by shelf space or
how much it costs to manufacture, transport, store, and deliver a product. Thus they can earn profits, even if only one or two units of a particular product sell each month. For example, Amazon sells nearly all of the more than 24 million books currently in print; a typical brick-and-mortar store can stock between 40,000 and 100,000 unique titles. For these niche offerings, which cannot profitably be provided by traditional brick-and-mortar channels, Anderson (2006) coins the term “Long Tail”—as represented by the grey part in Figure 1. He also argues that the long tail will grow longer and fatter as their exposure to niche products drives consumers to develop a taste for them. In turn, producers have an incentive to create more new niche products over time, as depicted by the dotted demand curve in Figure 1. Anderson (2006) thus predicts that total revenues from the niche products that do not sell well enough for traditional retail distribution ultimately will exceed sales from hits; that is, the grey area under the curve will become bigger than the white area.

![Figure 1: The Long Tail (adapted from Elberse 2008, p. 90)](image_url)

Brynjolfsson et al. (2010) reinforce this view in their study of Amazon, in which they find that the long tail has grown between 2000 and 2008, and niche books unavailable in brick-and-mortar stores account for 36.7% of Amazon’s sales. They propose that the long-tail phenomenon is driven by several demand and supply factors (Brynjolfsson et al. 2006). The supply side drivers include lower inventory storage and distribution costs, due to virtual shelf-space, make-to-order production, and electronic delivery. On the demand side, customers can more easily discover and search for niche products through intelligent discovery tools, recommendation engines, and virtual advisors, which significantly lower search costs (Brynjolfsson et al. 2011). Without such tools, consumers can easily become overwhelmed by too much choice, which will reduce their purchase intention (Gourville and Soman 2005).
These insights have urged many companies to revise their strategies to address the long tail explicitly. With its unique promise of delivering highly customized products at affordable prices, mass customization is clearly an appropriate strategy to exploit the long tail. The concept has gained remarkable momentum in the past two decades, with growing adoption by businesses and attention in many academic publications (Kumar 2007).

1.2.2 The History of Mass Customization

The first reference to mass customization is often attributed to Stanley Davis (1987), in his book *Future Perfect*, but the desire for uniqueness in manufactured products stretches back millennia. In 210 BC, the first emperor of China, Qin Shi Huang, commissioned a vast terracotta army to protect his mausoleum, which consisted of more than 7,000 soldiers (Ciarla 2005). The emperor wanted the figures to be diverse in appearance to reflect the individuality of soldiers in real armies. To achieve this monumental goal, the artisans used a series of standard molds that provided the basic forms for the bodies and faces of the figures. The heads, arms, legs, and torsos were created separately and then assembled (Portal and Dan 2007). Once assembled, the basic figures could be customized using premanufactured components, such as beards and hats, and clay was added to provide individual facial features.\(^7\)

Any mass customization strategy inevitably involves product differentiation, which itself has a long history in the economics literature (Jiang et al. 2006). Chamberlin (1962) coined the term product differentiation in his *Theory of Monopolistic Competition* to describe why a supplier could charge higher prices than perfect competition would allow if the provided solution met the specific needs of a customer. This implies that companies can obtain economic rents from customizing products and services. The price premium reflects the increment of utility that customers derive from a customized product, compared with the best standard product available (Kaplan et al. 2007). In his theory of customer demand, Lancaster (1966; 1979) provides an intuitive explanation for why people want custom products in the first place: He introduces the idea that products are bundles of characteristics combined into a single market offer and that these characteristics are the objects of consumer preference, not the products themselves. For example, consumers do not demand food in itself, but rather the nutrients and

\(^7\) In modern terminology, we would refer to such a technique as postponement or delayed differentiation (e.g., Feitzinger and Lee 1997).
flavors in the food. The characteristics possessed by a product are, on principle, objective and the same for all consumers (Hendler 1975). But each consumer may derive a different level of utility from those characteristics, so buying a standard product necessarily means some kind of sacrifice.

Mass production of customized goods as an emerging trend to remedy this problem was already anticipated three decades ago by Toffler (1970). But the term itself was coined in 1987 by Davis and defined as a situation in which “the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously … be treated individually as in the customized markets of pre-industrial economies” (Davis 1987, p. 169). The first scholarly article on mass customization appears to be From Mass Marketing to Mass Customization, by Kotler (1989). He considered mass customization a differentiation strategy to serve individual markets and claimed that “the mass market is dead” (Kotler 1989, p. 47). Pine (1993, p. 48) moved the concept into management literature, defining it as “developing, producing, marketing and delivering affordable goods and services with enough variety and customization that nearly everyone finds exactly what they want.” At that time, the concept of mass customization seemed visionary: The Internet had just plugged in, social media were still some 15 years away, and companies were struggling to implement kanban and just-in-time production, let alone produce a batch size of one. Nevertheless, Kotha (1995, p. 22) identified mass customization as “the emerging paradigm for competitive advantage” that would allow companies to pursue the generic strategies of cost leadership and differentiation simultaneously. According to Porter (1980; 1985), firms can achieve and maintain their competitive advantage by offering either low priced products with low operating costs or differentiated products with a price premium over competitors. From a strategic management perspective, mass customization offers a hybrid strategy: Firms might offer highly differentiated (i.e., customized) products without having to charge a price premium (Kaplan and Haenlein 2006, p. 176).

The concept of mass customization quickly became popular and was adopted by many researchers in various fields. Its dissemination was fueled by early success stories, such as those of Lutron Electronics (Spira 1993), Motorola (Eastwood 1996), Hewlett-Packard (Feitzinger and Lee 1997), and Dell (Falkenberg 1998). Mass customization also became prevalent in service industries; individually customized financial, insurance, and utility
services proliferated at the beginning of the new millennium (Hart 1995; Papathanassiou 2004; Piller and Kumar 2007). This evolution was made possible by the advances in information and communication technology that closed the gap between producers and consumers and significantly lowered transaction costs (Ansari and Mela 2003). In their meta-review, Kumar et al. (2007, p. 643) identify 1,124 articles on mass customization since 1987 and thus consider it “a robust, vital, and flourishing field that has high volumes of publications and applications.”

1.2.3 Defining Mass Customization

For empirical research to have impact on practice, it is important that researchers across a broad range of disciplines find consistency in labeling and identifying their concepts (Garcia and Calantone 2002). However, two decades of intense academic research have not produced a commonly accepted definition of mass customisation (Duray et al. 2000; Piller 2005a; Kaplan and Haenlein 2006). The multidisciplinarity of the concept makes it particularly difficult to reach a general consensus (Blecker et al. 2005). As Piller (2005a, pp. 214-215) rightly notes, mass customization has been related to all kinds of strategies that embrace high variety, personalization, and flexible production, and he attributes the limited diffusion and implementation of the concept to the lack of a common understanding.

Considering the various existing definitions of mass customisation, this section focuses particularly on two promising definitions. As mentioned in the introduction, Tseng and Jiao (2001, p. 685) propose a short, precise definition that is easily understandable for managers: Mass customization corresponds to “the technologies and systems to deliver goods and services that meet individual customers’ needs with near mass production efficiency.” In this definition, the term mass refers to “mass production efficiency” and the term customization relates to “individual customers’ needs.” Throughout this thesis, we will refer to companies applying the mass customization concept as mass customizers or mass customization companies/firms.

From a capabilities perspective though, the following definition by Piller (2005a) may be most appropriate, because it clearly distinguishes mass customization from similar concepts:
“Mass customization refers to a customer co-design process of products and services, which meet the needs of each individual customer with regard to certain product features. All operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes. As a result, the costs associated with customization allow for a price level that does not imply a switch in an upper market segment” (Piller 2005a, p. 315; emphasis added).

The definition set forth by Piller (2005a) consists of four key elements (see emphasis). The first element explains the genus of the mass customization concept, that is, customers are increasingly seen as partners (not recipients) in the value creation process who assume an active role and determine which product is offered to them by specifying its attributes (Wikström 1996). The second element deals with the solution space within which a mass customizer is able to satisfy customers’ needs. The range of available customization options is vast but also necessarily finite to avoid a cost explosion (Hart 1995). The third element states that a successful mass customization system is characterized by flexible, responsive but stable processes so that increased variability in customers’ demands does not significantly impair a firm’s operations or supply chains (Pine et al. 1993). As for the last element, in contrast to earlier definitions (e.g., Pine 1993; Hart 1995), it is not necessary that the cost level of mass customized products be comparable to that of mass-produced standard products. Recent empirical work has clearly revealed that customers frequently show a higher willingness to pay (WTP) for customized products (e.g., Franke and Piller 2004; Schreier 2006; Franke et al. 2009a). This price premium is commensurate with the added utility customers gain from the customized product compared with the best standard product available (Kaplan et al. 2007). Costs need thus only be low enough that mass customization firms are able to target the same market segment that was purchasing the standard products before.

But Hart (1995, p. 36) also realizes that mass customization is some kind of an ideal state which companies in the real world can, at best, only approximate. Instead, mass production and mass customization represent two ends of a continuum, on which most companies are located somewhere in between (Lampel and Mintzberg 1996; Radder and Louw 1999; Salvador et al. 2009). Furthermore, “implementing mass customization need not be framed as an ‘either-or’ proposition” (Kotha 1995, p. 36). This means that both approaches can even be practiced by the same company, aimed at different target markets (Radder and Louw 1999).
Large companies such as Adidas (miAdidas), Masterfoods (MyM&Ms), and Lego (Mosaic) successfully provide customized products to a premium segment of customers, together with their standard product lines.

But then what is mass customization? Is it a marketing tool, a manufacturing strategy, or an innovation process? Piller (2005a) concludes that mass customization is first and foremost a vision to become a truly customer-centric enterprise. Thus it should no longer be regarded as a business model or competitive strategy but rather as “a process for aligning an organization with its customers’ needs” (Salvador et al. 2009, p. 72). Putting this apparently simple statement into practice can be quite complex though, because it requires a distinctive set of capabilities that companies find hard to develop and difficult to sustain. This work therefore aims to identify the requisite strategic capabilities for mass customization and provide practical recommendations for their implementation.

1.3 Research Motivation

The simple statement, “Mass Customization is not for everybody” (Zipkin 2001, p. 82), is valid for both consumers and producers. Customers only demand variety when their preferences for certain product attributes differ sharply from what is readily available in the market (Kaplan et al. 2007). Moreover, not all customers are equally willing to engage in tedious co-design activities, pay a price premium for the customized product and wait considerable time before receiving it (Bardakci and Whitelock 2003; Fang 2008). However, as measured by the number of publications, few authors have critically assessed the concept of mass customization or its limitations from a company perspective. For example, Alptekinoglu and Corbett (2008) and Jiang et al. (2006) come to the conclusion that mass customization is not necessarily superior to a traditional mass production strategy. They advise companies to assess carefully, on the basis of the external market environment and their internal capabilities, whether and to what extent they should commit to mass customization. In an empirical study, Squire et al. (2006b) also conclude that mass customization may not represent the best strategy for all firms in all cases. They find significant trade-offs among customization, manufacturing costs, and delivery lead times. Some high-profile flops over the years have even prompted claims that mass customization is just unsustainable business hype (Salvador et al. 2009, p. 71). Not surprisingly then, Piller (2007) and Nambiar (2009) detect a widening gap between
the level of research in the field and the implementation of the concept. Perhaps a recap of some prominent cases can shed light on possible reasons for the limits and failures of mass customization business ventures.

(1) **Procter & Gamble** ceased its $60 million mass customization experiment, reflect.com, in 2005 (Anderson 2005). The site allowed customers to create their own unique make-up, skincare, hair care, and perfume products by selecting from a range of options, including color, fragrance, ingredients, packaging, and even the product name (Piller et al. 2004). But it seems that customers were simply overwhelmed by, say, more than 10,000 different shades of lip gloss and became frustrated with the complexity—a phenomenon Huffman and Kahn (1998) label “mass confusion.” Apparently Procter & Gamble failed to provide adequate choice navigation to customers, which would have enabled them to handle the variety (Piller 2005b). Moreover, the price point was too high for unbranded products, and the pure online distribution model excluded more traditional buyers (Bittar 2001). Yet the websites mybodylotion.de and liliemakeup.com currently are successfully capitalizing on similar ideas.

(2) **Land’s End** was once considered a pioneer in personalization techniques; it had been using virtual models and recommendation engines since 1999 (Abend 2001). In 2001, it began to offer made-to-measure pants and shirts, but it failed to combine its personalization know-how with mass customization to facilitate the customization process for the customer. While customization relates to changing, assembling, or modifying product components in accordance with customers’ needs and preferences, personalization in general is about selecting or filtering information objects for an individual by using information about that individual (e.g., from the customer profile) (Piller 2007). Today the company only offers customized dress shirts, tucked away in a corner of its website. In contrast, dolzer.com and new players such as indochino.com and youtailor.de excel in combining personalization with customization capabilities.

(3) **General Mills** still owns the domain “mycereal.com,” which launched in 2001—though the page now redirects visitors to the corporate homepage. The website formerly allowed customers to customize their cereals and choose the size of the servings, which came in plastic pouches or bowls. The customized cereals cost twice as much as prepackaged cereals, and choices were quite limited: Customers could only mix existing brands, such as Cheerios,
Chex, or Wheaties. No natural and organic ingredients were available. In the end, customers simply were not willing to pay a 100% price premium for someone else to mix cereal into little pouches and deliver it to their door (Rubin et al. 2001). Moreover, General Mills failed to establish a real relationship with their customers, as it never followed up on orders placed on the site. The German clone mymuesli.com instead has seen double-digits growth rates since its start in 2007 and recently expanded to other European countries. Not surprisingly, mixmygranola.com was quick to adapt the successful business model to the U.S. market.

(4) Levi’s used to offer custom jeans, but it closed its “Original Spin” program in 2003—even though it had been in the field since 1994, earned a strong reputation among customers, and was frequently quoted as textbook case for mass customization (e.g., Duray et al. 2000; Zipkin 2001). In an analysis of this case, Piller (2004) concludes that Levi’s concept was based solely on the availability of flexible manufacturing technology. It did not use the information gathered from custom orders to engage in individual relationships with customers. Nor did Levi’s create a unique purchasing experience in stores to address the high emotional involvement and perceived complexity associated with customized garments. Moreover, it never offered customers a choice in a key product feature: color. Instead, indicustom.com, getwear.com and diejeans.de are succeeding in making custom jeans.

(5) The business model of the computer supplier Dell has often been cited as a prime example of a successful mass customization strategy (e.g., Agrawal et al. 2001; Wind and Rangaswamy 2001; Randall et al. 2005). Dell's entire supply chain and distribution system is optimized to produce customized computers in a way that reduces the firm’s operating costs while improving responsiveness to customers. Few companies have come anywhere near achieving Dell’s success with mass customization. Yet Dell recently announced in a blog entry that it would be turning away from its mass customization business model (Williams 2010):

“In the past, we utilized a single direct configure to order model and we gave our customers a cascade of options to choose from when configuring a product specifically for their needs. This was, and still is, a great model for custom configuration where our customers value and will pay for this service but it has become too complex and costly for significant portions of consumer and some portions of our commercial businesses.”
It is only possible to speculate about the underlying motives, but two elements of the announcement are striking. First, customers are apparently no longer willing to pay a price premium for a configure-to-order computer; thus, Dell is not delivering superior value compared with a standard product anymore and likely needs to redefine its solution space. Second, Dell seems to have had difficulties managing its costs, due to the increased complexity of the value chain. This point suggests that Dell needs to revise the robustness of its processes to combat variability in customers’ requirements. Indeed, Dell also has announced that it is establishing a segmented supply chain to deliver lean fixed configurations to consumer and small business segments and configurable-for-customization products to commercial segments.

But why do some companies succeed while others fail to undertake mass customization in the same industry? On closer inspection, all of the failures have been failures of execution, not of concept. What they have in common is a lack of specific capabilities in the area of product development, process design, and customer interaction (Agrawal et al. 2001; Zipkin 2001; Piller and Ihl 2002; Reibstein 2002; Piller 2005a; 2007). It is striking, however, that small start-ups that pursue mass customization as their core business often seem to outperform established companies in the same industry (Gownder et al. 2011). Implementing a new business concept such as mass customization apparently requires specific capabilities that established companies do not possess and find difficult to develop. For example, mass producers often have just too many customers to start a real interaction process and learn about their customers’ diverging needs. Moreover, it can be challenging to manage the shift from product-focused mass production to customer-centric mass customization (Piller 2005a). If nothing else, embarking on mass customization is much riskier than betting on another variant of a mass product. Analyzing the distinctive capabilities for mass customization thus can provide insights into the business failures of the past while also increasing understanding of how to implement a profitable and sustainable mass customization strategy.

The importance of studying mass customization capabilities has been stressed by several researchers. For example, Bardakci and Whitelock (2003, S. 465) state that the “implementation of a mass-customisation strategy requires different capabilities than for mass production.” Broekhuizen and Alsem (2002) emphasize that it is primarily organizational capabilities that determine the capacity of a company to capitalize on customers’
heterogeneous needs. These capabilities encompass manufacturing flexibility, distribution and logistics flexibility, and customer information dissemination (Broekhuizen and Alsem 2002, pp. 323-324). But success in pursuing mass customization may also require the transformation of organizational structures, value systems, methods for knowledge creation and ways of relating to customers (Kotha 1996, p. 448). These capabilities must be build in an evolutionary process toward a mass customized firm (van Hoek et al. 1999, p. 354). Accordingly, Pine et al. (1993, p. 109) suggest that from constantly trying to fulfill unique customer needs, a mass customization organization can produce a “growing envelope” of capabilities that relates to processes as well as people. In their empirical investigation of the link between capabilities and company performance, Tu et al. (2001, p. 213) postulate that “firms with MC capabilities should be able to capture high sales volume and generate greater profits than competitors without them.” Similarly, Kotha (1995, p. 22) notes that “in changing environments a firm’s ability to develop and maintain a sustainable competitive advantage lies in its capability … along with strategic flexibility.” However, Zipkin (2001, p. 82) cautions that mastering the capabilities critical to mass customization systems is not an easy task.

In summary, as illustrated by the practical examples, what distinguishes successful mass customizers from less successful ones is specific mass customization capabilities. If these capabilities are not present, then they must be acquired (or learned) if mass customization business ventures are to be successful. There also seems to be general agreement among scholars that mass customization firms must create distinctive capabilities that enable them to quickly reconfigure their resources and skills in response to customers’ heterogeneous needs or changing business environments. If adequately developed, these capabilities can be powerful sources of economic rents and sustainable competitive advantage (Barney 1991; Grant 1991). Yet little published empirical evidence offers suggestions regarding which strategic capabilities firms need to realize mass customization and how these capabilities might be developed in practice (Salvador et al. 2008). Consequently, Tseng and Piller (2003, p. 529) call for more conclusive research on the nature of these capabilities. This appeal is backed by Moser (2007, p. 62), who thoroughly reviews the literature with regard to comprehensive models of capabilities for mass customization and concludes that “the existing literature does not adequately cover this open field.” That is, much work in the field is
conceptual, not empirically founded, and focuses on specific problems associated with the pursuit of mass customization.

1.4 Research Questions and Objectives
This call for research has been addressed by Salvador et al. (2009), who propose a comprehensive model of three strategic capabilities that determine the fundamental ability of a company to benefit from mass customization. First, a company seeking to adopt mass customization has to identify the product attributes along which customer needs diverge the most. With this understanding, the company can decide what degree of variability it is going to offer and define the so-called solution space. Salvador et al. (2009, p. 72) call this capability solution space development (SSD). Second, increased variability in customers’ requirements cannot lead to significant deterioration in the company’s operations and supply chain. Instead, there must be a robust process design (RPD) so that customized solutions can be delivered with near mass production efficiency and reliability (Salvador et al. 2009, p. 74). Third, choice navigation (CN) refers to the ability to support customers in creating their own solutions while minimizing complexity and the burden of choice during the customization co-design process (Salvador et al. 2009, p. 74). A more detailed discussion of strategic capabilities for mass customization appears in Chapter 4.

Existing research typically conceptualizes mass customization in terms of its performance outcomes, that is, the simultaneous achievement of customization, low cost, responsiveness, and quality (e.g., Åhlström and Westbrook 1999; Tu et al. 2001; Liu et al. 2006; Huang et al. 2010). The proposed framework instead advances the current state of research by defining mass customization in terms of its antecedents, as represented by the three strategic capabilities. This is unquestionably a fundamental step toward the construction of a general theory of mass customization, one that can be broadly applied across different industries (Salvador et al. 2008). Although the strategic capabilities framework of Salvador et al. (2009) is seminal from a research perspective, it has yet to prove itself in practice. The true value of the framework stems from the proposition that mass customization firms can gain a sustainable competitive advantage by developing and enhancing the three strategic capabilities.
Following the philosophical approach of logical positivism (e.g., Hirschmann 1986; Hudson and Ozanne 1988), this work thus aims to explain the structure of strategic capabilities for mass customization and predict their economic impact, with a strong focus on identifying causal linkages. This implies a deductive approach; that is, deriving hypotheses from theory and then testing the theory. For this purpose, large-scale empirical surveys and multivariate statistical analysis are the methods of choice. Our study focuses on the following five research questions:

(1) What are the strategically relevant capabilities for mass customization?
(2) How do the strategic capabilities relate to one another?
(3) Which activities are positively related to the development of these capabilities?
(4) What are the performance implications of strategic capabilities for mass customization?
(5) Which contingency factors moderate their impact on performance?

To answer these research questions, this study pursues the following steps:

1. Identifying different sources of costs and benefits associated with mass customization. With this effort, it is possible to develop an understanding of the mechanisms through which mass customization generates value for the customers.

2. Exploring how mechanisms might be positively influenced by the firm, such that mass customization eventually generates a higher net value for the customer than any mass production or conventional differentiation strategy. For this purpose, the study builds on the capabilities framework proposed by Salvador et al. (2009) and substantiates it with findings from diverse research disciplines, including operations management, innovation management, strategic management, marketing, and psychology.

3. Empirically testing the proposed capabilities framework for the first time and demonstrating its relevance for theory and practice. For a start, this step requires the development of appropriate measurement instruments for the different capabilities and their antecedents.

4. Analyzing which methods, tools, and routines relate positively to the development of strategic capabilities for mass customization in practice.
5. Empirically investigating the impact of strategic capabilities on company performance. One relevant aspect to explore in this context is whether the distinctive capabilities for mass customization are complementary in their effect on performance.
6. Examining the moderating effects of several contingency factors on the effectiveness of the capabilities framework.
7. Translating the findings into concrete recommendations for practitioners regarding how to develop and improve strategic capabilities to support mass customization efforts.

1.5 Research Process Overview

Following this introductory chapter, this thesis presents five core chapters and a concluding final chapter. In Chapter 2, we take a customer perspective and identify the mechanisms through which mass customization generates value for the customer: The utilitarian and hedonic benefits of buying a mass customized product must be netted against the increased acquisition costs and search and evaluation costs. We also discuss how mass customization firms can influence these levers to achieve a positive net effect.

In Chapter 3, we take a firm perspective and discuss why it is beneficial for firms to accumulate resources and develop capabilities. The central theory in this regard is the resource-based view of the firm (RBV) and its different schools of thought. We then link our insights to the concept of strategic fit. The chapter also reviews different capability models found in prior literature on mass customization.

In Chapter 4, we elaborate on the strategic capabilities framework of Salvador et al. (2009) and discuss specific methods, tools, and routines to develop the capabilities in practice. To do so, we draw on findings from related research disciplines, such as operations management, innovation management, strategic management, marketing, and psychology. For each capability, the discussion produces concrete hypotheses to be tested empirically.

The empirical research design of this thesis is outlined in Chapter 5. We first describe the data collection process and present descriptive statistics for the responding firms. We then develop measurement instruments for all constructs and establish their reliability and validity by means of exploratory and confirmatory factor analysis.
In Chapter 6, we present the empirical results of our study. First, we establish the dimensional structure of strategic capabilities for mass customization. Second, we examine the impact of various correlates on the respective capabilities. Third, we analyze the performance implications of the strategic capabilities. Finally, we consider three contingency factors that likely moderate the relationship between mass customization capability and company performance.

In Chapter 7, we discuss the empirical results in detail, highlight the theoretical and managerial implications, point out limitations of the work and outline potential avenues for future research. In the final section, we present our conclusion and outlook on the future of mass customization.
2 Mass Customization from a Customer Perspective

Most conceptual and empirical literature on mass customization focuses on questions of whether and how firms can deliver customization efficiently. In this context, researchers mainly have analyzed the trade-offs between customization and dimensions of operational performance, such as costs, responsiveness, and quality (e.g., Tu et al. 2001; Squire et al. 2006b). Notwithstanding the relevance of this research from a firm perspective, the impulse to implement a mass customization strategy should come from the customer, rather than the production capabilities of the firm (Bardakci and Whitelock 2003, p. 464). The importance of such a customer focus is well summed up by Drucker (1973, p. 79): “to satisfy the customer is the mission and purpose of every business.”

2.1 Theoretical Basics of the Customer Value Concept

In order to deliver superior performance, a firm must develop and sustain a competitive advantage (Porter 1980). But while competitive advantage was once based on internal improvements such as quality management, reengineering, downsizing, and restructuring, the next major source of advantage will likely be a more outward orientation toward markets and customers (Woodruff 1997). This prediction is supported by several studies that find a positive relationship between market orientation and organizational performance (e.g., Narver and Slater 1990; Jaworski and Kohli 1993; Pelham and Wilson 1995). A business may be considered market-oriented if it places the highest priority on the profitable and continuous creation of superior customer value while taking into account the interests of other key stakeholders (Slater and Narver 1995, p. 67). Thus, shareholder value and customer value are clearly interrelated (Walters and Lancaster 1999, p. 698). Consequently, Woodruff (1997, p. 151) argues that customer value–based competition is a key trend in managerial practice. But what exactly does customer value mean? Successful implementation of customer value strategies requires a detailed understanding of the concept itself.

A major difficulty in researching value is the variety of meanings expressed by consumers. Even in a single product category, value is highly personal and idiosyncratic. Squire et al. (2004, p. 461) identify 11 customer value criteria (e.g., price, quality, design), of which customization is only one. A combination of several criteria likely represents the greatest value to customers, and value criteria generally are not static; what customers want today may
Zeithaml (1988, p. 14) thus defines perceived value as “the consumer’s overall assessment of the utility of a product based on perceptions of what is received and what is given.” (Other definitions are proposed by Anderson et al. (1993, p. 5) and Monroe (1990, p. 46).) Upon closer examination, these definitions exhibit several commonalities (Woodruff 1997, p. 141): First, customer value is inherent to the use of some product. Second, customer value is something perceived by customers, rather than objectively determined by vendors. Third, customer perceptions typically involve a trade-off between benefits and sacrifices, and what varies across customers is what gets received (e.g., volume, high quality, convenience) and what they give (e.g., money, time, effort).

If different vendors offer the requested product, customers will buy from the firm that they believe offers the highest delivered value (Kotler et al. 2008, p. 373). To determine their profit or net value (NV), customers compare the gross utility (GU) they derive from a product offering to the acquisition costs (AC) and search and evaluation costs (SEC) associated with it:

\[ NV = GU - (AC + SEC). \]

The value a consumer places on a good or service depends on the pleasure or satisfaction he or she expects to derive from consuming it at the point of making a consumption choice. In economics the pleasure or satisfaction consumers derive from the consumption of consumer goods is called “utility”. However, consumers’ choices are constrained by their disposable incomes. Within the limits of their incomes, consumers make their consumption choices by evaluating and comparing consumer goods with regard to their “utilities” (Silberberg and Suen 2001). Acquisitions costs include the quoted price for a product, less any discounts allowed, plus shipping charges. Customers’ main motivation to search for products is to find a lower price or a product they better like, but the search process naturally incurs costs (Anderson and Renault 1999, p. 720). Search and evaluation costs can be divided into external and internal costs (Smith et al. 1999, p. 290): External costs include the monetary costs of acquiring the information and the opportunity cost of the time devoted to searching, whereas internal costs (or cognitive costs) are determined by the consumer's ability to undertake the search, depending on his or her intelligence, prior knowledge, education, and training. As a matter of

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8 “Net value” is used synonymously with the term “customer delivered value” proposed by Kotler et al. (2008, p. 373) to emphasize that the benefits resulting from the purchase and utilization of an offered product are netted against the costs in this view.
course, customers only purchase a product if they can expect a positive surplus (Villas-Boas 2009, p. 1339).

Several authors have argued that mass customization offers more customer value than a mass manufacturing strategy because it matches specific customer needs at prices that reflect the efficiencies of a mass produced product (e.g., Gilmore and Pine 2000; Tu et al. 2001; Schreier 2006; Franke et al. 2009a; Franke and Schreier 2010). However, Zipkin (2001, p. 85) cautions that though mass customization can, and often does, increase the value of an offering, it is not guaranteed. The fundamental question is whether customers really appreciate the concept of mass customization and for which group of customers it is an appealing option (Kaplan et al. 2007, p. 102). From a customer perspective, the appeal of mass customization depends on a simple economic equation: If the perceived benefits exceed the expected sacrifices, the customer is more likely to adopt mass customization (Piller and Müller 2004, p. 590). Mass customization can increase perceived benefits; customers can expect to receive better fitting products and a more enjoyable shopping experience. But it also may increase their sacrifices in terms of a price premium, time and effort spent, and uncertainty (Broekhuizen and Alsem 2002; Squire et al. 2004). Applying the previously outlined logic then, mass customization potentially creates value by increasing the gross utility (ΔGU) to the customer but also raises both acquisition costs (ΔAC) and search and evaluation costs (ΔSEC). Figure 2 shows that these opposing effects mean mass customization does not necessarily create a higher net value than any mass production or conventional differentiation strategy (Salvador and Piller 2009). In this example, the increase in gross utility is outweighed by the increased purchasing and search and evaluation costs, which results in a lower net value (NV''<NV'). To better understand this seemingly counterintuitive result, the next section addresses what customers want and believe they get from buying and using a mass customized product—and what they need to sacrifice in turn. The relevance of these questions has been underscored by academics and practitioners alike (Franke et al. 2010, p. 127).
2.2 Utility to the Customer

The trend toward ever more product variety is mainly driven by people’s growing needs for self-actualization. Maslow’s (1943) well-known hierarchy of needs often is portrayed in the shape of a pyramid, because according to the hierarchy, people increasingly strive for self-actualization and individuality after their physiological needs (e.g., food, water, sleep) and basic needs for safety, love, friendship, and esteem are satisfied. In today’s postindustrial societies, customers demand far more than a mere satisfaction of physiological and basic needs (Inglehart 1997). As a consequence, the original function of the product as a good or service has less relevance, but its role as an embodiment of symbolic meaning is increasingly pertinent. This obliges firms to adopt new strategies consistent with the changing consumption behavior. The concept of mass customization recognizes the growing importance of subjectivity, because it allows customers to ask for personalized products with a level of individual tailoring that was never possible before (Addis and Holbrook 2001, pp. 51-52).

This section outlines the different sources of benefits that can explain the increment of utility that customers derive from customized products. In particular, broad consensus among researchers (e.g., Broekhuizen and Alsem 2002; Franke and Piller 2003; Merle et al. 2010) indicates two sources of benefits from mass customization: (1) the value of product customization (i.e., utility increment from a better preference fit) and (2) possible rewards
from the co-design process. This twofold conceptualization has been popularized by the service-dominant (SD) logic of marketing (Vargo and Lusch 2004) that distinguishes between value-in-use and co-production value (i.e., participation in the creation of the offering). Addis and Holbrook (2001, pp. 57-60) also differentiate between utilitarian and hedonic benefits. Utilitarian benefits refer to what a customer can gain from the physical characteristics and technical performance of a product. Hedonic benefits instead relate to the multisensory aspects of the customer’s experience with a product. For mass customization, hedonic aspects likely gain in importance, due to the experiential nature of co-design and consumption. Combining these dimensions of how customers might evaluate product customization leads to the matrix in Figure 3. Accordingly, Schreier (2006, p. 317) identifies four distinctive factors that influence a customer’s decision to adopt customized products: functional benefit from a better fit between individual needs and product characteristics, perceived uniqueness of the self-designed product, process enjoyment of self-design, and pride of authorship. Because utilitarian benefits of the co-design process relate to reduced complexity, effort, and risk, they are discussed in the context of search and evaluation costs in Chapter 2.4.

![Figure 3: Dimensions of Customer Evaluations of Product Customization (adapted from Ihl 2009, p. 32) | Utilitarian benefits | Hedonic benefits
--- | --- | ---
**Customized product** | **Better fit** | **Perceived uniqueness**
 |  | **Pride of authorship**
**Co-design process** | **Reduction of perceived complexity, effort and risk** | **Process enjoyment**

![Figure 3: Dimensions of Customer Evaluations of Product Customization (adapted from Ihl 2009, p. 32) | Utilitarian benefits | Hedonic benefits
--- | --- | ---
**Customized product** | **Better fit** | **Perceived uniqueness**
 |  | **Pride of authorship**
**Co-design process** | **Reduction of perceived complexity, effort and risk** | **Process enjoyment**

Figure 3: Dimensions of Customer Evaluations of Product Customization (adapted from Ihl 2009, p. 32)
Better fit

Customers derive benefits from a product’s physical characteristics and features when the resulting product helps them reach an intended outcome in a satisfactory manner (Fournier 1991). It is a straightforward economic argument that a better fit between needs and product characteristics increases benefits for customers (Franke and von Hippel 2003). In an empirical study, Franke and von Hippel (2003) show that customers have unique needs, leaving many displeased with standard products. Poor customer fit also serves to explain the high failure rates of new products (Cooper 2011). Managers, with their acute awareness of this possibility, likely prefer a market segmentation approach when confronted with high heterogeneity of needs among customers. Market segmentation is the attempt to distinguish “homogeneous groups of customers who can be targeted in the same manner because they have similar needs and preferences” (Wedel and Kamakura 2002, p. 181), which makes it possible to create somewhat different products to address the average customer need in each segment. Yet in a meta-analysis of published cluster analyses, Franke et al. (2009b) find that after segmentation, 40% of the total variation in customer needs remains unaddressed. High remaining within-segment heterogeneity then might lead to segment-specific product offerings, advertising campaigns, or other marketing activities that are not actually responsive to individual customers’ needs or preferences (von Hippel 2005). In this case, many customers are persistently dissatisfied with standard offerings that meet only the mean preference of average customers. This scenario motivates mass customization, because each customer can configure a unique product that exactly fits his or her preferences (Gilmore and Pine 1997). The increased aesthetic and functional fit of mass customized products is well documented (e.g., von Hippel 2001; Dellaert and Stremersch 2005; Simonson 2005; Randall et al. 2007; Franke and Schreier 2008). The greater the deviation between a customer’s ideal preference (P*) and the characteristics of the best standard product available (1–4), as illustrated in Figure 4 by the example of apparel, the more salient the utilitarian benefit of a self-designed product (Reichwald and Piller 2009, p. 221). Effective means for identifying the idiosyncratic and unexploited needs and preferences of customers and thus developing responsive product offerings are discussed in Chapter 4.1 on solution space development.
Perceived uniqueness

In addition to the utilitarian benefits, mass customized products might render hedonic benefits by meeting customers’ needs for uniqueness. According to the theory of uniqueness (Snyder and Fromkin 1997), people are motivated to maintain a sense of difference because being too similar to others constitutes a threat to their identity. Consumer goods that offer differentiation are particularly valued in this context, because they satisfy the need for uniqueness without risking severe social penalties (Snyder 1992), which is why customers purchase novelty or original goods, handcrafted items, and vintage or antique goods that are not available en masse. Accordingly, costumers’ need for uniqueness can be defined as “the trait of pursuing differentness relative to others through the acquisition, utilization, and disposition of consumer goods for the purpose of developing and enhancing one’s self-image and social image” (Tian et al. 2001, p. 52). It includes three behavioral dimensions: creative choice counterconformity, unpopular choice counterconformity, and avoidance of similarity. Creative choice counterconformity implies that the costumer seeks to distinguish him- or herself from most others while also making selections that are likely to be considered good choices by others. Unpopular choice counterconformity refers to the deliberate choice of products and brands that deviate from group norms and thus risk social disapproval, which consumers withstand to emphasize their difference from others. Finally, avoidance of similarity implies that customers devalue and avoid the purchase of products that become commonplace. The nearly infinite

Figure 4: Mass Customization Reduces the Distance between an Ideal Preference Point and Standard Products Available (Reichwald and Piller 2009, p. 221)
variety of mass customized products makes it likely that such products are perceived as highly unique, which enhances differentiation from other customers along all three dimensions (Lynn and Harris 1997; Fiore et al. 2004; Michel et al. 2009). With an empirical study, Franke and Schreier (2008) confirm that perceived uniqueness contributes independently to the utility a customer experiences from self-designing a product, beyond its aesthetic and functional fit. Michel et al. (2009) also conclude that the motivation to adopt mass customized products varies among consumers, possibly driven solely by a desire for uniqueness, exclusively by their ability to overcome the disadvantages of standardized products, or some combination. Therefore, retailers should highlight both utilitarian and hedonic aspects in promoting mass customized products.

**Process enjoyment**

Traditional marketing considers customers passive participants in the value creation process, up to the point of sale (Wind and Rangaswamy 2001). Yet Toffler’s book *The Third Wave* predicted three decades ago that “the most creative thing a person will do twenty years from now is to be a very creative consumer…. Namely, you'll be sitting there doing things like designing a suit of clothes for yourself or making modifications to a standard design, so the computers can cut one for you by laser and sew it together for you by NC machine” (Toffler 1980, p. 274). The advent of mass customization has made this vision reality. Customers increasingly are partners (not recipients) in the process, integrated into value creation by defining, configuring, matching, or modifying their individual solution from of a list of options and predefined components in a mass customization toolkit (Piller et al. 2004, p. 436). Therefore, perceptions of the co-design process should be considered, in addition to improved preference fit, when assessing customers’ decision to adopt mass customized products (e.g., Huffman and Kahn 1998; Franke and Piller 2003; Fiore et al. 2004; Dellaert and Stremersch 2005).

However, even if co-design activities are a necessary prerequisite of mass customization to fulfill individual needs, they also increase perceived complexity, effort, and risk, from the customer’s perspective (Piller et al. 2005). In this context, process enjoyment, defined as “a positive affective reaction elicited by the process of self-designing the product” (Franke and Schreier 2010, p. 1021), may appear counterintuitive, in that work is usually regarded as a disutility in conventional economic models. But in reality, work often is voluntary, and people
seem to derive intrinsic benefits despite the effort involved. Consider, for example, programmers contributing to open-source software (Hertel et al. 2003) or traditional do-it-yourself (DIY) markets (Williams 2004). People engage in these activities because they find the “doing itself” rewarding, enjoyable, and fun (Schreier 2006).

Theoretical evidence of such positive affective reactions can be drawn from self-determination theory (Ryan and Deci 2000; Gagné and Deci 2005) and the concept of “flow experience” (Csikszentmihályi 1990). The former postulates that people have basic psychological needs for competence (i.e., effective in dealing with the environment), relatedness (i.e., to interact, be connected, and care for others), and autonomy (i.e., urge to be causal agents of our own lives). Satisfying these needs provides a motivation driven by an interest or enjoyment in the task itself (i.e., intrinsic motivation). In addition, “flow” refers to a mental state in which a person is fully immersed in a feeling of energized focus, full involvement, and success while engaging in an activity. Testing specifically for positive affective reactions, Franke and Schreier (2010) find that customers attribute more value to a self-designed product if they enjoy the process. Similarly, Ihl (2009) confirms that enjoyment of the co-design process has a significant positive effect on customers’ purchase intention. These findings are analogous to empirical studies that show that customers’ perceptions of retail environments can have positive impacts on buying behavior (Mattila and Wirtz 2001). Effective means to make co-design processes more enjoyable and rewarding are discussed in Chapter 4.3 on choice navigation.

**Pride of authorship**

Whereas process enjoyment is a process-oriented benefit (i.e., the benefit of doing it oneself), an output-oriented benefit can come from having done it oneself, or the “pride of authorship” effect in mass customization literature (Franke and Piller 2004, p. 412; Schoder et al. 2006, p. 15; Schreier 2006, p. 324). Assigning a high subjective value to one’s own creations is not a rare case, as demonstrated by examples such as pottering, cooking, knitting, painting, or writing a book, for which the outcome is often valued over and above the value that arises from merely purchasing an objectively similar product (Norton et al. 2011). This effect is likely inherent to the concept of mass customization; customers complete the entire design task in an autonomous and controllable way and get immediate (simulated) feedback about the potential outcome of their design ideas from the mass customization toolkit (Schreier 2006).
Theoretical support for this pride of authorship effect is available in general literature on pride and the endowment effect. Pride is an emotion elicited by achievements, closely associated with self-esteem and a positive self-image if a favorable outcome can be attributed to one’s own efforts (Lea and Webley 1997). The endowment effect predicts that people place more value on objects they own than on objects they do not (Thaler 1980). In a revised model of psychological ownership it is suggested that “the most obvious and perhaps the most powerful means by which an individual invests himself or herself into an object is to create it” (Pierce et al. 2003, p. 93). Franke et al. (2010, p. 125) relabel this phenomenon as the “I designed it myself” effect, defined as “the value increment a subject ascribes to a self-designed object, arising purely from the fact that she feels like the originator of that object.” On the basis of five studies, they provide experimental evidence that having designed a product with a mass customization toolkit delivers a positive value increment compared with a product obtained off the shelf, beyond the product’s improved preference fit. This finding has important implications for the design of mass customization toolkits, as discussed in Chapter 4.3 on choice navigation.

**Willingness to pay (WTP)**

Noting these different value components of mass customization, it seems pertinent to ask how the value increment eventually might be quantified. According to Porter (1985, p. 3), “value is what customers are willing to pay.” Specifically, willingness to pay (WTP) is a ratio-scaled measure of the subjective value the buyer assigns to a product (Wertenbroch and Skiera 2002, p. 228). The difference in WTP between a mass customized product and the most preferred (chosen) standard product yields the value increment of customization (ΔWTP):

\[
\Delta WTP = \frac{WTP_{Mass Customized Product} - WTP_{Standard Product}}{WTP_{Standard Product}} \times 100\%.
\]

For example, if a customized shoe sells for $150 and a standard shoe for $100, the ΔWTP is 50%. The revealed ΔWTP is commensurate with the increment of utility (ΔGU) that customers gain from a customized product. As noted previously, this increment in utility might originate from a better fit, the perceived uniqueness of the self-designed product, enjoyment of the co-design process, or pride of authorship, or some combination of these effects. Several researchers empirically test for the effects and consistently find a higher WTP
for mass customized products. For example, Franke and Piller (2004) find a ΔWTP of 100% for self-designed watches compared with the best-selling standard watches with the same technical quality. Schreier (2006) also reports a value increment of more than 200% for customized cell phone covers and more than 100% for individualized t-shirts and scarves. In a more recent study, Franke et al. (2010) state that customers are willing to pay a 40% premium for self-designed t-shirts and 60% for custom skis. Therefore, mass customized products appear to create substantial value increments.

Merle et al. (2009) propose an integrative framework to bring together the value components and WTP for mass customized products. They conceptualize mass customization value according to two components: mass customized product value and mass customization experience value. Figure 5 illustrates the theoretical model, including hypothesized direct (H2, H3) and indirect (H1) effects.

Figure 5: Theoretical Model of Mass Customization Value (Merle et al. 2009, p. 211)

The results from an experimental study with 547 customers who customized their favorite pair of shoes using the NIKEiD program support two of their hypotheses (Merle et al. 2009). First, mass customization experience value has a strong influence on mass customized product value (H1). Second, mass customized product value has a positive impact on WTP (H2). However, mass customization experience value does not have a direct influence on WTP, invalidating their H3. Consequently, mass customized product value offers a perfect mediator of the effect of co-design value on WTP. These results have important managerial implications. To increase WTP for mass customized products, mass customizers should play on the product value in their marketing concept but also realize the positive impact of experiential value.
2.3 Acquisition Costs

Purchasers, whether individual consumers or businesses, typically recognize the actual costs of acquisition. Acquisitions costs refer to the overall costs to purchase goods and services. Along with the actual purchase price, the acquisition costs factor in delivery charges, closing costs, and any discounts granted. The acquisition costs for the customer reflect the costs to produce the product and the producer’s profit too. For most customers, price expectations are set by mass producers, who have constantly lowered their production costs in the past. As a consequence, customers expect to receive customized products at prices close to those for mass produced standard products, which presents a major challenge to mass customization firms (Tu et al. 2001, p. 204). Although early definitions of mass customization suggest otherwise (e.g., Davis 1987; Pine 1993; Hart 1995), theory and anecdotal evidence indicate that mass customized products are more expensive to produce than standard products (e.g., Agrawal et al. 2001; Zipkin 2001; Piller 2006). Higher costs arise along the whole value chain (Piller et al. 2004), as analyzed in detail in Chapter 4.2.1. To counterbalance these costs, mass customizers usually charge a price premium over standard products in the same category. According to the theory of monopolistic competition (Chamberlin 1962), product prices should reflect the utility provided to the customers; customers thus are willing to pay this premium only if it matches the increment in utility they attain from the customized product’s better fit with their preferences and the hedonic benefits they derive from customization (Kaplan et al. 2007).

Common practice in mass customization is it to tie prices to customizable product features and the respective quality levels (Bernhardt et al. 2007). The final price of the customized product thus depends on the specifications selected by the customer (Jiang et al. 2006). A classic example of this form of price differentiation is car configurators; discerning customers are usually willing to accept a higher price for increasing levels of vertical features (e.g., engine performance expressed in terms of horsepower) because of the higher expected utility (Herrmann et al. 2007). Two customers pay the same price only if they choose to configure the same customized product. In this pricing scheme, a customized product can theoretically also represent a price reduction instead of a premium, if customers select fewer features or lower levels than would be available in the base product. While the idea of customized pricing is very appealing, many mass customization firms follow a different approach: charging the
same price (premium) for the customized products even if different costumers choose different options in the customization process (Syam and Kumar 2006, p. 526). This pricing scheme is particularly advisable if customization is about horizontal features (e.g., color) and the marginal costs of production do not vary significantly with the “particulars” of customization (Bernhardt et al. 2007, p. 1402). For example, shoes with white laces cost Adidas as much to produce as shoes with blue laces. Accordingly, miadidas differentiates prices based not on features, but on product categories: Customized shoes sell on average for about $130–150, compared to $100 for the standard model (Berger et al. 2005). The managerially relevant question of which strategy will ultimately result in a higher purchase price is discussed in Chapter 4.3.2.

### 2.4 Search and Evaluation Costs

Generally, customers try to gain an overview of the alternatives being offered in the market, before deciding whether to expend effort to evaluate product alternatives. This search process invokes monetary costs of acquiring the information and opportunity costs of the time taken to search. After observing the number of alternatives available, a customer then decides whether it is worth incurring evaluation costs to find a satisfactory fit. Processing information about the product attributes of each product and the corresponding prices is costly and takes time. Kuksov and Villas-Boas (2009) postulate that evaluation costs may cause customers not to buy (not to incur evaluation costs) if choice is proliferating. This reasoning goes back to information overload literature (e.g., Jacoby 1977; O'Reilly III 1980; Malhotra et al. 1982) and the idea that decision makers can process only a limited amount of information (e.g., Miller 1956; Shugan 1980; Simon 1995). In this respect, Hauser and Wernerfelt (1990) argue that customers strategically limit their consideration sets to reduce evaluation costs. But how much choice is enough or too much? Contemplating this question is essential for determining a mass customization strategy.

Choice literature begins with a donkey. In the fourteenth century, the French philosopher Jean Buridan argued that if forced to choose between a stack of hay and a pail of water, a hungry and thirsty animal would be paralyzed by indecision and die. This paradox is commonly referred to as Buridan’s ass (Rescher 1960). Making the right choice is even more difficult in a multifaceted choice setting. The average U.S. supermarket stocks close to 50,000 items, more
than five times the number in 1975. Britain’s Tesco offers 91 different shampoos, 93 varieties of toothpaste, and 115 versions of household cleaner (The Economist 2010). Amazon lists nearly 24 million books, and digital television provides hundreds of channels (Iyengar 2010). Although it seems logical to assume that if some choice is good, more is better, recent research suggests that psychologically this assumption is inaccurate. Observing growing trends of clinical depression, psychologist Barry Schwartz (2002) argues that Americans are more affluent but also sadder than ever before. No single factor can explain decreased well-being, but the explosion of choice definitely appears to be part of the answer. Free choice is frequently deemed a cornerstone of liberal democracy that makes markets work, drives competition, and generates economic growth. But if freedom of choice becomes excessive, it might create a tyranny of choice (Schwartz 2004). Empirical evidence concurs that choice can be demotivating. In a landmark experiment, Iyengar and Lepper (2000, pp. 996-998) set up a tasting booth in an upscale grocery store in California that displayed either a limited (6) or an extensive (24) selection of different jam flavors. The findings were striking: Of the customers who passed the extensive selection, 60% stopped at the booth, whereas only 40% of the customers who passed the limited selection of jams stopped. However, nearly 30% of the customers in the limited choice condition went on to purchase a pot of jam, compared with merely 3% in the extensive choice condition. The authors thus conclude that an extensive array of options can seem highly appealing at first, but it subsequently reduces consumers’ motivation to purchase the product. They repeated the experiment with chocolate and student essay topics and found similar results. Therefore, they formulate a choice overload hypothesis: Facing too many attractive options ultimately decreases the motivation to choose any of them. Similar results emerge from experiments with choices among pens (Shah and Wolford 2007), gift boxes (Reutskaja and Hogarth 2009), coffee (Mogilner et al. 2008), and even 401(k) pension plans (Iyengar et al. 2004). Huffman and Kahn (1998) also observe a similar effect in the context of mass customization, which they label mass confusion.

Schwartz (2004, p. 73) also proposes a threshold in the relationship between the number of available choices and customer satisfaction, beyond which added choice decreases happiness. Figure 6 shows the proposed inverted U-shaped relationship between variety and the positivity of the consumption experience.
The curve on the graph can be divided into three segments (Desmeules 2002, pp. 9-10): (I) an upward sloping segment, (II) a relatively flat section, and (III) a downward sloping segment. The three segments are separated at satisfaction and regret. Adding an option in segment (I) increases the positivity of the consumption experience, because it increases the chance of meeting the customer’s needs. Theoretically, satisfaction could be attained with one option, but the point probably requires more choices in most cases. With satisfaction, the figure enters a relatively flat section, such that additional options considered (or ignored) by customers have little effect on their experience. Past the point of regret though, customer happiness decreases due to the stress, frustration, and anticipated or experienced regret created by an overabundance of choices. Regret is a potent force in human decision making (Festinger 1957), and as the number of option grows, customers experience increasing feelings of doubt about their choice. The customer even may quit the purchasing process due to an inability to conduct all the evaluations necessary to arrive at an optimal choice. However, the point of regret differs on an individual level and depends on a customer’s expertise in a certain domain, expectations, risk perceptions, and involvement. German consumers, for instance, appear less overwhelmed by choice than Americans are (Scheibehenne et al. 2010), and younger people who grow up surrounded by abundant choice presumably should be less intimidated by it. Therefore, firms need to understand their customers’ identity. For example, Schwartz et al.
(2002) distinguish between “maximizers” (who always aim for the best possible choice) and “satisficers” (who accept a “good enough” choice). When satisficers find a product that meets their standards, they stop looking. But maximizers make great efforts to compare every option, so making a purchase decision becomes increasingly discouraging as the number of choices rises. Worse, after making a decision, they are afflicted by thoughts of the alternatives they lacked time to investigate. Thus maximizers objectively make better choices than satisficers, but they derive less satisfaction from them.

These findings have important managerial implications. Boatwright and Nunes (2001) demonstrate that reducing the number of low-selling stockkeeping units (SKU) on an online grocery site increased sales by 11% on average across 42 product categories. When Procter & Gamble cut the number of Head & Shoulders shampoos from 26 to 15, sales increased by 10% (Schiller and Burns 1996). Do these findings thus call a mass customization strategy into question? Actually, they provide good arguments in favor of customization: Increased variety may enable a few additional customers to find a product that meets their needs, but only at the expense of increased time and effort sorting through alternatives. And most customers still fail to find a perfect match. As Gilmore and Pine (1999, p. 76) put it: “Fundamentally customers don’t want choice; they just want exactly what they want.” It is important to realize that variety is not the same as customization (Pine et al. 1993, p. 114). Increasing assortment variety thus implies preservation of the mass production paradigm, whereas customization demands production in response to a customer’s particular needs.

In addition to excess choice, Piller et al. (2005, p. 9) identify two other sources of search and evaluation costs during the customization co-design process: (1) difficulties matching needs to product specifications and (2) an information gap about the manufacturer’s behavior. First, customers often lack the technical knowledge and skills to transfer their personal needs into an explicit product specification (Jeppesen 2005; Randall et al. 2005; Franke et al. 2008). Even a standard, relatively simple product like a shirt becomes quite complex when one has to decide among countless designs, fabrics, collars, sleeves, cuffs, pockets, buttons, and monograms— not to mention take one’s own measures correctly. Customers faced with these challenges likely fear their potential to create aesthetically or functionally displeasing products. Other cognitive costs can arise from discrepancies between customers’ subjective and objective needs. Subjective needs lead customers to make particular decisions, but objective needs lead
customers to make an optimal decision, if they knew them (Abdelkafi 2008, p. 115). But what customers want at the time of purchase often exhibits low correlations with what they prefer at the time of the consumption, such that customers “miswant” their previous purchases (Riquelme 2001, p. 441). When product assortments encompass high variety, customers tend to configure and purchase products that fail to match their real requirements (Syam et al. 2008, p. 380). Second, product customization is still an unfamiliar process for many customers, which causes uncertainty (Terwiesch and Loch 2004, p. 147). The co-design process between the customer and the mass customization firm may involve an asymmetrical distribution of information—a typical principal-agent relationship (Fama and Jensen 1983). The customer (principal) orders and often pays the mass customizer (agent) in advance for a product, before having seen or tested it, and usually must wait considerable time before receiving it (Piller 2005a, p. 324). In other words, the temporarily intangible product might produce unpleasant surprises and feelings of regret when it finally arrives (Randall et al. 2005, p. 80). The standard agreement that firms are not obliged to replace products customized to the customer’s specifications exacerbates the problem. Therefore, to overcome the mass confusion phenomenon and effectively reduce search and evaluation costs, mass customization firms must develop adequate capabilities that facilitate choice navigation, as discussed in more detail in Chapter 4.3.

In summary, firms are increasingly competing on the aspect of delivering superior customer value (Woodruff 1997). While it is often argued that mass customization offers greater customer value than a mass production strategy, this is not necessarily the case (Zipkin 2001). Mass customization can potentially create value by increasing the utility to the customer, but it also raises both acquisition cost and search and evaluation cost; the net effect is a priori uncertain (Salvador and Piller 2009). However, firms can positively influence the mechanisms through which mass customization generates value for the customer by developing several core capabilities, the nature of which is the subject of the next chapter.
3 Mass Customization from a Strategic Firm Perspective

An organization’s ability to successfully involve customers in co-design processes is a function of the resources it possesses or develops (Hart 1995; Brown and Bessant 2003). Resources and capabilities are critical considerations in formulating a strategy that might deliver a sustained competitive advantage to any company (Barney 1991; Grant 1991). Consequently, mass customization literature has focused largely on resources in the past (Squire et al. 2006a). A number of articles have investigated how factors such as product strategies (Duray 2002), manufacturing strategies (Brown and Bessant 2003), process technology (Kotha 1996), and organizational structures (Vickery et al. 1999) can aid the implementation of a mass customization strategy. However, to contribute to sustainable competitive advantage, these resources must also be deployed in ways that differentiate how a specific company fulfills heterogeneous customer needs; and they must be combined with other resources and embedded in a set of functional policies and activities to raise the barriers to imitation (Collis and Montgomery 1995).

3.1 The Resource-Based View

The market-based view of the firm, long the dominant theory in strategic management (e.g., Bain 1956; Caves and Porter 1977; 1978), explains the competitive advantages of a company with primarily exogenous factors, such as relative positioning and industry structure (Porter 1991, p. 100). In contrast, the resource-based view (RBV) assumes that firms differ in their internal resources, and this heterogeneity provides the source of performance differences (e.g., Wernerfelt 1984; Barney 1991; Peteraf 1993). Resources are the tangible and intangible assets or inputs to production that a firm owns, controls, or has access to (Helfat and Peteraf 2003, p. 999). For this work, the RBV applies to explore possible reasons behind the mixed successes of mass customization business ventures.

Penrose (1959, p. 24) was the first to emphasize that firms are essentially “a collection of productive resources,” which they must combine effectively to enhance competitive positions. Building on Penrose’s idea of looking at firms as broader sets of resources, Wernerfelt (1984, p. 171) coined the term “resource-based view” and discussed the correlations among resources, products, and firm performance. Firms thus could earn above-normal returns by identifying resources that sustain a resource position barrier (Wernerfelt 1984, pp. 173-175).
Barney (1991, p. 105) formalized this literature into a comprehensive theoretical framework and based his discussion of the RBV on two fundamental assumptions: Resources are *heterogeneously distributed* among firms and are *immobile*. For competitive advantage to emerge and persist, resources must fulfill the *VRIN* criteria (Barney 1991, pp. 106-112):

- **Valuable**: A resource must enable the firm to deploy a value-creating strategy, either by exploiting opportunities or by neutralizing threats in the firm’s environment.
- **Rare**: By definition, a valuable resource possessed by many competitors cannot be a source of a competitive advantage.
- **In-imitable**: Valuable and rare resources can be sources of sustained competitive advantage only if competitors cannot replicate these strategic assets perfectly.
- **Non-substitutable**: Even if a resource is rare, potentially value-creating, and in-imitable, there must be no strategically equivalent resource that enables a competitor to implement the same strategy.

However, meeting the VRIN criteria is not of itself sufficient to sustain a competitive advantage, because resources are less heterogeneously distributed than previously assumed (Eisenhardt and Martin 2000, p. 1108). Thus the differentiation between resources and capabilities demands further elaboration, as offered by the capability-based view.

### 3.2 The Capability-Based View

The RBV postulates that firms can gain a competitive advantage by being more effective than their competitors in *selecting* resources. In contrast, the capability-based view asserts that firms gain a competitive advantage by being more effective than their rivals in *deploying* resources. Consequently, Makadok (2001, p. 389) defines capabilities as “an organizationally embedded non-transferable firm-specific resource whose purpose is to improve the productivity of the other resources possessed by the firm.” Similar differentiations between resources and capabilities have been suggested by Grant (1991, p. 118) and Amit and Schoemaker (1993, p. 35). Moreover, Teece at al. (1997, p. 529) clarify that “capabilities cannot easily be bought; they must be built.” In this sense, the resource-based and the capability-based views are not mutually exclusive but rather complement each other. By
definition, capability building does not improve profitability if the firm fails to acquire the resources whose productivity would be enhanced by its capabilities (Makadok 2001, p. 394).

Management literature readily adopted the capability-based view and highlighted examples of companies with particular capabilities that outperformed their competitors. Prahalad and Hamel (1990) use the term core competencies to refer to capabilities and present the case of NEC versus GTE. In the early 1980s, both companies had comparable business portfolios, but GTE enjoyed almost three times the sales of NEC. By 1988, GTE’s international position had eroded, and NEC’s sales were considerably higher. Why did these two companies perform so differently? The authors trace the reason back to NEC’s belief that it was not a collection of strategic business units but rather a portfolio of core competencies. Core competencies represent the company’s collective knowledge about how to deploy diverse production skills and technologies. Thus, even if a company seems to comprise portfolios of unrelated businesses, in terms of end products, customers, and distribution channels, its underlying core competencies make the disparate businesses coherent. For example, Canon’s core competencies in optics, imaging, and microprocessors have enabled it to enter such seemingly diverse markets as copiers, laser printers, cameras, and scanners. To sustain a competitive advantage, a core competence must provide potential access to a wide variety of markets, significantly contribute to the perceived customer benefits of the end product, and be difficult for competitors to imitate (Prahalad and Hamel 1990, p. 84).

Stalk et al. (1992, p. 57) instead compare Walmart to Kmart, which leads them to proclaim a new era of “capabilities-based competition.” Competitive advantage can be achieved by transforming a company’s key business processes into hard-to-imitate strategic capabilities. To be strategic, business processes must be linked to real customer needs and distinguish a company from its competitors in the eyes of customers. Finally, competing on capabilities requires strategic investments in a support infrastructure that transcends traditional strategic business units (SBUs) and functions and goes beyond justifications based on conventional cost–benefit metrics (Stalk et al. 1992, p. 62). One example of such a strategic capability is Walmart’s expertise in inventory replenishment, which reduces its inventory and handling costs and makes its low prices possible. These everyday low prices lure in customers, which allows Walmart to reduce the expenses associated with frequent promotions. If the key processes are designed to be flexible and robust, such that the same set serves many different
businesses, capabilities-based companies can rapidly enter new segments or markets and enjoy huge growth opportunities. Walmart thus repeated its success in other retail sectors, including pharmacies, no-frills grocery stores, and warehouse clubs. Kmart instead filed for Chapter 11 bankruptcy protection in 2002 and merged with Sears in 2004 (Hakim and Kaufmann 2002).

The capabilities-based view thus provides a first clue as to why some companies succeed in mass customization while others fail: They may differ in the way they exploit their resource endowments. But both the resource-based and the capability-based views are static in concept and do not elucidate how firms can sustain competitive advantages in dynamic environments (Priem and Butler 2001, p. 33). Such an understanding is a prerequisite for evaluating business models in highly dynamic markets for customized products.

3.3 Dynamic Capabilities

Teece et al. (1997) were among the first to address the limitations of the RBV by rethinking firms’ competitive advantage in turbulent environments. They propose a dynamic capabilities framework “to explain how combinations of competencies and resources can be developed, deployed, and protected” (Teece et al. 1997, p. 510). The framework attempts to explain firm-level success and failure in industries marked by rapid change in technology and market forces. Dynamic capabilities are “the firm’s ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments” (Teece et al. 1997, p. 516). Thus unlike the RBV, which emphasizes “resource picking” or selecting valuable synergistic combinations of resources, the dynamic capabilities framework focuses on “resource renewal,” that is, reconfiguring existing synergistic combinations of resources into new operational capabilities (Makadok 2001, p. 388). According to Teece et al. (1997, pp. 518-524) the firm’s resource renewal ability is driven by processes, positions, and paths. Managerial and organizational processes refer to how resources get coordinated and integrated. But processes also imply learning, which enables a firm to reconfigure and transform its resource endowments. The firm’s position is determined by its specific assets, including both internal (e.g., technological, financial, structural) and external (e.g., reputation, market structure, institutional settings) assets. Finally, the notion of path dependencies recognizes that a firm’s future behavior is determined by its repertoire of routines, its “history.”
Eisenhardt and Martin (2000, p. 1108) further state that dynamic capabilities exhibit greater commonalities (e.g., best practices) across firms than traditional RBV thinking would imply. Thus dynamic capabilities are necessary but not sufficient conditions for sustained competitive advantage (2000, p. 1106). Although dynamic capabilities typically are valuable and rare, these authors challenge the assumption that they are also in-imitable and non-substitutable. Dynamic capabilities are imitable because managers can begin to develop a capability from different starting points and take unique paths but still end up with similar capabilities. Moreover, dynamic capabilities are substitutable, because best practices exist for particular capabilities across firms. Especially in high-velocity markets, dynamic capabilities are often simple, experiential, iterative, and unstable, which makes them difficult to sustain (2000, p. 1113). Eisenhardt and Martin (2000, p. 1118) thus conclude that the strategic value of dynamic capabilities lies in their ability to alter resource configurations into value-creating strategies, not in the capabilities themselves.

The concept of dynamic capabilities also applies to the present work. Markets for mass customized products clearly represent highly dynamic environments. Established methods to reduce uncertainty in mass markets, such as market segmentation (e.g., Smith 1956), customer demand planning (e.g., Moon et al. 2000), or product lifecycle management (e.g., Grieves 2007), are less effective in such environments. Thus managers in markets for mass customized products must continuously create new, situation-specific knowledge and routines, based on their interactions with customers, and then reconfigure business models accordingly. Furthermore, all mass customization companies have access to more or less the same customization tools and practices. Sophisticated configuration technology is readily available in the market, and practices such as product modularity, process modularity, or postponement are virtually common knowledge. Consider the example of customized muesli: In principle, the same ingredients are available to all market players, and the mixing does not require specialized skills or expensive machinery. Yet the German market leader mymuesli.com has far outpaced its clones, such as kern-energie.com, müsli.de, and muesli4ever.de, in terms of both volume and sales—not to mention General Mills, which soured on its attempt to establish a similar business in the United States, despite its superior resource endowments and strong market positioning. Disregarding first-mover advantages, mass customizers appear to compete
primarily on how they leverage existing resources through configuration, complementarity, and/or integration (Tseng and Piller 2003, p. 529).

### 3.4 Strategic Fit

The concept of fit has a long tradition in the strategy literature (Venkatraman and Camillus 1984; Venkatraman 1989). It is commonly held that the suitability of a firm’s strategy can be defined in terms of its external and internal fit (Zajac et al. 2000).

*External fit* demands that organizations match their structure and processes to environmental contingencies (Miller 1992). As Miles and Snow (1994, p. 12) put it: “The process of achieving fit begins, conceptually at least, by aligning the company to its marketplace … this process of alignment defines the company’s strategy.” For example, to cope with uncertain environments, firms may foster organizational differentiation and specialization (e.g., Lawrence and Lorsch 1967), scan markets for emerging trends, threats, and opportunities (e.g., Hambrick 1982), and promote flexible, informal decision making (e.g., Fredrickson 1984). In this respect, the pursuit of mass customization can generally be seen as an attempt by firms to improve external fit, that is, to keep up with the individualization of demand and better align the organization with its customers’ needs (Salvador et al. 2009, p. 71).

On the other hand, *internal fit* refers to the alignment between strategy, structure, systems, and other organizational activities within the firm (Miller 1996; Siggelkow 2001). It is important to note, however, that internal fit should not be thought of as bivariate relationships between variables, but as internally consistent gestalts or configurations, describing a state of congruence among a larger set of organizational elements (e.g., Drazin and van den Ven 1985; Miller 1986; Meyer et al. 1993). Accordingly, Nadler and Tushman (1997, p. 23) see organizations as “highly integrated system[s] whose performance is determined by the degree of alignment among the major elements.” The importance and complexity of achieving internal fit is also a central theme in the mass customization literature (McCarthy 2004; Kumar 2005). As previously discussed, many firms embarking on mass customization seem to have difficulties in aligning their different modes of organizational structures and value chain

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9 It is the core construct of fit that unites the contingency perspective (Drazin and van den Ven 1985; Venkatraman and Prescott 1990). Contingency perspectives include structural contingency theory (e.g., Burns and Stalker 1961; Pennings 1992) with its emphasis on external fit, as well as configurational studies (e.g., Miles and Snow 1978; Miller 1986) concerned with internal fit.
constellations in order to develop suitable mass customization capabilities (Tseng and Piller 2003, p. 529).

Both external and internal fit have traditionally been viewed as having positive performance implications (Drazin and van den Ven 1985; Ginsberg and Venkatraman 1985; Miles and Snow 1994). A stronger view is that strategic fit may contribute to enhancing and sustaining competitive advantage (Miller 1996; Porter 1996; Rivkin 2000). In the widely known *Harvard Business Review* article “What is strategy?”, Porter (1996) prominently featured the concept of fit, suggesting that strategy is essentially about combining activities. To support this proposition, he cites the example of Southwest Airlines, the largest airline in the U.S. in terms of passengers carried, which has remained profitable for over 30 years at a time when the airline industry is troubled with fare wars, mass layoffs, and soaring operating costs. The competitive advantage of Southwest cannot be explained by a single element; it is based on various activities that fit and reinforce one another in order to deliver low cost and convenient service to the customers (Porter 1996, p. 70). For instance, Southwest reduced turnaround time at the gate by avoiding congested hub-and-spoke airports and opting for short-haul, direct flights. Through this faster turnaround, they are able to keep planes flying longer hours than competitors and provide frequent departures with fewer aircraft. The strict limitations on the type and length of routes allow it to use a standardized fleet of Boeing 737 aircraft, which boosts the efficiency of maintenance (Porter 1996, p. 64). Creative solutions have further lowered costs, such as being the first airline to introduce ticketless travel, which allowed Southwest to avoid travel agent commissions. Another low-cost approach was abandoning full-service activities that slow down other airlines such as cargo, meals, seat reservations, interline baggage checking, or premium service classes. Moreover, Southwest implemented a profit sharing program so that employees would feel and act like they owned the company. This provides them with a motivation to increase productivity in turnarounds, therefore boosting profitability. Finally, an important pillar of Southwest’s strategy is branding and loyalty building. Southwest makes heavy use of marketing to present itself as a low-cost leader, even though it may not always offer the cheapest fare (for a comprehensive analysis of the success factors of Southwest, see Freiberg and Freiberg 1996; Gittell 2003). The fit among these activities substantially reduces costs and increases differentiation from the competition. Porter (1996, pp. 71-73) identifies three generic types of fit: (1) simple consistency between
each activity and the overall strategic goals, (2) mutual reinforcement between activities, and (3) optimization of effort across activities to eliminate redundancy and minimize unnecessary effort. Much of the recent literature on fit focuses on activities that reinforce each other, that is, the value of one activity is increased by the presence of other elements (e.g., Siggelkow 2002; Makadok 2003; Carmeli and Tishler 2004).

Strategic fit between an organization’s activities is fundamental not only to creating competitive advantage but also to sustaining that advantage (Porter 1996, p. 73). Over time, the critical ingredients of Southwest’s winning strategy were revealed through numerous journal articles, case studies, analyst reports, and books by former executives (e.g., Hallowell 1996; Bunz and Maes 1998; Gittell 2003). It seemed that nearly any competitor could imitate Southwest’s activities and Continental Airlines decided to attack Southwest on a number of point-to-point routes with its budget carrier Contintental Lite. After all, any airline could lease the same planes, increase departure frequency, shorten turnaround time, and eliminate meals and first-class service. Yet Continental Lite proved to be unprofitable and was finally ceased after only two years of operations (Porter 1996, pp. 68-69). This raises the question of what makes a strategy inimitable even though it is open to public scrutiny. Using simulation studies, Rivkin (2000) suggests that the complexity of a successful business strategy raises a barrier to imitation. Strategic complexity is determined by the sheer number of elements in a strategy and the degree of interaction among them (Simon 1962). Hence, by tightening the fit among its large number of activities, a firm can prevent imitation even if each individual activity is imitable (Rivkin 2000, p. 825). When activities complement each other, competitors can gain little from imitation unless they successfully match the entire system. Therefore, a competitive positioning built on a system of activities is far more sustainable than one based on individual activities (Porter 1996, p. 73). A number of empirical studies beyond the airline industry support the notion that complexity can raise a barrier to imitation: McDuffie (1995) finds that human resource practices in the auto industry affect performance not individually but as coherent bundles; and that these practices are more difficult to imitate when they are integrated with manufacturing policies under the organizational model of a flexible production system. In their analysis of the steel finishing industry, Ichniowski et al. (1997) also document clusters of complementary human resource practices that successfully resist imitation. In a study of the innovation process in the pharmaceutical industry, Cockburn et al. (2000) show
that many firms are slow to adopt the favorable combinations of practices that make their rivals’ science-driven drug discovery effective.

The strategic fit theory also supports the postulation of the resource-based view (RBV) of the firm. In particular, the RBV assumes that firms can be conceptualized as bundles of resources which drive variability in organizations’ performance (e.g., Penrose 1959; Wernerfelt 1984; Barney 1991; Peteraf 1993). Like activity systems, when these resources exhibit reinforcing complementarities, their potential to create and sustain competitive advantage is enhanced (Collis and Montgomery 1995). Recent empirical work has begun to explore the linkage between the RBV and the concept of fit even more explicitly (see, for example, Zajac et al. 2000; Carmeli and Tishler 2004). The topic of fit has also been seen as having significance for the dynamic capabilities perspective. Studying deregulation of the U.S. airline industry, Peteraf and Reed (2007, p. 1089) suggest that “the ability to achieve fit under changing conditions may express a dynamic managerial capability.”

However, despite its widespread adoption in the field of strategic management, the concept of fit has been repeatedly criticized because of the weak links between theory building (i.e., verbalizing fit-based relationships) and theory testing (i.e., statistical testing of such relationships) (Galbraith and Nathanson 1979; Venkatraman and Camillus 1984). This criticism is tied directly to problems in translating the postulated relationships to the analytical level, including how to measure fit and test for both its existence in organizations and its performance effects (Drazin and van den Ven 1985; Venkatraman 1989). Accordingly, Schoonhoven (1981, p. 351) laments the lack of specificity as to the nature of fit and notes that “the mathematical function of the implied interaction…is seldom made explicit.” To overcome this weakness, economists have begun to create mathematical frameworks that allow rigorous modeling of mutually reinforcing interactions (Siggelkow 2001). In particular, the economic theory of complementarity by Paul Milgrom and John Roberts (1990; 1995) outlines the super-additive value of combining activities. Analyzing the shift from traditional mass production to modern lean manufacturing, the authors find that various elements of a firm’s strategy, including flexible machines, highly skilled and cross-trained workers, broad product lines, small batch sizes, and cross-functional development teams, tend to be adopted together, such that each makes the others more effective (Milgrom et al. 1991, p. 84). As they define it, Edgeworth complementarities between activities exist “if doing (more of) any one of them
increases the returns to doing (more of) the others” (Milgrom and Roberts 1995, p. 181). This notion is often expressed in the phrase, “the whole is more than the sum of its parts” (Milgrom and Roberts 1995, p. 184). Researchers in diverse fields have adopted the notion of complementarities, which provide important sources of path dependence (Dewatripont and Roland 1996), self-propelled change (Milgrom et al. 1991), and diversification (Granstrand et al. 1997). For example, human resource management practices (Laursen and Foss 2003), organizational learning processes (Lichtenthaler 2009), and marketing and technological capabilities (Song et al. 2005) have been found to exhibit complementarity. As Whittington et al. (1999, p. 584) assert, the work on complementarities has helped to legitimize the concept of fit, particularly that of internal fit.

In the light of this discussion, a relevant question emerges: Does each of the three strategic capabilities proposed by Salvador et al. (2009) have a positive benefit for the mass customization firm, or are these capabilities complementary in their effect on company performance, such that they should be developed simultaneously? The ways in which strategic elements and complementarities among them can enhance a mass customization firm’s performance are discussed in more detail in Chapter 4.4.2.

Finally, this section concludes with a mention of Grant’s (1991, p. 133) notion that capabilities “are the primary constants upon which a firm can establish its identity and frame its strategy, and they are the primary sources of the firm’s profitability.” How academic literature on mass customization caters to this perception is the topic of the following section.

3.5 Literature Review: Mass Customization Capabilities

A count of the number of published academic articles on mass customization reveals that research interest has been high for several years. From 2000 to 2010, 423 peer-reviewed articles addressing the topic of mass customization were published in academic journals (Source: EBSCO Business Source Premier). A full-text search used both “mass customization” and “mass customisation” as search terms but not other terms, such as personalization. Moreover, because the analysis was conducted on February 14, 2011, it is likely that the full year of 2010 was not included. The resulting number thus can only be indicative. Figure 7 provides additional details about the literature analysis.
From a strategic firm perspective, we are particularly interested in research on the distinctive capabilities mass customization firms should develop to alter their resource configurations into value-creating strategies. A number of researchers have studied mass customization capabilities by applying the concepts and terms of the RBV theory (e.g., Wikström 1996; Zipkin 2001; Squire et al. 2006a). But literature that systematically reviews, compares, and evaluates existing work on these capabilities is scarce. Although da Silveira et al. (2001), Berman (2002), Broekhuizen and Alsem (2002), and Blecker et al. (2005) present some relevant results, they include only a small selection of articles in their reviews and fail to apply theoretical frameworks in their evaluations.

The first comprehensive review of literature on mass customization competencies is presented by Moser (2007, pp. 52-62) who lists 60 articles during 1993–2005.10 These articles were identified in the EBSCO Premier Source Database, by applying a set of predefined search terms listed in Appendix 8.1.1. These results then were supplemented with articles on mass customization competencies retrieved from other databases and sources. To assess these articles, Moser (2007, p. 39) draws on the generic value chain concept (Porter 1985) and derives a conceptual framework of seven distinctive competencies. That is, the primary

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10 Moser (2007, p. 32) notes that the terms “competencies” and “capabilities” are essentially interchangeable. However, for the sake of clarity, we use the term “competencies” when referring to Moser’s (2007) framework and the term “capabilities” in connection with the framework of Salvador et al. (2009).
activities of a mass customization organization consist of (1) product development, (2) customer interaction, (3) production, and (4) logistics, whereas its support activities are (5) IT systems, (6) complexity management, and (7) leadership & organization. The resulting analytical scheme covers research types (conceptual, empirical case study, empirical statistical), an evaluation of the comprehensiveness of the results (comprehensive model, model of competencies, list or individual competence), and the areas of competencies considered. Thus Moser (2007) derives four important findings:

1. Most articles focus on analyzing a selection of or individual competencies (Moser 2007, p. 54). Few authors (e.g., Zipkin 2001; Potter et al. 2004; Blecker et al. 2005) attempt to develop comprehensive models.

2. Competencies related to “production” dominate the field; they are discussed in 33 of the 60 analyzed articles (Moser 2007, p. 54). This focus is not surprising, because the mass customization discussion originated with flexible manufacturing, and the first generation of mass customization companies mainly tried to capitalize on the benefits of efficient flexibility (Piller 2005a, p. 329).

3. The capabilities presented in the literature are often difficult to relate to specific practices and methods, and can hardly be associated with an effect on company performance (Moser 2007, p. 61).

4. Most research is either conceptual or conducted empirically with case study research; few articles present empirical statistical models. Thus Moser (2007, p. 62) concludes that “the literature study on competencies motivates research of an empirically founded comprehensive model of competencies, as the existing literature does not adequately cover this open field.”

In a more recent comprehensive model, Salvador et al. (2009) propose three fundamental strategic capabilities that firms must develop to implement and pursue mass customization. As previously noted, these fundamental capabilities are (1) the ability of an organization to identify the product attributes along which customer needs diverge the most and define its solution space accordingly (solution space development), (2) the ability to reuse or recombine existing organizational and value chain resources to deliver customized solutions with high efficiency and reliability (robust process design), and (3) the ability to help customers identify their own needs and create solutions while minimizing complexity and the burden of choice
(choice navigation). Before adopting this framework for our empirical study, we attempt to assess its generalizability in two ways: First, we validate how the capabilities framework by Salvador et al. (2009) applies to the 60 articles analyzed by Moser (2007). For this comparison, it is necessary to match the seven areas of competencies with the three strategic capabilities. Product development competence should relate to solution space development capability, while customer interaction is reflected in choice navigation capability. The areas of competencies of production, logistics, IT systems, complexity management, and leadership and organization are integral parts of a robust process design capability. Figure 8 shows the hypothesized relationships across the seven areas of competencies and the three strategic capabilities for mass customization. Second, we extend the literature review by applying the capabilities framework to research published from 2005 until today. The relevant question is whether extant research on capabilities for mass customization can be fully subsumed under the capabilities framework of Salvador et al. (2009), or whether it misses out on important aspects for achieving sustainable competitive advantage through mass customization.

![Figure 8: Matching Seven Areas of Competencies (Moser 2007) with Three Strategic Capabilities for Mass Customization (Salvador et al. 2009)](image)

The application of Salvador et al.’s (2009) capabilities framework to Moser’s (2007) original literature review appears in Table 2. The matches across the seven areas of competencies and the three capabilities are mainly as predicted. Articles focused on the robustness of the process
design clearly dominate, and 15 of the 60 analyzed articles cover all three strategic capabilities for mass customization. A few exceptional cases, in which the two frameworks do not match, are shaded in grey in Table 1 and discussed in detail subsequently.

Amaro et al. (1999) emphasize the joint responsibility of companies and customers for product design and specification, but they remain silent on concrete approaches to simplify the navigation of the company’s product assortment from a customer perspective. That means the fundamental capability of choice navigation is not covered in their work. Similarly, Barnett et al. (2004) suggest a novel approach for customizing shoe design and production, but they do not expand on how to elicit customer preferences for shoes. Frutos and Borenstein (2003) describe an object-oriented model for implementing mass customization in the building industry. Beyond a detailed specification of the IT requirements for such a model, they explicitly address the design of the customer interface and list several success factors that foster an agile company–customer interaction (choice navigation). Haddock et al. (2005) present a comprehensive framework of five principles for customization that covers strategy formulation, solution space definition, complexity management, business process alignment, and change management, but they fail to include the important aspects of customer interaction and choice navigation. In an article on electronic product development for mass customization, Helander and Jiao (2002) differentiate among front-end, back-end, and infrastructure. The front-end relates to human computer interaction and the decision-making process for customizing products (choice navigation); the back-end refers to product platform design and product family modeling (solution space development); and infrastructure covers important enablers for creating robust processes, such as virtual teams across the supply chain or workflow management. In summary, the capabilities presented by Helander and Jiao (2002) come very close to the framework of Salvador et al. (2009). Finally, Sahin (2000) analyzes differences and key features of manufacturing systems, such as factory focus, lean manufacturing, mass customization, and agile manufacturing, but fails to link these systems to the process of customer preference elicitation.
<table>
<thead>
<tr>
<th>Author</th>
<th>Research Type</th>
<th>Evaluation</th>
<th>Areas of Competencies</th>
<th>Strategic Capabilities</th>
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</thead>
<tbody>
<tr>
<td>Akkermans et al. (2003)</td>
<td>Conceptual, empirical case study, empirical-statistical</td>
<td>Comprehensive model, model of competencies, list of competencies (list or individual competence)</td>
<td>(1) Product development</td>
<td>X X ▲</td>
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<td>Amaro et al. (1999)</td>
<td>Empirical case study</td>
<td>Model of competencies</td>
<td>X X X X X ▲ ▲</td>
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<td>Blecker et al. (2005)</td>
<td>Conceptual</td>
<td>Model of competencies</td>
<td>X X X X X X ▲ ▲ ▲</td>
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<tr>
<td>Bourke and Arts (1999)</td>
<td>Conceptual</td>
<td>List of competencies</td>
<td>X X ▲ ▲ ▲</td>
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<tr>
<td>Chatha et al. (2003)</td>
<td>Empirical case study</td>
<td>List of competencies</td>
<td>X ▲</td>
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<tr>
<td>Da Silveira et al. (2001)</td>
<td>Conceptual</td>
<td>Model of competencies</td>
<td>X X X X X X ▲ ▲ ▲</td>
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<tr>
<td>Duray et al. (2000)</td>
<td>Empirical case study</td>
<td>List of competencies</td>
<td>X X ▲ ▲ ▲</td>
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<tr>
<td>Author</td>
<td>Research Type</td>
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<td>Areas of Competencies</td>
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<td>Haddock et al. (2005)</td>
<td>Empirical case study</td>
<td>Model of competencies</td>
<td>X X X</td>
<td>▲ ▲ ▲</td>
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<td>McCarthy et al. (2001)</td>
<td>Empirical case study</td>
<td>Model of competencies</td>
<td>X X X X X</td>
<td>▲ ▲ ▲</td>
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<tr>
<td>Mchunu et al. (2003)</td>
<td>Conceptual</td>
<td>Model of competencies</td>
<td>X X X X X X</td>
<td>▲ ▲</td>
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<tr>
<td>Author</td>
<td>Research Type</td>
<td>Evaluation</td>
<td>Areas of competencies</td>
<td>Strategic Capabilities</td>
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<tr>
<td>Pine (1993)</td>
<td>Empirical case study</td>
<td>(Model of external conditions)</td>
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<tr>
<td>Su et al. (2005)</td>
<td>Empirical-statistical</td>
<td>List of competencies</td>
<td>X X</td>
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<tr>
<td>Tu et al. (2001)</td>
<td>Empirical-statistical</td>
<td>List of competencies</td>
<td>X</td>
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<tr>
<td>Tu et al. (2004b)</td>
<td>Empirical-statistical</td>
<td>List of competencies</td>
<td>X X X</td>
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<tr>
<td>Tu et al. (2004a)</td>
<td>Empirical-statistical</td>
<td>List of competencies</td>
<td>X</td>
<td>▲</td>
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<tr>
<td>Yunfeng and Minglei (2005)</td>
<td>Conceptual</td>
<td>Model of competencies</td>
<td>X X X X X X X</td>
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</table>

Table 1: Matching Moser’s (2007) Literature Review with Salvador et al.’s (2009) Capabilities Framework
The extended literature review since 2005 is in Table 2. It uses the same format as Table 1 but refers exclusively to Salvador et al.’s (2009) capabilities framework and includes short summaries of the results of each article. The predefined list of search terms used to identify the articles appears in Appendix 8.1.1. In total, 19 articles explicitly note success factors, competencies, and capabilities in the context of mass customization.

<table>
<thead>
<tr>
<th>Author</th>
<th>Research Type</th>
<th>Summary of Results</th>
<th>Evaluation</th>
<th>Strategic Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blecker and Abdelkafi (2006a)</td>
<td>Conceptual, empirical case study, empirical-statistical</td>
<td>Capability of managing variety and complexity is necessary competence for firms embarking on mass customization</td>
<td>List of capabilities</td>
<td>X</td>
</tr>
<tr>
<td>Cross et al. (2009)</td>
<td>Conceptual</td>
<td>Model that explains the flow of design-related information throughout the mass customization firm</td>
<td>Comprehensive model</td>
<td>X X X</td>
</tr>
<tr>
<td>Duray (2006)</td>
<td>Empirical-statistical</td>
<td>Teamwork and worker flexibility lead to increased financial performance for mass customizers</td>
<td>List of capabilities</td>
<td>X</td>
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<tr>
<td>Helms et al. (2008)</td>
<td>Conceptual</td>
<td>Linkage between knowledge management and e-commerce capabilities is necessary to gather customer preferences</td>
<td>List of capabilities</td>
<td>X X</td>
</tr>
<tr>
<td>Hendry (2010)</td>
<td>Empirical case study</td>
<td>Cumulative capabilities are needed to pursue product customization, with a low cost competence often included</td>
<td>List of capabilities</td>
<td>X</td>
</tr>
<tr>
<td>Huang et al. (2010)</td>
<td>Empirical-statistical</td>
<td>Organic organization structure plays significant role in enabling firms to pursue MC capability</td>
<td>List of capabilities</td>
<td>X</td>
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<tr>
<td>Authors</td>
<td>Study Type</td>
<td>Research Focus</td>
<td>Model/Category</td>
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<tr>
<td>Huang et al. (2008)</td>
<td>Empirical-statistical</td>
<td>Internal and external learning, mediated by effective process implementation, has positive impact on MC capability</td>
<td>List of capabilities</td>
<td>X</td>
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<tr>
<td>Ismail et al. (2007)</td>
<td>Empirical case study</td>
<td>Successful implementation of MC starts with the design of product families</td>
<td>List of capabilities</td>
<td>X</td>
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<tr>
<td>Jiao et al. (2007)</td>
<td>Empirical case study</td>
<td>Generic routing of product families is imperative in building up customization capabilities</td>
<td>List of capabilities</td>
<td>X</td>
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<tr>
<td>Kristal et al. (2010)</td>
<td>Empirical-statistical</td>
<td>Quality management practices have positive impact on MC capability</td>
<td>List of capabilities</td>
<td>X</td>
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<tr>
<td>McIntosh et al. (2007)</td>
<td>Conceptual</td>
<td>Rapid changeover capability is an essential prerequisite to mass customization</td>
<td>List of capabilities</td>
<td>X</td>
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<tr>
<td>McIntosh et al. (2010)</td>
<td>Conceptual</td>
<td>Requisite product design and manufacturing system design capabilities for food customization</td>
<td>List of capabilities</td>
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<tr>
<td>Poulin et al. (2006)</td>
<td>Empirical case study</td>
<td>Requisite manufacturing capabilities depending on the type of personalization offer</td>
<td>Model of capabilities</td>
<td>X</td>
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</tbody>
</table>
The extended literature review reveals that extant research on mass customization largely focused on production and organizational issues for the implementation of mass customized manufacturing. The various facets of robust process design are discussed in all but one of the 19 analyzed articles. Researchers have only recently begun to address the importance of understanding the consumer’s perspective as a starting point for all activities by a customer-centric enterprise (e.g., Randall et al. 2007; Dellaert and Dabholkar 2009; Franke and Schreier 2010). However, they mostly fail to relate their findings to concrete capabilities to be developed by mass customization firms and thus are not included in the above review.

Models of capabilities appear in work by Helms et al. (2008), Ismail et al. (2007), Poulin et al. (2006), and Shamsuzzoha et al. (2009). Helms et al. (2007) posit that linking e-commerce and knowledge management capabilities makes mass customization a more viable strategy. Specifically, knowledge management can support firms as they gather data about customers’ past interactions, purchases, and behaviors from their e-commerce systems and leverage the information into knowledge on customers’ needs and preferences. Ismail et al. (2007) propose an agility capability framework that consists of operation agility, process agility, organization agility, people flexibility, and product flexibility to help small to medium-sized enterprises (SMEs) embark on mass customization. These authors argue that the successful implementation of mass customization starts with product flexibility, namely, identifying the most economical modules and maximizing their reusability and application to offer customers choice. By example of the golf club industry, Poulin et al. (2006) evaluate the implications of different personalization options on production and inventory strategies within the demand and supply network, thus linking aspects of solution space development and robust process
design. These personalization options differ with regard to the position of the customer decoupling point in the value chain. Shamsuzzoha et al. (2009) present an integrated configuration system for facilitating customer co-design and collaboration, linking both the front- and back-end features of the customized product development process. At the front-end, the customers’ needs are collected, and their choice is guided by a relative set of attributes. The outcome of this process then influences the manufacturing requirements such as planning, scheduling, and resource management at the back end. The result is a smoother operational performance that allows firms to more efficiently serve customers individually.

Comprehensive models address all three fundamental capabilities for mass customization, including those developed by Moser (2007), Cross et al. (2009), and Salvador et al. (2008). Using 14 in-depth case studies, Moser (2007, pp. 196-198) derives eight dominant competencies for mass customization that companies can use to pursue one of the seven mass customization strategies: (1) customer integration, (2) application of product configuration systems, (3) employment of product modularity, (4) product variant management, (5) central production and logistics planning, (6) management of mass and individual production, (7) management of flexible organization and processes, and (8) process documentation and IT support. The main strategy of establishing a sustainable business features three corresponding mass customization strategies: (I) profit taker, (II) vehicle for market entry, and (III) path to mass producer. If the company pursues a main strategy of supporting a non-customized business, the respective strategies instead are (IV) entry barrier, (V) symbol to industry, (VI) vehicle for learning, and (VII) vehicle for increasing operational efficiency. The synthesis is a model of mass customization typology that lists the relevance of eight dominant competencies for every mass customization strategy in approximate percentages (see Table 3).
Table 3: Model of Mass Customization Typology (Moser 2007)

However, Moser’s (2007) work is also subject to some limitations. The classification attributes of the typology are empirically founded but not empirically measured with quantitative methods. Moreover, the performance implications of the dominant competencies are not analyzed.

Cross et al. (2009, p. 161) instead propose a model that explains the flow of customer-related information throughout the firm. The product creation flow illustrates how customers use the configurator to identify their own needs and create solutions (choice navigation). This information then moves to production, and the product gets manufactured and delivered to the customer (robust process design). The second flow is the update flow, which includes the marketing department, design department, and production engineers. This cycle involves an analysis of customer needs and wants and subsequent translations into product offerings and system improvements (solution space development). These authors thus develop a
comprehensive model of a mass customization company that describes activities by department and specifies required information flows in detail. Despite this outstanding level of detail, a clear limitation of this work is that the model was developed from literature and was not empirically confirmed.

Salvador et al. (2008) lament that mass customization research often focuses on formalizing specific production and organizational issues associated with the implementation, rather than the capabilities the firm must develop to generate value from mass customization. As a consequence, mass customization has typically been defined in terms of its performance outcomes, that is, the simultaneous achievement of flexibility, low cost, and rapid delivery. Relatively little research attention centers on the necessary conditions, or antecedents, for achieving mass customization. Building on their own work on the topic of individual capabilities (e.g., Salvador et al. 2002; Salvador et al. 2004; Salvador and Forza 2007), the authors thus propose a theory-based model of requisite strategic capabilities for mass customization that features solution space definition capability, robust process and supply chain design capability, and choice simplification capability. They empirically validate the model with a sample of 238 plants in eight European countries, providing evidence for the proposed definition of mass customization as encompassing three principal constituents. Consequently, Salvador et al. (2008, p. 6) posit their work as a step forward in articulating a general theory of mass customization, one that models it in terms of both its antecedents and its performance implications. One point of criticism, however, is that Salvador et al. (2008) rely solely on secondary survey data, so the measurement scales were not developed specifically to measure strategic mass customization capabilities. Moreover, they do not explicitly test whether the strategic capabilities have direct positive effects on company performance. Nevertheless, this article laid the foundation for the seminal strategic capabilities framework proposed by Salvador et al. (2009).

In summary, we demonstrate that the framework by Salvador et al. (2009) is collectively exhaustive, that is, it fully characterizes the large body of conceptual and empirical research on the success factors, competencies, and capabilities that a company must develop to benefit from mass customization. It is striking, however, that solution space development and choice navigation—the two capabilities directly related to the way firms interact with their customers—produce considerably fewer matches in the literature review than robust process
design. This suggests that previous research has centered mainly on improving the operational effectiveness of mass customization firms, which essentially means performing similar activities better than rivals do. Porter (1996, p. 63) gets right to the point: “Few companies have competed successfully on the basis of operational effectiveness over an extended period.” Instead, firms should realize that mass customization is a holistic attempt to redesign the organization, at both the strategic and the operational level, in order to capitalize on customers’ heterogeneous needs (Tseng and Piller 2003). How firms need to adjust and integrate their capabilities, including product design, production, sales, and supply chain design, to achieve the goal of customer centricity presents an important set of questions raised by the capabilities framework of Salvador et al. (2009). However, despite its broad applicability, that framework only partially addresses the fundamental criticisms voiced by Moser (2007, p. 54). In particular, the framework is also conceptual, not empirically founded, and it does not link to any business performance measures. Moreover, although the capabilities are connected to a few specific practices and methods, the discussion is more of an exemplary nature, without practical recommendations for implementation. To overcome these weaknesses, this study empirically tests the strategic capabilities framework of Salvador et al. (2009) for the first time and investigates the impact on firm performance.
4 The Strategic Capabilities Framework

Possen, a Dutch pioneer of customized fashion, states its business vision as follows: “In general, too little use is made of the advantage, that all people are different.” 11 Hence, few would question that mass customization is an attractive business proposition in these times. But the analysis of the limitations and failures of mass customization businesses suggests that a mass customization strategy is more difficult to implement than originally assumed (Piller 2007). As the preceding discussion has shown, in order to reap the benefits of mass customization, firms must essentially resolve two questions that lie at the heart of the strategy development process (Grant 2005, p. 93):

1. *What do our customers want to buy?*

   The value contribution of mass customization must be evaluated first and foremost from a customer perspective. As outlined in Chapter 2, customers will only decide to buy a mass customized product if the (expected) utility exceeds the (expected) costs (Piller and Müller 2004, p. 590). Thus, before customers recognize positive value in any customization venture, companies must configure their resources sufficiently to minimize the sacrifices required of the customers in terms of price and effort (Squire et al. 2004, p. 462).

2. *What does the firm need to do to achieve and maintain a superior competitive position?*

   As discussed in Chapter 3, translating the resource endowments the business has accumulated into value-creating strategies requires dynamic capabilities (Eisenhardt and Martin 2000). Capabilities are essentially the glue that holds the resources together and enables firms to deploy them to its advantage. Every business acquires a portfolio of capabilities; some will be equal to those of competitors, others will be inferior, and few will be distinctive in that they support a market position that is valuable and difficult to imitate (Day 1994, p. 39). But these distinctive capabilities are hard to identify for the management, because capabilities are deeply embedded in the organization’s routines and practices (Dierckx and Cool 1989), and much of their knowledge component is tacit and dispersed (Leonard-Barton 1992).

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11 See possen.com.
In their article “Cracking the Code of Mass Customization,” Salvador et al. (2009) provide a compelling answer to these questions. Building on the findings of multiple research projects, they propose that the most distinctive features of successful mass customization organizations are their mastery of the following three capabilities: solution space development (SSD), robust process design (RPD), and choice navigation (CN). Because these capabilities are difficult to develop, they resist imitation, and as such can contribute to sustainable advantage and superior profitability. Conceptually, the capabilities are directly targeted at the levers of customer value creation; that is, they potentially increase the utility to the customer and reduce the mass customization–related costs. Thus, by combining the customer perspective and the strategic firm perspective on mass customization, the capabilities framework of Salvador et al. (2009) provides concrete guidance to managers on how to turn customers’ heterogeneous needs into opportunities to create value. However, Salvador et al. (2009) also realize that developing these capabilities often requires radical organizational changes and substantial upfront investments; they therefore caution that there is no one best way to mass customize. Instead, what is needed is a modular toolbox of ways to develop the capabilities, from which managers can choose the approaches that best suit their specific business model.

The following paragraphs elaborate on the three strategic capabilities for mass customization in more detail and discuss specific methods, tools, and routines to implement them in practice. The methods that support these capabilities are not new; many have been described by other researchers. The current challenge is to combine the methods to create capabilities in a meaningful and integrated manner. To do so, this study draws on findings from related research disciplines, such as operations management, innovation management, strategic management, marketing, and psychology. To substantiate the discussion, this chapter also cites a great number of real-world examples and key facts from various empirical studies. Finally, the discussion of the three strategic capabilities for mass customization will produce concrete hypotheses to be tested empirically.

4.1 Solution Space Development Capability (SSD)

4.1.1 Theoretical Basics

Traditional mass manufacturers aim to identify the average preferences of customers in a specific segment and target them with a few standard products (Smith 1956). In contrast,
companies seeking to adopt mass customization must (1) identify the idiosyncratic and unexploited needs of individual customers, (2) establish the product attributes on which customer needs diverge the most, and (3) estimate the marginal utility of different attribute levels (Salvador et al. 2008). Based on this information, firms can define their solution space (Tseng and Piller 2003) or product space (Lancaster 1971), clearly delineating what universe of benefits an offer intends to provide to customers, and what specific permutations of functionality can be provided within this universe (Pine 1995). Hart (1995, p. 37) argues similarly that products should be customized within a “predetermined envelope of variety”. This means that in mass customization, the range of available customization options is vast but also necessarily finite to avoid a proliferation of complexity and costs. Value creation within a finite solution space differentiates mass customization from conventional craft customization (e.g., Pine 1993; Lampel and Mintzberg 1996; Robertson and Ulrich 1998). Setting an appropriate solution space thus is one of the greatest competitive challenges for a mass customization company, because it directly affects the customer’s perception of the utility of the customized product and determines the efficiency of downstream processes in the fulfillment system (Tseng and Piller 2003, p. 6). The corresponding SSD capability is defined as follows:

Solution space development is the ability of an organization to identify idiosyncratic and unexploited needs and preferences of each customer, to optimize the functional, aesthetic, and hedonic fit between the product variants offered by a firm and the needs and preferences of every customer (adapted from Salvador et al. 2009, p. 73).

In practice, however, many companies still lack this capability – the solution space is often defined more or less intuitively and without much planning (Piller 2005a, p. 316). This comes as no surprise, as academic literature on mass customization provides little guidance to managers regarding how they might define an appropriate level of customization. To close this gap, this chapter condenses fragmented research on SSD into a coherent structure, comprehensible to both managers and academics. Before detailing several methods to develop the solution space, the next section discusses which factors limit the solution space from a company perspective. Moreover, it identifies several conditions that make it particularly difficult to elicit preference information from customers in a mass customization context.
**Width and depth of the solution space**

The *width* of the solution space is determined by the number of predefined base products and the modules a customer may use and modify during the co-design process. Theoretically, the larger the solution space, the more likely customers are to find exactly the product they want. The positive impact of (perceived) variety on expected utility has been repeatedly confirmed empirically in the context of product customization (e.g., Dellaert and Stremersch 2005; Ihl 2009). From a company perspective, however, the width of the solution space is bounded by three limiting factors, namely, economical efficiency, technical restrictions, and standards and laws, as depicted in Figure 9 (Berger 2011).

![Figure 9: The Solution Space, Bounded by Three Limiting Factors (adapted from Berger 2011)](image)

To illustrate how these factors limit the solution space in practice, consider the example of the German pure-play mass customizer Chocri, which lets customers create their own chocolate bars:12

1. *Economically efficient* production is only possible if the design falls within the “pre-existing capability and degrees of freedom built into a given manufacturer’s production system” (von Hippel 2001, p. 252). The reason to enforce this constraint is to ensure custom products can be produced at a reasonable price level, because the user designs can be implemented with low-cost adjustments to the production process. Responding to customer requests outside this predetermined solution space would require

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12 See chocri.de. The English language version of this website can be found at www.createmychocolate.com.
substantial investments. Consequently, a mass customizer must reserve the right to reject a specific customer order if it goes beyond its solution space. Chocri’s whole production system is geared toward the efficient production of customized chocolate bars at high volumes. It would have to make a significant investment in machinery and rework the entire production process if it were to allow customers to order products from seemingly related categories such as filled chocolates, chocolate ice cream or chocolate cookies.

2. The solution space only permits those solutions that acknowledge specific technical restrictions. Chocri’s machinery cannot produce any form other than rectangular chocolate bars of 100g (3.5 oz.).

3. Custom production is also subject to standards and laws. Food customization in particular is subject to various hygiene regulations and general food laws. For example, chocolate must not contain more than 5% of vegetable fats other than cocoa butter according to European law, and adding animal fats, flour, or starch is prohibited.

Customization options

In the solution space, products can be customized along three dimensions to match the unique needs of customers: fit, design/taste, and functionality. Along these generic dimensions, any of which can become a starting point for customization, it is possible to derive heterogeneities in customer demand (for the following, see Piller and Stotko 2003, pp. 107-109; Piller 2005a, pp. 320-322). The variety of customization options for each base product or module determines the depth of the solution space.

- **Fit**: Tailoring a product according to body measurements or the dimensions of a room or other physical objects is a traditional starting point for customization in consumer goods markets. Several studies in the apparel industry (Outsize 1998; Zitex Consortium 1999; EuroShoe Consortium 2002) identify better fit as the most important argument in favor of mass customization. For example, 78% of suit buyers are not satisfied with its measurements (Zitex Consortium 1999, p. 23), and 59% of women and 51% of men report that they cannot find shoes that completely satisfy their fit needs (EuroShoe Consortium 2002, p. 79). More than 40% of the orders at the shoe customizer selve.net are requests for different sizes for right and left shoes (Kieserling 2001). However, clothing fit is very difficult to achieve in customer interaction and
manufacturing stages, requiring sophisticated systems such as 3D scanners to capture the customer’s proportions exactly and translate them into a custom product based on parametric design (Berger et al. 2005). In particular, determining fit over the Internet has been a challenge that innovative companies are addressing by adding “Virtual Try-On (VTO)” services to their websites. These services enable customers to evaluate physically simulated 3D garments on a static 3D representation of their own body (Servive Consortium 2011). To overcome the challenges associated with made-to-measure garments, zafu.com offers a different approach (Piller 2007): It asks women a few simple questions about how they prefer jeans to fit, but instead of using this information to create a custom cut, it matches the information to an existing assortment of 100 major brands and provides personalized advice to help women find the best fitting jeans (i.e., match-to-order).

- **Design/Taste**: This dimension refers to modifications that target visual and haptic senses, such as selecting particular colors, cuts, applications, or flavors. With the advances in digital printing technology, the customization of design is relatively easy to implement, so many vendors in business-to-consumer (B2C) e-commerce settings center co-design possibilities on the outer appearance of a product. But Piller (2005a, p. 322) questions whether design customization really creates sustainable value for the customer, given growing peer orientation and brand awareness. Proponents of this type of customization often refer to customers’ need for uniqueness, as rooted in psychological marketing literature (e.g., Tian et al. 2001). That is, customers acquire and display certain products to distinguish themselves from most others but also gain approval from these others (choice counterconformity). Yet demand for a particular style often is inspired by fashion, peers, or role models, and people strive to copy and adapt such trends, not to create them. In this context, the key point is that individualization per se is not a benefit for most customers; they just want exactly what they want (Piller and Ihl 2002, p. 15). Empirical evidence on this topic is scarce, but many companies that have focused on design customization only have failed (e.g., getcustom.com, customatix.com).

- **Functionality**: This dimension refers to sections of functions such as speed, precision, power, cushioning, interfaces, or nutritional value. A traditional starting point for
customization in business-to-business (B2B) markets, functionality is often overlooked as a customization option in consumer goods fields. It requires some efforts to elicit preferences on functionality from customers, comparable to those required to assess fit. In manufacturing, stronger software content has facilitated the customization of functional components. For example, with more than 500,000 apps, Apple’s App Store enables consumers to customize the functionality of their smartphones (Wehner 2011).

Piller (2005a, p. 322) postulates that mass customization offerings can attract customer demand and be more sustainable if they combine all three customization dimensions. For example, miadidas.com allows customers to change the fit, design, and functionality of their sport shoes (Berger and Piller 2003; Berger et al. 2005). In the case of footwear, a “last” determines the fit of a shoe. At miadidas.com, customer’s feet are measured and matched to an existing library of lasts. This approach is less complex and costly to implement, for both manufacturing and sales, than full customization based on an individualized last. With regard to functionality, Adidas offers a range of outsoles, midsoles, sole patterns, and upper materials that can be freely combined to enhance the performance of the shoe. Finally, customers can choose from 140 possible color combinations to alter the aesthetic design of their shoes. In addition, to increase the emotional value of the products, they can personalize each shoe with a self-selected name or player number. In principal, most products are customizable with regard to all three dimensions, but many companies focus on one dimension only. To illustrate this point, consider the example of Chocri again. It caters to individual tastes with untold thousands of combinations of base chocolates and toppings. But how could Chocri tackle the other two dimensions? For chocolate bars, fit likely refers to package size, so Chocri could offer a pocket-sized, 50 g bar and a family bar of 250 g, in addition to the standard 100 g bars. Reduced calorie or lactose-free chocolate could then provide functional value to the customers.

However, not every product feature needs to be customized. Companies should only offer customization in those areas where customers’ needs diverge the most or where they actually care about the differences (Broekhuizen and Alsem 2002, p. 319). As Kakati (2002, p. 91) clarifies, “understanding customers is the starting point, not the dizzying possibilities of technology to produce variety that nobody wants.” Thus, the critical question is, which customization options are valued most by customers.
Customer requirements and “sticky” information
It has become common knowledge that “products should be designed to reflect customers’ desires and tastes” (Hauser and Clausing 1988, p. 63). This paradigm, while not trivial, is easier to deal with in a pure mass production context where consumer markets are viewed as homogeneous segments and design is focused on a manageable number of product variants. For mass customization firms, the need to offer an increasing variety of products that essentially serve the same fundamental purpose (e.g., all variations of custom muesli satisfy hunger) exacerbates the complexity of design engineering by pushing decision impact to more granular levels of design attributes (Ferguson et al. 2011). One practical method of coping with this complexity is the adoption of an iterative process known as quality function deployment (QFD), which was first applied in Japan by Mitsubishi in 1972 (for a comprehensive literature review, see Chan and Wu 2002). QFD supports a multidisciplinary team of people from marketing, design engineering, R&D, manufacturing, and other relevant functions of an organization to focus on product development from the time the product is first conceived until it is delivered to the customers to satisfy their requirements (Hauser and Clausing 1988). The goal of QFD is to translate subjective customer needs and preferences into objective quality criteria that can be used to design and manufacture the product (Akao 1990). Each of the four phases in a QFD process uses a matrix, also referred to as a “house,” to link the needs of the customer with various business functions and organizational processes (Hauser 1993). Applications of the concept typically begin with the House of Quality (HOQ), which is used by firms to understand customer needs (what) and translate them into technical descriptions or proposed performance characteristics of the product (how). Subsequent houses continue to convey the customer attributes into parts characteristics, key process operations, and production requirements (Hauser and Clausing 1988). In this way, QFD replaces erratic, intuitive decision making processes with a structured methodology that establishes all relevant informational needs throughout the organization and lays the foundation for organizational learning (Govers 1996). When properly executed, QFD can lead to decreased product development costs and time, and improved customer satisfaction (Griffin 1992). The concept of QFD, and in particular the HOQ, was originally developed for integrated products; it may also serve as a practical guideline for determining the width (i.e., the number of base products and modules) and depth (i.e., the variety of customization features for each base product or module) of the solution space in a mass customization context.
With regard to its implementation, Hauser and Clausing (1988) indicated that there is nothing mysterious or particularly difficult about the HOQ. However, most articles on the concept simply take customer requirements as given input and remain silent on concrete approaches to elicit customer needs and preferences (Gerards 2010, p. 20). But even when customers know precisely what they want, retrieving that information and transferring it to the company is not easy, because this information is “sticky” (Thomke and Hippel 2002, p. 5). Stickiness of information is “the incremental expenditure to transfer that unit of information to a specified locus in a form usable by a given information seeker. When this cost is low, information stickiness is low; when it is high, stickiness is high” (von Hippel 1994, p. 430). Information can be costly to transfer for a number of reasons: Some reasons have to do with the nature of information itself (e.g., tacitness of information: Polanyi 1958), some with the amount and structure of the information that must be transferred (Rosenberg 1976), and some with attributes of the seekers and providers of information (e.g., absorptive capacity: Cohen and Levinthal 1990). In its original sense, the notion of “sticky” information was used for information transfers between stakeholders in technical projects (von Hippel 1994). Accessing end customers’ need information is presumably even more costly and time consuming, because customer needs are often complex, subtle, and unstable (Thomke and Hippel 2002, p. 6). Customization options such as tastes, design patterns, and even functionalities are subjective and difficult to decode. Thus, many customers cannot describe their needs clearly or translate them into a concrete product specification that allows the company to create a customized product (Piller et al. 2004, p. 440).

There is no doubt that access to customer information is a basic requirement for implementing a successful mass customization strategy (Piller 2006, p. 237-238). But identifying differentiating product attributes, testing product concepts, and collecting customer feedback can be a costly and complex endeavor (Salvador et al. 2009, p. 72). Therefore, several methods to obtain sticky information from customers will be discussed in the following.

### 4.1.2 Methods for Solution Space Development

In line with the idea of a customer-centric enterprise (Tseng and Piller 2003; Piller et al. 2006), solution space development should be an interactive relationship between manufacturers and customers. Within this relationship, customers can assume different roles.
Expanding on work by Dahan and Hauser (2002) and Urban and Hauser (2004), these roles can be structured along three different modes: (1) ask customers, (2) build with customers, or (3) listen in on the customer domain. The three modes differ in their degree of customer integration and type of activities. Figure 10 provides an overview of the different methods and tools for SSD outlined in this chapter.

**Figure 10: Methods for Uncovering Customers’ Needs Along Three Different Modes**

1. **Mode 1: Ask customers**
   - Voice of the customer
   - Menu-based conjoint analysis

2. **Mode 2: Build with customers**
   - Toolkits for user innovation

3. **Mode 3: Listen in on the customer domain**
   - Log file analysis
   - Netnography
   - Opportunity recognition

### Mode 1: Ask customers

The first approach accesses need-related information explicitly, by simply asking customers. Griffin and Hauser (1993) coined the term “voice of the customer” to describe this type of customer input through a process of identifying, structuring, and prioritizing customer needs. In the first step, the manufacturer must engage in qualitative research techniques such as personal interviews and/or focus groups to produce a detailed set of customer needs and wants for a specific market segment. Needs are “a description, in customer’s own words, of the benefit to be fulfilled by the product or service” (Griffin and Hauser 1993, p. 4). Discussions with customers typically identify 200 to 400 needs, which include *basic needs* (what customers assume the product will do), *articulated needs* (what they say they want the product to do), and *excitement needs* (which would delight and surprise customers if fulfilled).

However, it is difficult for a product development team to work with so many customer needs simultaneously. To manage the complexity, customer needs thus should be characterized according to apparent patterns and themes and organized into a hierarchical structure of primary, secondary, and operational needs (Griffin and Hauser 1993, p. 5).Primary needs,
also referred to as strategic needs, are generally the five to ten top-level needs that are used by the team to set the strategic direction for the product. For example, a primary need for a technical product such as a smartphone or laptop computer might be “ease of use.” Each primary need is then elaborated into three to ten secondary needs. Secondary needs, also known as tactical needs, describe in more detail how to satisfy the corresponding strategic or primary need. For example, the primary need “ease of use” might be further detailed as “easy to set up,” “easy to operate,” and “fast to use” (Hauser 1993, p. 62). Tertiary or operational needs indicate specifically how the secondary needs can be fulfilled through engineering and R&D. For instance, a customer may judge the ease of setting up a smartphone (secondary need) by the tertiary needs intuitive menu navigation, easily comprehensible user manual, and responsive online support.

Customers usually want all their needs fulfilled, but some needs are more important than others. To prioritize customer needs, the cost of fulfilling a need should be balanced against the desirability of fulfilling it, from the customer’s perspective (Griffin and Hauser 1993, p. 5). Customer perceptions of performance gaps between the company’s current product and competitive products provide further input for the product development process and may help to identify opportunities. This information is usually obtained through customer surveys. If no comparable product exists yet, the responses reveal how customers currently fulfill the needs satisfied by the product (Griffin and Hauser 1993, p. 5). With these insights, the manufacturer can develop different product concepts and present them to customers to capture their reactions (Moore 1982; Page and Rosenbaum 1992). For this purpose, a manufacturer may recruit pilot customers or beta users (Dolan and Matthews 1993). Modern rich, virtual prototypes support early tests of preliminary designs, well before physical prototypes are built (Tseng et al. 1998). In general, customer input should be integrated iteratively multiple times during the product development process, to reduce the risk of failure (Dahan and Hauser 2001, p. 232).

This method of capturing customers’ expectations, preferences, and aversions is dominant in consumer goods sectors. For a number of reasons, however, it may not be sufficient for mass customizers attempting to measure heterogeneous needs and preferences (Jeppesen 2005, p. 349): First, the utility of this technique depends on the analyst’s ability to determine accurately the product attributes that customers value most from these data. Second, a problem arises if
the manufacturer filters the retrieved customer data through its own biases. Third, customers frequently form new preferences and change their opinion by the time the actual product launches. Moreover, von Hippel and Katz (2002, p. 830) point out that conventional market research techniques are geared toward collecting data about the average needs of customers to develop standard products. Companies pursing mass customization instead are interested in variation in customer needs. If customers have not heard about mass customization or purchased a mass customized product, they also may find it difficult to articulate their preferences in surveys, interviews, or focus groups (Piller 2005a, p. 313). Mahajan and Wind (1999) thus have called for richer market research models to foster new product development in a mass customization environment.

Shapiro and Varian (1999, p. 53) note that companies can learn a great deal about their customers by simply offering them a menu of products and seeing which ones they choose. To illustrate this point, consider how a restaurant serves meals. The guest chooses the combination of starter, main dish, dessert, and beverage that best satisfies his or her hunger and thirst. The challenge for the restaurant owner is to decide what to put on the menu, how much of each ingredient to stock, and how to price each item to balance the value for the customer against profit for the restaurant (Cohen and Liechty 2007, p. 30). Mass customizers face a similar problem. To solve it, Cohen and Liechty (2007) propose menu-based conjoint analysis. Conjoint analysis is a powerful statistical technique for determining customer preferences for product features by systematically manipulating product or service descriptions within an experimental design (e.g., Green and Srinivasan 1978; 1990). A survey of its wide commercial usage and a critical reflection on this technique appears in Wittink and Cattin (1989). In traditional choice-based conjoint analysis, customers make a single choice from competing alternatives, with one total price for each alternative. However, when a firm has the capability to offer myriad choices, it is interested in assessing feature demand and pricing for optional features (Liechty et al. 2001). With menu-based conjoint analysis, customers make multiple simultaneous choices of features and options from each menu, each of which is priced separately, so the final price paid is the sum of prices of the individual features. The menu-based approach delivers some very useful outcomes with regard to solution space development. For example, it indicates the unique utility for each feature, net of its price, which reveals the intrinsic attractiveness. Moreover, by accounting for combinations,
it uncovers complements and substitutes among the features. Complements are suitable for marketing in a bundle, whereas substitutes can be eliminated (Cohen and Liechty 2007, pp. 31-32).

However, like most market research techniques, the methods share the downside that customers remain more or less isolated from the firm. Their role is limited to that of information providers who deliver feedback upon request. An alternative approach is to actively involve customers in the design or development of future offerings.

**Mode 2: Build with customers**

Traditional product development is an iterative process of trial-and-error between manufacturer and customer. Using need-related information retrieved through conventional market research, manufacturer-based designers develop a prototype; the customer tests the initial solution, finds flaws, and requests improvements (von Hippel 2001, p. 248); and then the cycle repeats through costly, time-consuming iterations until a satisfactory fit with customer needs finally is reached. Von Hippel (1978, p. 243) describes this approach as the “manufacturer active paradigm,” where customers assume a passive role and are “speaking only when spoken to.” The result is that most products never make it to the market, and those that do suffer 25%–45% failure rates (Cooper 2011, p. 18).

To overcome this problem, *user toolkits for innovation* have been proposed as methods to make traditional product development faster and less expensive. These toolkits resemble in principle a chemistry set with nearly limitless combination possibilities. The idea is to equip customers with appropriate tools that allow them to design and develop their custom products, highlighting unsatisfied needs during the process. The resulting information then can be evaluated by the company and incorporated into the solution space (Salvador et al. 2009, p. 73). In this way, companies can abandon expensive, frustrating efforts to understand customers’ needs and outsource the need-related aspects of their product development process to customers (von Hippel and Katz 2002, p. 821). Furthermore, the inevitable trial-and-error cycles during product development can be expedited, because the iterations are carried out by customers only (Thomke and Hippel 2002, p. 7). However, developing an effective toolkit for user innovation is far from a simple task. Toolkits must fulfill five basic requirements (for the following, see von Hippel and Katz 2002, pp. 825-829):
1. They should enable customers to perform complete cycles of trial-and-error learning as they create their designs. That is, customers can create a preliminary solution, simulate or prototype it, and finally test and evaluate it. If the evaluation indicates a need for improvement, the cycle can be repeated. For example, 3D computer simulations and augmented reality applications help customers try out ideas and design alternatives in their own usage environment, supplemented by rapid prototyping using additive manufacturing technologies.

2. The design freedom that a toolkit offers should be subject to some limitations to ensure the created designs can be produced by the manufacturer perspective and take technical restrictions, standards, or laws into account.

3. Toolkits should be user-friendly, in the sense that they enable customers to leverage the skills they already have and do not require them to learn an entirely new design language.

4. They should include libraries of useful standard components and modules that have been pretested and debugged. Customers then can focus on truly novel aspects.

5. The technology of the toolkit should be synchronized with the production systems so that user-generated designs can be transferred to production without extensive revisions by engineers or designers.

Essentially, toolkits for user innovation are applicable to all product categories in which customer demand is heterogeneous and tailored solutions are valued by buyers. However, toolkits for innovation are not of interest to all or even most customers for any given type of product. Customers must consider their sacrifice to use a standard product high enough that it offsets the costs of using an innovation toolkit (von Hippel and Katz 2002, pp. 830-831). Innovation toolkits thus tend to be offered only to lead users, whose strong need foreshadows the general need in the market (Lilien et al. 2002). Finally, Jeppesen (2005, p. 347) raises the question of whether more customer involvement in innovation toolkits increases the need to support those customers. In other words, some of the costs companies save by using innovation toolkits could reemerge in the form of consumer support costs. A potential remedy would be to establish a platform for customer support interactions, as already prevalent in open-source software fields.
A frequently cited example of the successful adoption of an innovation toolkit is the “Concept Lab” developed by Fiat in 2006. It enabled potential customers to express their preferences about the exterior and interior design of a new Fiat 500, well before the first vehicle was built (Salvador et al. 2009, p. 73). After only a few months, Fiat had attracted nearly 15 million registered users and received about 170,000 user-generated designs—giving it a pretty good idea of how customers envisaged the design of the new model. As expected, the introduction of the new Fiat 500 was a great commercial success. The Concept Lab represented a huge product development effort that no other carmaker could replicate internally—not to mention a huge draw for free media coverage prior to the market launch.

McDonald’s also has invited its customers to create burgers online, choosing from 21 meat variations, three types of buns, and 28 extras (e.g., salad, cheese, tortilla chips, various sauces). Other customers then voted on the custom burgers, and the best creation was introduced in restaurants all over Germany. This savvy move gave McDonald’s a vast amount of valuable data about the preferences of its customers, which it can use in turn in its new product development efforts. But not all customers want to complete extensive questionnaires or engage in design activities. So how can firms learn about customers without being intrusive?

**Mode 3: Listen in on the customer domain**

It has become commonplace knowledge that a firm’s capability to generate intelligence about customers’ needs and how best to satisfy them is essential for creating superior customer value. Intelligence is generated when raw data are collected and turned into knowledge that affects organizational decision making (Slater and Narver 2000, p. 121). Thus, in developing and refining their solution space, companies should deploy some form of customer intelligence generation, by meticulously gathering data on customers’ past interactions, purchases, and behaviors and systematically analyzing this information to determine customer preferences. Online environments provide especially rich sources of data, and several methods are available for turning such data into action (Montgomery and Srinivasan 2003, p. 125).

13 See www.fiat500.com/lab.
14 See www.mcdonalds.de/meinburger.
In particular, the *analysis of log files* has attracted significant academic and commercial interest. Log files record the browsing behavior of customers who use online configurators, including which products they evaluated or ignored, how long they viewed them, and at what point they quit the process. When customers take their business elsewhere, that information also is incorporated. With such information, a mass customizer might learn that it can eliminate options that are rarely explored or selected and add more variants for popular modules and components (Salvador et al. 2009, p. 73). More generally, log files are an unfiltered and immediately available record of what customers have done, not what they intended to do or what they were prompted to say (Nicholas and Huntington 2003, p. 391). In addition, the information obtained from a log file analysis can be enriched with purchase and transaction data (e.g., price, coupon usage) and demographic data (e.g., gender, age) to create personalized environments for customers, eventually resulting in higher customer value and more loyal and profitable customers. Data mining capabilities can be useful for processing these data sets, because the data are fairly easy to collect but large and difficult to analyze (for an overview of the techniques, see e.g., Han and Kamber 2006). But listening in on the customer domain also means condensing information from more traditional input channels—interactions with customers in the brick-and-mortar stores, knowledge transfer between B2C and B2B units, call-center recordings, orders from last season, or research reports by third parties.

The term “netnography” also has gained some currency in consumer research fields as a description of qualitative, interpretative research that adapts traditional ethnography approaches to online communities and cultures (Kozinets 2002; 2009). Netnography makes use of publicly available information in online forums to identify and understand the consumption patterns of relevant consumer groups. Online communities are an important locus of novel ideas and concepts, largely because of their members’ high commitment to the product field. Franke and Shah (2003) analyze four firm-independent sports communities (sail planning, canyoning, bordercross, handicapped cycling) and find that 32% of the members report having innovated in the past. The majority of these innovations were improvements on existing products, but nearly 15% represented completely new products. Similarly, Lüthje (2004) shows that 37% of the users of a local outdoor community generated at least one idea for improved or new outdoor-related products and more than 9% developed a prototype or a
marketable product. Within customer communities, such product development is not an individual task but rather a collaborative effort, such that innovators receive assistance from others during the process (Franke and Shah 2003, p. 164). These effects also could arise in firm-hosted customer communities. In these cases, firms can pick up promising innovations, integrate them in future versions of the products, and benefit by selling them back to all users (Jeppesen and Frederiksen 2006). Through Internet diffusion, many customer communities have evolved into virtual meeting places, where users discuss their usage experiences and develop ideas for product improvements and innovations. In summary, monitoring innovative customer communities may be an efficient method for companies to identify commercially appealing options for their solution space. A great example is LUGNET, the Lego user community created by adult fans, totally independent of the company. Its members swap parts and share pictures of their individual designs, and they collaboratively developed open-source software to design expert constructions. Some users sell unique Lego models, which provide a source of inspiration for new products for the company. Compared with focus groups or interviews, netnography is less time consuming and costly, and it can be conducted in an entirely unobtrusive manner.

Research on entrepreneurship has focused largely on investigating the nature of opportunity recognition—the process through which ideas for potentially profitable new business ventures are identified (e.g., Kirzner 1979; Bhave 1994; Shane 2003). Although opportunity recognition is not an exact method, our discussions with founders of mass customization firms have reinforced our belief that it plays an important role in developing the initial solution space. In fact, many entrepreneurs started their businesses simply by translating their own unsatisfied needs into a custom product offering. In the era of mass production, customers implicitly agreed to trade off less customization for lower prices (Addis and Holbrook 2001, p. 51). Gilmore and Pine (2000, p. viii) described the situation: “as new mass-produced items rolled off the lines, most consumers gladly sacrificed what they wanted exactly in order to simply obtain one.” In this case, customer sacrifice is a measure of the gap between what a customer really wants and what he or she must settle for today (Pine and Gilmore 1999, p. 78). Customers put up with all kinds of sacrifices: inconveniences, discomforts, long waiting times, product deficiencies, high costs, difficult order processes, poor fulfillment options, and so on.

15 See www.lugnet.com.
Companies devising a new mass customization business must uncover the few dimensions, or even just the one dimension of sacrifice, that will yield the most value for customers—and ultimately for them (Hart 1995, p. 40). One way to do so is to observe the workarounds adopted by customers. If customers take a mass produced product and adjust it to their own needs, it indicates the potential that other customers out there would prefer a similarly customized item. The websites indicustom.com and diejeans.de even built their business model on the realization that many customers take their jeans to a tailor after purchasing them. The first customized chocolate bar by Chocri was an attempt to create an original, last minute birthday gift. The tricky task in determining what should be customized, or not, is to detect what sacrifices most customers make, not just one. Mass customizers also must realize that many customers have gotten so used to their sacrifices that they do not notice them anymore (Gilmore and Pine 2000, p. xviii).

Finally, it is important to note that solution space development is not a one-off activity but rather a continual, iterative improvement process. What customers want today may be different tomorrow (Simonson 2005). Companies should thus implement a formal process to revise, trim, or extend their solution space at regular intervals. Once the basic rules have been established, firms also can outsource the task of extending the solution space to customers, with the assumption that (at least some) customers are willing to make self-designed product modules publicly available by uploading them into a design library (Ihl 2009, p. 98). Other customers then can evaluate and vote for these additions to the solution space. Threadless is a prominent example: It only produces those t-shirt designs submitted by customers that received the highest scores from the large customer community (Ogawa and Piller 2006). This phenomenon is commonly referred to as “crowdsourcing” (Howe 2006).

**Modular product architecture**

After assessing the firm’s internal restrictions and identifying the customization options valued most by customers, the solution space must be translated into a suitable product architecture to enable the configuration of a wide variety of end products (Mikkola 2007). The product architecture can be regarded as the connecting element between a mass customizer’s solution space and its fulfillment system. The choice of the product architecture strongly impacts the manufacturing firm’s performance, since it determines the efficiency of
downstream processes for manufacturing and supply chain management (Blecker et al. 2005, pp. 163-164). There is a broad consensus among researchers that mass customization firms must utilize modular product architectures to achieve manufacturing efficiencies that approximate those of standard mass produced products (e.g., Duray et al. 2000; Tseng and Jiao 2001; Kumar 2005; Piller 2006). For example, Pine (1993, p. 196) notes that “the best method for achieving mass customization…is by creating modular components that can be configured into a wide variety of end products and services.” However, the term remains ambiguous; definitions and views on the meaning of product modularity have proliferated during more than 40 years of research in engineering and management (Salvador 2007). Taking previous definitions by Ulrich and Tung (1991, p. 73), Ulrich (1995, p. 422), and Ericsson and Erixon (1999, p. 19) into account, Abdelkafi (2008, p. 145) defines product modularity in the context of mass customization as “an attribute of the product architecture that characterizes the ability to mix and match independent and interchangeable building blocks with standardized interfaces so as to create a wide range of product variants.” Both research and practice commonly suggest that firms confront a trade-off between variety and operational performance, which can be mitigated by pursuing modularity (Salvador et al. 2002, p. 550). That is, designing and deploying a modular product architecture makes it possible to produce customized products and simultaneously reduce the number of variants to be dealt with internally, which thus reduces complexity, shortens lead times, and decreased costs (Ulrich and Tung 1991, p. 75; Ericsson and Erixon 1999, p. 18; Piller 2006, p. 232). In addition to economies of scale and scope, product modularity enables firms to achieve economies of substitution, through reusability and easier upgrade facility (Garud and Kumaraswamy 2003, p. 48). By reusing standardized modules across product generations, modularity acknowledges that changes in customer preferences likely require mass customizers to update their solution space over time. Because components with frequent design changes get integrated into separate modules, products can be easily upgraded by varying just a few modules, even as a subset of modules remains stable, potentially shortening development lead times.

Despite these advantages, the development of a modular product architecture also entails some risks though (Piller 2006, p. 233): First, developing a modular product architecture tends to be costlier than devising a comparable, integrated product family. Second, modular product
architectures cannot fulfill every customer need, because the extent of variety is necessarily finite and limited to the number of module combinations. Third, modularization potentially undermines innovation, in that firms are tempted to use the same modules over and over again. Fourth, modular products can be easily imitated by competitors through reverse engineering, that is, dismantling a product into its components and reassembling it. Nevertheless, Tu et al. (2004b) show empirically that product modularity, combined with process modularity and postponement, is a primary means of achieving mass customization capability. But how can modularity be implemented in practice?

Each product can be decomposed into several modules that serve a well-defined function (i.e., *width* of the solution space). For each module, several options or variants are available that differ in their performance level on that specific function (i.e., *depth* of the solution space). For example, the engine, clutch, and gears are essential modules of a car. The engine module is available in multiple variants that can be differentiated by type of fuel (e.g., petrol, diesel, natural gas, electricity), power, cylinder capacity, and engine control (example modified from Hvam et al. 2008, p. 30). Modularity means that the different variants of the engine can be combined with a corresponding number of variants to the gear and clutch modules and thus produce a high variety of cars economically. However, a challenge in designing a modular product architecture is developing standardized interfaces so the various modules can be easily assembled and tested as a total unit. Finally, to handle the complexity in a configuration system, explicit rules (constraints) must be defined that describe how to combine the modules legally. However, modularity is not a dichotomous property of product architectures, which are neither modular nor integral. Rather, different types of modularity can be embedded into product architectures, depending on the characteristics of the manufacturing process. Some typologies of modular architecture have been proposed by Pine (1993), Ulrich (1995), and Salvador et al. (2002).

Companies must consider carefully where they want to give customers choices—and where they do not. To wrap up this section, the example of Chocri, the customized chocolate bar manufacturer, is insightful. Chocri allows customers to customize two modules: the base chocolate and the toppings. The base chocolate is available in four variants, but customers can choose from over 100 toppings (Magar 2011). Thus there are more than 10 billion possible combinations. The question of interfaces is not relevant; the toppings are simply spread on the
liquid chocolate. Chocri chose not to allow customers to determine how much of each topping to use per bar, because it could ensure consistent quality of the chocolate bars this way. Even in the case of this relatively simple product, nearly endless possibilities define the modules. Other customization modules could have featured the size and shape of the chocolate bar or the packaging. But insights from continuous revisions of its solution space have led Chocri only to introduce a fourth base chocolate after two years of operations; it also eliminated a few toppings that had been rarely selected by customers. The company also hopes to downsize its solution space further by offering a less comprehensive set of highly popular toppings, supplemented by changing seasonal toppings (e.g., Christmas, Valentine’s Day). To reduce the perceived risk for the customers who customize their own chocolate bars, Chocri offers 29 preconfigured creations. It also allows them to select some toppings without an additional charge, which function as teasers for the customization process.

It is important to note though that a scalable modularized mass customization production means more than modular product architectures; it also demands a corresponding process structure. The requirements for robust process design are the topic of Chapter 4.2.

4.1.3 Summary and Hypotheses

A key result of this discussion is the clear recognition that mass customization does not imply infinite choice. Finding the right extent of customization is a foremost competitive capability for a mass customization firm. Figure 11 summarizes the reasoning developed in this chapter.

![Figure 11: Developing a Solution Space from Internal Degrees of Freedom and Customer Demands](image)
To benefit from mass customization, firms should contemplate three questions that are fundamental to the development of an appropriate solution space.

- **What is economically producible, given the firm’s fulfillment system?**
  A firm embarking on mass customization must define the *width* of its solution space, that is, the predefined base products and modules that customers may use and modify during the co-design process. In making this decision, *efficiency considerations* with regard to the production process, *technical restrictions*, and *standards and laws* must be taken into account. Within the solution space, the firm can allow customization of its products on three dimensions: *fit*, *design/taste*, and *functionality*. The variety of customization options per base product or module defines the *depth* of the solution space. These internal parameters of the solution space should mirror real customer needs.

- **Which customization options are valued most by the customers?**
  Companies should offer customization only along those dimensions on which customers’ needs diverge widely and they actually care about the differences. Retrieving such information is not an easy task, because customers often have poorly defined preferences, and the information is sticky. There are three main modes to access this sticky information: *ask customers*, *build with customers*, and *listen in on the customer domain*. Methods for asking customers include conventional market research techniques such as personal interviews, focus groups and surveys, and more advanced approaches such as menu-based conjoint analysis. Building with customers refers to the use of innovation toolkits to tap the creative potential of customers. Finally, listening in on the customer domain refers to the process of gathering data about customers’ preferences from the analysis of Internet log files or the monitoring of innovative customer communities. Moreover, opportunity recognition heuristics might also play an important role in developing custom product offerings. When the relevant options to be presented in the solution space have been determined, they should be transferred to a product offering.
How can the solution space be translated into a product offering?

Modular product architecture provides an effective means to produce a high variety of products economically. Modularity helps firms mitigate the trade-off between variety and operational performance and achieve economies of scale and scope in production.

Developing a distinctive SSD capability enables mass customization firms to understand their customer’s idiosyncratic needs and more effectively meet them with their product offerings. As a result, defining an appropriate solution space is likely to increase utility for the customer, due to the improved preference fit and hedonic benefits. Therefore,

\[ H1: \text{Solution space development capability is an essential facet of a firm's overall mass customization capability.} \]

Furthermore, with regard to the discussion of the success factors and methods for SSD, several related hypotheses are proposed:

\[ H1a: \text{Systematic analysis of customer information relates positively to solution space development capability.} \]
\[ H1b: \text{Systematic analysis of secondary information relates positively to solution space development capability.} \]
\[ H1c: \text{Opportunity recognition abilities relate positively to solution space development capability.} \]
\[ H1d: \text{A formal revision process relates positively to solution space development capability.} \]
\[ H1e: \text{Product modularity relates positively to solution space development capability.} \]

4.2 Robust Process Design Capability (RPD)

4.2.1 Theoretical Basics

Advances in information and manufacturing technology have created a myriad of possibilities to mass customize. But understanding what constitutes a strategy and effectively putting it into practice are two different issues (McCarthy 2004, p. 347). Brown and Bessant (2003, p. 715) emphasize that for companies to translate mass customization into reality, they must undertake radical changes of their operations and supply chain structure, instead of just “fine tuning”
their existing operational capabilities. This is a difficult task, especially for mass producers moving into customization, which are accustomed to operating according to traditional management concepts (Blecker et al. 2005, p. 45). The proliferation of product variety to meet heterogeneous customer needs is a main driver of operational complexity in mass customization fulfillment systems, which may lead to performance losses (e.g., MacDuffie et al. 1996; Thonemann and Bradely 2002). Drawing on the results of a large-scale empirical survey among U.K. manufacturing firms, Squire et al. (2006b) conclude that customization is not free; significant trade-offs remain between variety and both manufacturing costs and delivery lead times. Therefore, a fulfillment strategy for mass customization must ensure that increased variability in customers’ demand does not incur significant lead time or cost penalties (Åhlström and Westbrook 1999, p. 263). This assurance can be achieved with a robust process design (RPD). Value creation based on RPD is a second key differentiation for mass customization compared with traditional one-of-a-kind (craft) customization. Craft customizers produce custom products using craft production techniques; they essentially must reinvent their processes for each customer (Piller and Stotko 2003, p. 195). In contrast, to deserve the prefix “mass,” customization companies must implement stable, but still flexible processes to achieve something close to mass production efficiency in their operations and supply chains (Tseng and Jiao 2001, p. 685). For these conditions, the acquisition costs for custom products can be kept on a level similar to that for mass produced standard goods. The corresponding RPD capability thus is defined as follows:

Robust process design is the ability of an organization to reuse and/or recombine its resources along the value chain to address variability in customers’ requirements, while avoiding any deterioration in the performance of the organization’s processes compared with a mass production system (adapted from Salvador et al. 2009, p. 73).

But before discussing adequate methods to improve the performance of mass customization fulfillment systems, it is necessary to understand the causes and consequences of complexity in mass customization, as well as the sources of their additional costs.

**Variety-induced complexity**

Providing a sufficient level of variety is an integral part of any mass customization strategy (Pine 1993, p. 44). Variety enables the manufacturing firm to address customers’
heterogeneous needs and thus differentiate themselves from competitors and potentially achieve a competitive advantage. Moreover, increasing variety-seeking behavior among customers means that more choice can help companies to increase their market share by acquiring new customers and retaining existing ones (e.g., Kahn 1995). But variety can also have negative effects on efficiency (for an overview of studies in this field, see Abdelkafi 2008, pp. 63-64). The variety inherent in any mass customization system induces a high level of complexity in operations and supply chain management (Blecker and Friedrich 2007, p. 6). Dealing with complexity in a mass customization environment effectively begins with an actionable understanding of the concept. However, no satisfactory and generally accepted definition of complexity has emerged (Blecker and Abdelkafi 2006a, p. 909).

As a result of this ambiguity, the terms “variety” and “complexity” are often used interchangeably in the mass customization literature. It is important to understand though that complexity is not necessarily connected to product variety; it can be driven by organizational hierarchies, information asymmetries, or suboptimal managerial decisions too (Wildemann 1998, p. 48). For this reason, Abdelkafi (2008, pp. 93-94) proposes the term *variety-induced complexity* to refer to complexity aspects strongly related to the diversity of customer needs and preferences. In a mass customization environment, variety-induced complexity might originate in the internal mass customization production system or the supply chain. Moreover, as discussed in Chapter 2.4, variety may have detrimental consequences for the customer, due to the paradox of choice.

According to Suh’s (2005) complexity theory, the complexity of a system is determined by its functional requirements and design parameters. Functional requirements refer to what the system should achieve; design parameters instead describe how the functional requirements can be satisfied. In this context, complexity is defined as a measure of uncertainty in achieving the specified functional requirements (Suh 2005, p. 4). Applying this framework to *mass customization production systems*, Blecker and Abdelkafi (2006a, pp. 912-913) identify three functional requirements to be fulfilled: (1) satisfaction of customer needs, (2) economic production, and (3) fast delivery. As a first requirement, customer needs must be satisfied along three dimensions within the predefined solution space: fit, design/taste, and functionality. The second functional requirement on the mass customization production system is the capacity to produce efficiently, so that the costs associated with customization
allow for a price level comparable to the prices of similar standard products. Finally, delivering customized products quickly meets customer delivery time demands. When customers must wait too long, they might switch to a competitor or demand a discount as recompense for the longer wait (Waller et al. 2000, p. 141). To achieve these functional requirements, three design parameters are critical: (1) product variety, (2) position of the customer order decoupling point, and (3) production flow (Blecker and Abdelkafi 2006a, p. 914). It is a straightforward argument that product variety is a necessary condition to fulfill heterogeneous customer needs. The decoupling point is the point in the value chain at which the customer order penetrates (e.g., Olhager 2003; Wikner and Rudberg 2005). The placement of this point is a strategic decision affecting the level of customization and waiting time until delivery. Finally, the flow of production is determined by the organization of the production process.

Relating the three functional requirements to the three design parameters illustrates the various interdependencies in a mass customization production system (Blecker and Abdelkafi 2006a, p. 915). The satisfaction of customer requirements is related to product variety and the decoupling point’s position. Obviously, more product variety increases the chance of satisfying a wider range of customer needs. As the decoupling point moves upstream in the value chain, customers can affect the production process earlier, which increases the perceived degree of customization possibilities. The system’s efficiency can be affected by all three design parameters. In an empirical study, Wildeman (2001) shows that doubling the variants increases unit costs by 20–35% for firms with traditional manufacturing systems, but for segmented and flexible automated plants, the unit cost increases are only 10–15%. Thus efficiency depends not only on product variety but also production flow. In addition, the decoupling point determines the proportion of mass production in the mass customization production system. Similarly, delivery time is influenced by all three design parameters. For instance, moving the decoupling point further downstream, toward the end customer, shortens lead times, because more production steps can be completed in advance, prior to the customer order. A smoothly running production also positively affects lead times. On the other hand, greater product variety may contribute to slowing down the production process through more frequent product changeovers, which increases lead times.
Overall then, a change in any design parameter affects more than one functional requirement. Management decisions about one functional requirement cannot be made independently of the others, which causes complexity (Blecker and Abdelkafi 2006a, p. 916). Furthermore, in addition to the complex relationships between functional requirements and design parameters, many experts from different functions, such as marketing, product development, purchasing, production, and logistics, are involved in the design tasks in a mass customization production system, creating greater communication and personnel-related complexity. However, variety-induced complexity can be kept under control if the firm implements effective variety management strategies (Blecker and Abdelkafi 2006a, p. 926). For example, by deploying delayed differentiation (postponement) and flexible automation strategies, managers can decrease the dependency between satisfaction of customer needs and the decoupling point. Moreover, delivery times are less dependent on the position of the decoupling point with modularized products and processes. Finally, personnel-related complexity can be effectively mitigated by investing in flexible human resources, as detailed further in the next section.

The performance of the mass customization production system depends heavily on the configuration and nature of the relationships in the supply chain system. Not surprisingly, as product variety grows, so does supply chain complexity. To analyze variety-induced complexity in mass customization supply chains, it is appropriate to focus on the buyer–supplier relationship, with the mass customizer as the focal company (Abdelkafi 2008, pp. 110-111). For mass customizers, it is difficult to predict demand for each end product, because the same product rarely gets sold twice. This demand uncertainty at the product level, caused by customers’ buying behavior and product variety, translates into uncertainty in component sourcing. Furthermore, the so-called bullwhip effect means that small demand fluctuations at the end of the supply chain cause higher levels of variability for upstream suppliers, which increases the risk of a stockout along the chain (e.g., Lee et al. 1997). This situation potentially makes deliveries more unreliable. Therefore, to mitigate the negative effects of demand uncertainty, the principle of delayed product differentiation (postponement) should be applied at the supply chain level too.

In summary, companies should seek a balance between the negative effects of complexity and the value of variety. In economic theory, from the customer’s point of view, the optimal variety is infinite (Lancaster 1998, p. 5), but the real-world optimum for a manufacturing firm
The Strategic Capabilities Framework is “the level of variety at which consumers will still find its offerings attractive and the level of complexity that will keep the company’s costs low” (Child et al. 1991, p. 74). In other words, firms must root out any complexity that the market does not justify. The main problem triggered by high variety-induced complexity is hidden costs, in the form of overhead that cannot be easily or fairly allocated to single product variants (Quelch and Kenny 1994, p. 156). Moreover, complexity costs related to investments (fixed costs) are partially irreversible, so firms find it difficult to retreat to their initial cost position, even after undertaking complexity reduction measures (Child et al. 1991, p. 73). In turn, a good understanding of the cost drivers of complexity is required, before any discussion of appropriate strategies for managing variety in a mass customization system.

**Cost drivers of variety-induced complexity**

In a mass customization environment, complexity represents the uncertainty in satisfying customer requirements, producing economically, and delivering quickly that results from increased variety (Blecker and Abdelkafı 2006a, p. 926). This complexity can be measured in monetary units. Complexity costs are the difference between the firm’s actual cost position and the costs of producing a single standard product with no variety at the same volume (Anderson 2004, p. 89). For example, if it costs Chocri €0.90 to produce a chocolate bar in more than 10 billion possible combinations, compared with €0.60 to produce a single variant of chocolate (or more realistically, 5–10 variants) at the same volume, complexity costs are €0.30, or 50%. Complexity strikes the manufacturing firm in many cost areas. Thus, though the impact of complexity on a single cost factor may be insignificant, its compound effect across a wide range of cost areas can badly harm the competitive position of a firm (Olavson and Fry 2006, p. 65). Firms embarking on mass customization thus must identify the exhaustive set of cost areas affected by variety-induced complexity, because higher costs are possible along the whole value chain (the additional cost drivers of mass customization are described in detail in e.g., Kotha 1995, p. 38; Agrawal et al. 2001, pp. 67-69; Piller and Stotko 2003, pp. 192-202; Piller 2006, pp. 138-150).

In *research and development*, designs of product families based on modular product architectures and component commonality are normally more complex and costly than devising completely integral designs (Piller and Stotko 2003, pp. 114-119). Moreover, some modules and components likely are designed in anticipation of customer needs but rarely
selected by customers in reality, such that they get eliminated during a regular revision of the solution space without ever yielding a significant return (Piller 2006, p. 143).

With regard to procurement and materials management, a firm applying a mass customization strategy should be able to source and ship small quantities of highly differentiated products efficiently; typical supply chains in mass production instead are geared toward handling large quantities of similar or identical products. Mass customizers thus must maintain relationships with more suppliers, spend more time on procurement market research, and invest in the integration of supply chain management systems (Piller 2006, p. 144). Furthermore, inventory costs may rise, because the firm keeps a greater variety of modules or components of different quality in stock to fulfill various customer needs without significant delay (Agrawal et al. 2001, p. 67).

Smaller batch sizes are also a key cost driver for production. Because mass customizers operate on a low volume, high mix premise, costs increase through the loss of economies of scale (standardization and specialization), compared with mass production (Kotha 1995, p. 23). Specifically, higher set-up costs, frequent changeovers, costs for highly skilled production workers, and increased complexity in production planning and control drive up the cost level (Piller 2006, p. 145). Moreover, quality control becomes more burdensome, because each product must be examined to ensure it fulfills the customer’s individual requests, in contrast with mere sample testing for mass production (Piller and Stotko 2003, p. 194). Nor is it possible to manufacture for stock during low capacity utilization periods. The experience curve effect (Henderson 1968), which states that the more often a task is performed, the lower the cost of doing it, is also less pronounced because of the minimal degree of repetition in production. Overall, the incremental cost of production depends on the flexibility of the manufacturing systems. Increasing this flexibility requires high upfront investments in flexible automation units and appropriate information systems.

Mass customization also leads to higher distribution and after-sales-service costs. If product delivery occurs on a per item basis, handling and transportation costs jump (Piller 2006, p. 147). Firms also must factor in that the return rates for customized goods are likely higher. In this context, a “no questions asked” policy is essential to reduce customers’ perceived risks. Customized products that do not meet customers’ requirements lower the probability of a
repurchase and potentially lead to negative word of mouth. The mass customizer You tailor thus aggressively advertises its unique satisfaction guarantee: If the first ordered garment is not a perfect fit, it will remanufacture a new garment free of charge or reimburse the customers’ costs for minor changes. Finally, maintaining the necessary inventory of diverse customized modules and components poses a challenge to spare parts management (Piller and Stotko 2003, pp. 200-202).

However, a significant proportion of additional costs associated with mass customization stems not from complexity in manufacturing and supply chain management but rather from the customer interaction. Direct interaction with the customer to elicit individual preference information, which subsequently can be translated into a concrete product specification, is a constitutional element of any customization strategy (Piller 2006, p. 143). This interaction process creates additional information and communication costs, such as upfront investments in configuration systems online or in physical stores, as well as training of sales personnel and establishment of dedicated customer service centers. A sophisticated communication policy and special promotion activities also are necessary to create awareness of customized products and establish trust with the customers (Piller and Stotko 2003, pp. 199-200).

Yet it is a mistake to assume that the cost drivers of complexity cannot be influenced. Several methods help reduce the magnitude of these effects, as discussed next.

4.2.2 Methods for Robust Process Design
Rigorous variety management is an essential capability for firms that practice mass customization or intend to embark on such a strategy (Blecker et al. 2005, p. 38). Before going into detail, this section briefly outlines the objectives pursued through different RPD methods in a mass customization environment. In a case study analysis, Da Silveira (1998, pp. 280-282) postulates that firms may pursue adaptive strategies, flexibility strategies, or a combination to mitigate the trade-offs between variety and manufacturing costs or delivery lead times. Adaptive strategies strive to master the proliferation of variety without operational changes. For example, firms might adapt by passing on additional costs of variety-induced complexity to customers in the form of higher acquisition costs. However, the success of such a strategy is doubtful, because it depends on the competitive situation in the industry. Recall
from Chapter 3.2 that customers will pay a premium for mass customized products only if it matches the increment in utility they derive from customization.

In contrast, companies that adopt flexibility strategies develop the requisite methods, tools, and labor skills to cope with high variety while avoiding deterioration in the performance of the organization’s processes. Upton (1994, p. 73) defines flexibility as “the ability to change or react with little penalty in time, effort, cost or performance.” A successful mass customization strategy requires the pursuit of both production volume flexibility and product mix flexibility to counterbalance market volume and mix uncertainties (Zhang et al. 2003, p. 178). Volume flexibility is the ability to run various batch sizes and produce below or above the installed capacity for a product, profitably and effectively (e.g., Khouja 1997; Jack and Raturi 2002). This ability can be assessed by the cost curve: If it is U-shaped with a long flat bottom, the firm can sustain profitability over a wide range of production volumes (Zhang et al. 2003, p. 178). Volume flexibility thus is a prerequisite of production scalability, which represents a major obstacle to growth for many SMEs embarking on mass customization. For example, Chocri had to shut down its website before Christmas in its first year of operations because it could not keep up with demand. In the light of this experience, it tripled production capacity before Easter in the following year. The same problem afflicted Blank Label, a producer of custom dress shirts, which suddenly received 50 orders per hour after being mentioned in a New York Times article (Magar 2010). Mix flexibility instead refers to an ability to switch across different product variants with low changeover costs (e.g., Li and Tirupati 1997; Berry and Cooper 1999). Such firms can react to changing customer requirements in a timely manner, without affecting volume or capacity (Zhang et al. 2003, p. 178). As we define it, a mass customization firm’s process design can be considered robust if it provides the levels of volume and mix flexibility required to ensure that the firm can efficiently serve its customers individually. The robustness of the processes can be increased through postponement, process modularity, flexible automation, and flexible human resources.

Postponement

The key drivers for implementing postponement are the increased difficulty of firms to forecast demand, and customers demand for higher levels of customization (Matthews and Syed 2004, p. 31). Also known as delayed differentiation, postponement can be defined as “an organizational concept whereby some of the activities in the supply chain are not performed
until customer orders are received” (van Hoek 2001, p. 161). It separates the fulfillment system into a standardized pull subsystem and a customer-specific push subsystem at the decoupling point (Blecker and Abdelkafi 2006a, pp. 912-913). The decoupling point specifies the position in the value chain where the customer order penetrates, distinguishing forecast from order-driven activities. Hence, postponement is a suitable strategy for moving the decoupling point closer to the end customer, thereby improving flexibility and efficiency in the supply chain (Yang et al. 2004, pp. 475-476).

Postponement is widely considered effective for achieving RPD in mass customization (e.g., Pine 1993; Kotha 1995; Lampel and Mintzberg 1996; Feitzinger and Lee 1997). Specifically, literature on postponement distinguishes three delay strategies: time, place, and form postponement (Bowersox and Closs 1996, p. 472). In the time postponement strategy, the forward shipment of products gets delayed until customer orders arrive. Place postponement refers to the strategy of maintaining an anticipatory inventory of differentiated goods at strategically central locations in the supply chain to achieve a balance between inventory cost and responsiveness. Finally, form postponement delays the customization of products until later stages of the supply chain. It therefore is generally considered an adequate response to increasing demand for customized products (Matthews and Syed 2004, p. 31). Depending on the industry context, form postponement can be achieved through two distinctive approaches: retaining product commonality as far downstream in the supply chain as possible and re-sequencing production processes (Yang et al. 2004, pp. 477-481). The first approach requires modular product designs. Thus firms can maximize the number of standard components common to each configuration, preassemble those components at early stages of the production process, and postpone the addition of differentiating components until later in the process (Feitzinger and Lee 1997, p. 117). The second approach entails redesigning the processes to reverse the sequencing of production. A classic example comes from Benetton, which reversed the production process of its sweaters. Instead of dyeing the yarn first, Benetton knits plain wool into sweaters and postpones the dying of its inventory until it identifies the colors that will be in vogue for the season (Lee and Tang 1997, p. 48). For postponement to be successful, Van Hoek et al. (1998, p. 33) postulate that the three basic strategies—time, place, and form postponement—should be combined in one manufacturing system. Going even further, Yang et al. (2004, p. 474) claim that to achieve mass
customization, postponement should extend beyond a manufacturing context to spread throughout the supply chain, as companies more and more frequently compete on the basis of the configurations of their supply chains, not products (Waller et al. 2000, p. 138). Yang and Burns (2003, p. 2077) thus propose five postponement strategies along the supply chain and connect them to a continuum of customization and standardization proposed by Lampel and Mintzberg (1996).

The increased flexibility resulting from postponement enables a firm to offer a wide range of customized products at changing volumes with sufficient cost efficiency. In particular, cost savings stem from reductions in inventory costs and the risk pooling effect. Inventory costs shift upstream to less expensive generic products (Matthews and Syed 2004, p. 34). A better match of supply and demand also reduces inventory obsolescence costs (e.g., write-offs, clearance sales) (Feitzinger and Lee 1997, p. 119). Furthermore, in a certain planning period, it is possible to obtain the benefits of risk pooling, because it is more accurate to forecast aggregate demand for a common component than single demands for many different components (Eynan and Fouque 2003, p. 704; Sheffi 2005, p. 102). Finally, postponement can result in improved order fill rates and service levels with decreased order lead times (Waller et al. 2000, p. 136; Matthews and Syed 2004). Because the finished products are produced from prefabricated components and not from scratch, firms can better deliver goods on time and substantially increase customer satisfaction.

**Process modularity**

Postponement determines the overall structure of the fulfillment system; process modularity can be applied to redesign processes within the push and pull subsystems (Abdelkafi 2008, p. 158). Without process modularity, the complete production process must be performed in a single run, which leads to long cycle times and inflexibility in meeting demands for the broad variety of end products (Lee 1998, p. 88). Process modularity instead involves the practice of breaking down manufacturing processes into loosely coupled subprocesses, or process modules, that communicate through standardized interfaces (Tanriverdi et al. 2007, p. 282). These process modules “can be resequenced easily or new modules can be added quickly in response to changing product requirements” (Tu et al. 2004b, p. 151). Each module represents a distinct part of the production process, such as cutting, molding, assembling components, or mixing ingredients, typically linked to a specific source of variability in customers’ needs.
Modular process architectures exhibit several desirable features that increase flexibility in manufacturing. First, the process modules, which could include suppliers, distribution centers, or vendors, do not interact in the same sequence for every customer order. Rather, modular manufacturing processes can be resequenced and postponed to provide a broad range of customized products (Feitzinger and Lee 1997, p. 119). Second, if a process module is loosely coupled with other processes and operated independently, disturbances (e.g., part shortages) can be localized to specific subprocesses. Thus a temporary breakdown of one process will not cause the whole manufacturing process to come to a halt (Sanchez and Mahoney 1996, p. 65). Third, standardized process interfaces and a loosely coupled architecture allow for process innovations to be carried out autonomously on specific modules, without involving other subprocesses (Sanchez 1997, p. 87). Fourth, process modules can be easily outsourced to other organizations to increase flexibility and lower costs, because the interaction parameters are fully specified and standardized (Baldwin and Clark 1997, p. 87). It is important to note though that a modular process architecture places high requirements on the flexibility of the workforce, as discussed in a separate section on flexible human resources.

With a sample of 303 companies, Tu et al. (2004b) demonstrate that product and process designs consistent with modularity are an effective way for manufacturing firms to improve mass customization capability. Specifically, process modularity helps reduce work-in-process inventories and lowers assembly costs while shortening production cycle times through prefabrication and parallel processing (e.g., Lee 1998, p. 88; Cooper 1999, p. 101). Postponement and process modularity start with the design of the production and value chain system; another possibility relies on flexible automation on the shop floor.

Flexible automation
Manufacturing practices generally reflect the customer’s changing requirements (Molina et al. 2005, p. 525). In the mass production paradigm, economies of scale were the guiding principle for manufacturing planning. Companies thus had to trade off between producing more of the same product at smaller unit costs or producing a greater variety of products at higher unit
costs (Goldhar and Lei 1995, p. 76). Today, customers demand customized, high-quality products with shorter lifecycles, so manufacturing systems need a greater degree of flexibility to produce a vast variety of products at low costs and in batch sizes as small as one (Boyer 1999, p. 825). In response, highly sophisticated automation systems have evolved to include several key characteristics (Mehrabi et al. 2000; Molina et al. 2005): First, the systems are designed to provide the functionality and capacity that is needed, when it is needed. Second, they can be readily updated with new technologies. Third, they can be rapidly reconfigured by incorporating basic process modules, both hardware and software, to manufacture new products or accommodate changes in production volume.

Flexible automation is an umbrella term that refers to the use of high variety–oriented manufacturing and design technologies, such as robotics, flexible manufacturing systems, automated material handling systems, group technology, and computer-aided design and engineering. These technologies are normally supported by administrative systems such as knowledge management, decision support systems, manufacturing resource planning, activity-based accounting systems, and industrial communication systems that enable supply chain integration (Boyer 1999, p. 832). The advantages of flexible automation include greater flexibility, increased control of the manufacturing process, and the possibility to combine economies of scale and scope. At the plant level, economies of scope allow for the production of a broad range of products without the cost penalties associated with traditional mass manufacturing technologies. Yet economies of scale also can be achieved by aggregating demand over multiple products, eliminating the risk that an investment in facilities to produce a single high volume product might be rendered obsolete by changes in customer demand (Goldhar and Lei 1995, p. 76). In a longitudinal study, Boyer (1999) finds support for the proposition that investments in flexible automation technology relate positively to performance improvements. With higher investments, firms show on average higher sales growth, returns on sales, earnings growth, and market share. However, these data indicate a time lag of two years between the initial investment and the performance improvements, presumably because the workforce must adapt to the new production environment. In a large-scale empirical study among mass customizers, Tu et al. (2004a) also show that several flexible manufacturing practices have a statistically significant and positive impact on mass customization capability, especially when environmental uncertainty is high.
Additive manufacturing technologies are a special case of flexible automation that is fundamentally changing the standard of producing custom products (Ryan 2011). Additive manufacturing is the fabrication of objects directly from 3D model data, usually layer upon layer using 3D printers, as opposed to traditional subtractive manufacturing methodologies, such as cutting, drilling, and bending materials (Petrovic et al. 2011). The technology allows for a great deal of customization and makes economies of scale obsolete: The producer does not have to make thousands of items to recover its fixed costs. Almost any form can be printed from materials ranging from stainless steel to glass, plastics to sandstone, without any costly retooling. Thus less capital is tied up in work in progress or raw materials, and the lead time from design to production drops significantly (The Economist 2011). Although additive manufacturing applications originated in tooling, biomedicine, and lightweight structures for the automotive and aerospace sectors, a handful of companies (e.g., Shapeways, Ponoko, i.materialise) have found ways to offer 3D printing to customers and small businesses (Ryan 2011). Additive manufacturing lowers the cost of entry for businesses that make products; entrepreneurs can run off a few samples to see if they sell or quickly make design changes requested by customers, before investing in conventional mass production or large-scale 3D printing (The Economist 2011). This increased ability to produce small series of customized products economically could even mean the return of manufacturing to the West from inexpensive centers of production in underdeveloped countries (Petrovic et al. 2011).

However, to achieve a competitive advantage based on flexible automation, technological capabilities need to be complemented by organizational capabilities that foster agility and generative learning (Goldhar and Lei 1995, p. 82).

**Flexible human resources**

The successful exploitation of a mass customization strategy requires long-term investments in human resources. It is humans, in conjunction with advanced information and manufacturing technology, that create knowledge about customers, develop new capabilities, and promote the diffusion of best practices to align the organization with its customers (Kotha 1996, p. 448). Pine et al. (1993, p. 110) get right to the point: “robots don’t make suggestions.” In this context, human resource flexibility in particular is a valuable firm capability, because it facilitates the adaptation of employee attributes to rapidly changing competitive environments (Wright and Snell 1998; Wright et al. 2001). To achieve flexibility in human resources, firms
embarking on mass customization must break apart bureaucratic organization structures that prioritize functionally defined jobs and embrace instead loosely coupled networks of adaptable, highly-skilled teams (Pine et al. 1993, p. 111).

Such teams may be characterized as *multifunctional*, because they combine the knowledge and skills needed to satisfy the customer, and *dynamic*, because they enable rapid reconfiguration to meet ever-changing customer requirements (Yauch 2007, p. 21). Multifunctional teams require *skill flexibility* on the employee level, which can be generated in two ways. Firms may have fewer employees with broad-based skills who can use those skills in various demand conditions, or they can employ many specialist employees with unique skills (Bhattacharya et al. 2005, p. 625). The first approach is generally applied to teams of shop floor employees, whereas the second tends to characterize concurrent engineering teams in product design and development. Multifunctional production teams can be accomplished by cross-training workers and rotating them among workstations. Thus workers can float among the different workstations or even plants to add capacity where it is most needed (Yauch 2007, p. 21). Furthermore, workers may rotate between custom and mass production in companies that pursue a dual strategy, creating substantial knowledge spillover effects (Kotha 1995, p. 32).

The concept of dynamic teams instead refers to the application of modularity principles to human resource management (Tu et al. 2004b, p. 152). Project or production teams are dynamic modules with shared culture and values that can be reconfigured quickly in response to changes in the product design or manufacturing process (Galunic and Eisenhardt 2001, p. 1229). The teams are temporary in nature, with changing membership (Yauch 2007, p. 22). For dynamic teams to function optimally, they need *behavior flexibility* on the employee level, that is, “the capacity of people to adapt to changing situations or to exhibit appropriate behavioral repertoires under different situations” (Bhattacharya et al. 2005, p. 625). Higher individual adaptability means that organizations do not need to recruit new people with new skills to respond to environmental changes.

This reasoning with regard to flexible human resources is backed by empirical evidence. Bhattacharya et al. (2005, p. 634) find that skill and behavior flexibility relate positively to firm financial performance; investments in human resource development thus are likely to pay off. Tu et al. (2004b, p. 161) show further that team modularity is an effective way to improve
mass customization capabilities. However, a word of caution is required: Increased human resource flexibility also can have detrimental effects. Excessive responsibility in multifunctional teams can lead to increased pressure and fear of failure. Dynamic teams also create more potential for conflict, because there is not sufficient time to establish group norms (for an overview of the negative impacts, see Yauch 2007, p. 24).

4.2.3 Summary and Hypotheses

A key result of this discussion is the recognition that customization is not for free. Therefore, manufacturing firms embarking on mass customization must ensure, through robust process design, that increased variability in customers’ demand does not significantly impair their operations or supply chains. Figure 12 summarizes the reasoning developed in this section.

![Figure 12: Mitigating the Negative Effects of Complexity Through Robust Process Design](image)

To benefit from mass customization, firms should contemplate three questions that are fundamental to the design of robust processes:

- **What are the causes of complexity in a mass customization system?**
  The main source of complexity in mass customization is variety in customer needs and preferences, which justifies the term *variety-induced complexity*. Firms must understand that variety-induced complexity can originate in the *mass customization production system*, the *supply chain system*, or the *customer system*, and each form demands different approaches. The challenge for mass customization firms is to balance the negative effects of complexity with the value of variety.

- **What are the consequences of complexity for a mass customization system?**
  The main problem triggered by variety-induced complexity is hidden costs. *Complexity costs* can occur along the whole value chain in research and development, procurement
and materials management, production, distribution, and after-sales service, as well as in customer interactions. The impact of complexity on a single cost factor might be insignificant, but its compound effect can ruin the cost position of a firm. Therefore, it is of paramount importance for mass customization firms to identify which cost areas in the organization are affected by variety-induced complexity.

- How can complexity be effectively managed and reduced?

To counterbalance the negative effects of variety-induced complexity, mass customization firms should increase their flexibility with regard to both production volume and product mix, such as through postponement, process modularity, flexible automation, and flexible human resources. Postponement implies delaying some activities in the supply chain until customer orders come in, which improves efficiency and flexibility. Process modularity describes the practice of breaking down manufacturing and supply chain processes into subprocesses that can be resequenced or postponed in response to changing customer requirements. Flexible automation is an umbrella term for high variety manufacturing and design technologies that allow firms to produce a large variety of products cost effectively in batch sizes as small as one. Finally, human resource flexibility is required to deal with novel and ambiguous tasks in a mass customization environment and to facilitate interaction among functions in the process of delivering tailored solutions to the customer. Not all methods for robust process design are equally relevant for mass customization firms; their value in managing complexity depends on the type of the business. It is also important to note that achieving a robust process design capability involves combining tangible assets, knowledge, and skills, which necessarily incurs some costs.

In summary, developing a robust process design capability enables mass customization firms to mitigate the trade-off between variety and costs by reusing or recombining existing organizational and value chain resources. Improving the robustness of the process design should reduce acquisition costs for custom products to a level comparable to that for mass produced standard products. Therefore,

\[H2: \text{Robust process design capability is an essential facet of a firm’s overall mass customization capability.}\]
Furthermore, in line with the preceding discussion of the different methods to support RPD, the following hypotheses are proposed:

\[ H2a: \text{Process modularity relates positively to robust process design capability.} \]
\[ H2b: \text{Flexible automation relates positively to robust process design capability.} \]
\[ H2c: \text{Flexible human resources relate positively to robust process design capability.} \]

Finally, the interdependencies among product modularity, process modularity, and postponement suggest the following hypothesis:

\[ H2d: \text{Product modularity relates positively to robust process design capability.} \]

### 4.3 Choice Navigation Capability (CN)

#### 4.3.1 Theoretical Basics

Developing an appropriate solution space and a robust process design is not enough to reap the benefits of mass customization. The manufacturer must also develop a mechanism for obtaining specific information on customers’ needs and preferences and then translating them into a definite product specification (Piller et al. 2004, p. 437). This mechanism, which Zipkin (2001, p. 82) refers to as “elicitation”, goes beyond a simple exchange of information between manufacturer and customer. Rather, the individual customer should be integrated into the manufacturer’s value creation process (Ramirez 1999). Instead of passively choosing from a standard product assortment, costumers assume an active role and determine which product gets offered to them by specifying its attributes. In a mass customization system, most of this interaction takes place during the configuration or design phase for customer-specific products, so Franke and Piller (2003, p. 578) opt for calling customers co-designers. The term “customer co-design” is frequently used in literature to refer to cooperation between a firm and its individual customers during the configuration process of a customized product (e.g., Wind and Rangaswamy 2001; Anderson-Connell et al. 2002; Kumar 2007; Merle et al. 2008; da Silveira 2011). It also relates to the collaborative customization approach identified by Gilmore and Pine (1997, p. 92), in which “customizers conduct a dialogue with individual customers to help them articulate their needs, to identify the precise offering that fulfils those needs, and make customized products for them.” The customization co-design process thus is the core element that differentiates mass customization from other high-variety strategies, such
as agile manufacturing or lean management (Piller 2005a, p. 315). Yet, firms can raise the question, “Are customers really willing to engage in co-design activities?”

Forrester Research reports that 61% of U.S. online customers, in principle, are willing to lend a hand to create products they eventually would purchase; they also appear open to co-creation across a wide range of products, services, and brands (Williams et al. 2010). Furthermore, empirical evidence indicates that enjoyment of the co-design process has an added impact on the perceived value of the customized product and enhances willingness to pay (e.g., Ihl 2009; Franke and Schreier 2010; Merle et al. 2010). This evidence seems like good news for firms embarking on mass customization, but they still need to consider the other side of the coin. Co-design activities also induce perceptions of greater complexity, effort, and risk among customers (Piller et al. 2005, p. 2). These burdens and drawbacks are generally subsumed within the term “mass confusion” (Huffman and Kahn 1998). As a consequence of mass confusion, customers might postpone their buying decisions, opt for a standard product alternative, or reassign their budget to a different vendor (Piller 2005a, p. 324). Mass customization firms must explicitly address these two sides of the same coin to create a positive co-design experience for their customers. The corresponding choice navigation (CN) capability thus is defined as follows:

Choice navigation is the ability of an organization to support customers in identifying their needs and creating their own solutions, such that choice complexity is minimized and enjoyment of the search/configuration process is maximized (adapted from Salvador et al. 2009, p. 73).

Effective choice navigation requires adequate interaction systems to facilitate searches of the solution space for optimal product configurations. Advances in information technology have made these interaction systems both less expensive and more powerful, lowering the barriers to mass customization for start-ups and SMEs (Gownder et al. 2011, p. 2). Interaction systems are considered to be among the most important enablers for the successful implementation of a mass customization strategy because they considerably affect the outcome of the total customization co-design process (Blecker and Abdelkafi 2007, p. 40). Especially for purely web-based mass customizers, these systems also constitute the central interface with customers. Customers who configure a product online have no choice but to rely on
information provided by interaction systems, so their choices are largely dependent on the quality of the information and the richness of the visualization conveyed by the system (Abdelkafi 2008, p. 239). Any problems along these lines cause customers to lose trust in the competency of the firm and perhaps abandon the purchase. However, though mass customization firms offering the possibility for online configuration and purchase are the primary focus of this empirical study, choice navigation is not restricted to software-based solutions. Successful brick-and-mortar mass customization firms such as Build-a-bear, Dolzer, or Adidas rely on specially trained sales staff and unique store environments to interact effectively with customer co-designers (Berger et al. 2005).

Requirements on mass customization interaction systems
Mass customization interaction systems must basically satisfy two requirements: Reduce perceived complexity during the co-design process and create a feeling of fun, pleasure, or excitement (Franke and Piller 2003). Recall from Chapter 2.4 that perceived complexity during the customization co-design process stems from three main causes (Piller et al. 2005, p. 9):

- **Burden of choice**: More variety increases the difficulty of finding the right product configuration. The burden of choice leads to information overload (e.g., Malhotra et al. 1982), due to the limited information processing capabilities of humans (e.g., Miller 1956).

- **Preference uncertainty**: In many cases customers seem to have poorly defined preferences and they often lack the expertise to translate them into a concrete product specification (Simonson 2005). Furthermore, what customers choose on the purchase occasion may not correlate well with what they want at the time of consumption, which is why customers frequently end up “miswanting” purchases (Syam et al. 2008).

- **Principal-agent problem**: The co-design process is a typical principal–agent relationship (Fama and Jensen 1983). The customer (principal) orders and pays the mass customizer (agent) for a product before having seen or tested it and usually must wait considerable time to receive it (Piller 2005a, p. 324).
Thus designing an individual product requires more effort than picking a standard product off the shelf; customers must engage in exhaustive, time-consuming problem-solving activities. The perceived effort of co-designing the product then could carry over to evaluations of the process outcome, such that it lowers the value customers attribute to the customized product (Franke and Schreier 2010, p. 1023). As suggested in Chapter 2.1 though, the co-design process could also add value if customers perceive it as enjoyable and self-rewarding (e.g., Ihl 2009; Franke and Schreier 2010; Merle et al. 2010), such as when interactions with web-based co-design systems lead to a mental state of “flow.” In this optimal experience, the customer becomes fully immersed in the interaction process and perceives a good balance between the challenges of the task and his or her own skills (Novak et al. 2000). This customer is likely to value the co-designed product, as measured in terms of willingness to pay. In the following, we aim specifically to assess the effects that the different features of mass customization interaction systems have on perceived complexity and process enjoyment.

4.3.2 Methods for Choice Navigation

In the early days of mass customization, firms could play on the novelty effect of their product offerings to win over customers, regardless of the level of sophistication of their interaction systems. Today, as more and more players enter the market, mass customization firms increasingly compete on the performance of their interaction systems and offers of additional online services. In popular product categories such as customized apparel or food in particular, competition has greatly intensified recently, leading researchers to investigate which features attract customers in different mass customization interaction systems and why they prefer one configuration over another (Dellaert and Stremersch 2005, p. 219; Simonson 2005, p. 35; Dellaert and Dabholkar 2009, p. 44). Such questions are highly relevant for firms in the process of designing or revising their mass customization interaction systems, which often involves significant financial investments. In this context, configuration toolkits, or configurators, are the most frequently researched approach to help customers navigate a mass customizer’s product assortment. We also discuss some more advanced methods for choice navigation, such as recommender systems and embedded toolkits.
Configuration toolkits

Configuration toolkits create a virtual environment for visualizing, evaluating, readjusting, and pricing different product variants, as part of the customer’s learning-by-doing process (Franke and Piller 2003, p. 580). These user-friendly design interfaces also allow for trial-and-error learning and provide immediate simulated feedback on potential outcomes of design ideas. Thus customers can engage in multiple sequential experiments until they find an optimal fit between the available options and their needs (von Hippel 2001, pp. 250-252; von Hippel and Katz 2002, pp. 825-827).

Forza and Salvador (2008, p. 821) differentiate two core functions of a configuration toolkit: sales and technical configurations. The former guides customers toward a set of product specifications that are as close as possible to their needs. The result of this sales configuration process is a complete commercial description of a product the customer is willing to buy, which becomes the input to a technical configuration process. In turn, this process links the commercial characteristics of a product to documentation that describes how to manufacture the product, including bills of materials, computerized numerical control (CNC) programs, and production sequences. Modern product configurators support both functionalities, supplemented with product data management and customer relationship management systems that facilitate efficient and effective customization (Forza and Salvador 2008, pp. 822-829). When mass customization configuration problems are highly complex, firms should deploy a constraint-based approach (Xie et al. 2006, p. 91), which defines product components by a set of attributes and interfaces that connect them to other components. For each configuration step, the configurator makes suggestions of components the customer can select; present constraints prohibit a combination of components or request for a specific combination that does not work (Rogoll and Piller 2002, p. 78). Such constraint-based configuration thus supports validity checks and guides the customer in making all the necessary choices. In principle, configuration tools can be provided offline, such as a stand-alone terminal in a shop, or online, usually embedded in a company’s website.

Despite their benefits, online configuration toolkits cannot automatically solve all problems associated with the complexity of co-design. Customers often report minimal familiarity with product configurators: Only 6% of the U.S. online customers reported that they used a configurator for their last purchase (Forrester 2010). To effectively decrease configuration
complexity and improve overall customer satisfaction, configurators need to exhibit certain system features, whether basic or advanced (Abdelkafi 2008, p. 253). Basic features constitute the minimum requirements to be satisfied by the configurator to operate in a web-based mass customization environment; without them, customers might not finish the configuration process. Yet these features have only limited benefits for reducing complexity and creating enjoyment. Thus advanced features are needed to reduce the cognitive costs customers incur during the interaction process and convey a unique buying experience. In the following, we detail some features that have been introduced in prior literature; their effectiveness for achieving the key objectives outlined above largely has been proven empirically.

**Basic features of configuration toolkits**

To allow for trial-and-error learning processes, customers should be able to navigate back and forth between the configuration steps and make adjustments to their designs if necessary. This functionality is particularly important if customers realize that they have exceeded their planned budget. Customers should also be able to save their design and resume configuration at a later point in time. Some combinations of modules or customization options may not be allowed due to technical constraints or standards and laws. The configurator thus should be able to recognize these inconsistencies to ensure that customers are only allowed to order product variants that can be produced, thus avoiding disappointment. A configurator should also provide some kind of help button leading to meaningful information, a hotline, or an online form for help requests (for an overview of features of configuration systems, see Rogoll and Piller 2002; Randall et al. 2005). Online configurators for mass customization must also meet basic web usability requirements, such as high downloading speed, clear layout, easy navigation, and concise language (Bee and Khalid 2003). However, these basic features are generally unsuitable for differentiation from competitors in web-based mass customization. More advanced features are therefore required, which we discuss in the following, substantiated by a number of real-world examples.

**Attribute-based product information and alignability**

In one stream of research, authors investigate how information presentation formats—whether by attribute or by alternative—can affect perceived complexity. In the first approach, a customer expresses preferences for each individual attribute of the product (e.g., processor, memory, screen, and hard drive of a laptop computer). After gathering the preferences, the
configurator presents the customer with a product from the assortment that best matches his or her preferences or else develops a relevant, customized solution. In the second approach, customers review a set of fully specified products (e.g., 10 different laptops) and formulate their preferences by comparing these alternatives. When Huffman and Kahn (1998) asked respondents to choose a sofa and a hotel based on attributes or alternatives, they found that for high variety assortments, the attribute-based format reduced perceived complexity, increased satisfaction with the process, and facilitated customers’ willingness to make a choice. Perhaps information presented in an attribute-based format leads customers to assume they have seen all the options; information presented in an alternative-based format instead may leave customers wondering if other (better) alternatives remain. An attribute-based approach also facilitates learning about preferences. Kurniawan et al. (2006) find that using attribute-based product configurations in mass customization settings result in higher product and process satisfaction, as well as lower cognitive costs (i.e., shorter total time spent, fewer product alternatives searched). This effect is even stronger when there are more choices, which suggests that the relative benefits of attribute-based configuration increase with variety. In a series of empirical studies, Valenzuela et al. (2009) allow for self-customization of products (computers, DVD players, ballpoint pens) and services (travel insurance) by attribute or by alternative. In the customizing-by-attribute procedure, customers (1) tend to choose an intermediate (compromise) option, (2) perceive lower levels of difficulty, (3) are more satisfied with the customized option, and (4) exhibit more willingness to purchase. These findings likely reflect the reduced choice complexity and lack of information overload, but they also indicate that the trade-offs among characteristics are less explicit in the customizing-by-attribute procedure. In summary, extant research suggests that mass customization firms should present product information in terms of attributes.

Product attributes also can be distinguished as either alignable or nonalignable. Alignability exists when the products differ along a single compensatory dimension and are readily comparable (Gourville and Soman 2005, p. 384). In a car for example, engine performance expressed in terms of horsepower is alignable if at least two attribute levels are available, say, 120 horsepower and 170 horsepower. Choosing between product alternatives characterized by alignable attributes requires only within-attribute trade-offs. In contrast, if one car is equipped with a navigation system but the other has a leather interior, the attribute difference is
nonalignable, so the comparison between them is more difficult for customers, because it
demands between-attribute trade-offs. In two experimental studies, Herrman et al. (2009) find
that customers are more satisfied with a product choice based on alignable attributes.
Customers also demonstrate a higher willingness to pay and are quicker to select a product. If
a mass customization firm seeks to increase customer satisfaction by expanding the range of
product variety, nonalignable product attributes should be transformed into alignable ones.
Alignability can be achieved through pseudo-alignable labels, which are commonly used by
traditional mass producers (Herrmann et al. 2009, p. 339). For example, credit card companies
use the labels silver, gold, and platinum to link the nonalignable differences in their included
services. In the digital camera industry, companies such as Canon employ technical names,
such as the IXUS 115HS, 220HS, and 310HS to transform several nonalignable attributes into
one alignable attribute and thus impose a hierarchy in the product alternatives.

Default configurations and sequencing of attributes

Another stream of research explores the impact of providing customers with a default
configuration as a starting point in the customization co-design process. The default level of
an attribute gets proposed automatically if the customer does not explicitly specify another
duces customers’ perceptions of difficulty but has no significant effect on their purchase
likelihood. In setting default values for their customizable products, mass customization firms
can either give customers a base model and ask them to add desired options or provide a fully
loaded model and ask customers to delete some features (Levin et al. 2002, p. 335). Thus the
managerially relevant question is which strategy will result in a greater number of options
chosen and ultimately a higher purchase price, assuming that each additional option yields a
positive contribution margin.

Dellaert and Stremersch (2005) show that customers obtain a higher utility from a customized
PC when they begin with a base default version rather than an advanced version, because they
appear more willing to switch up to higher priced, higher quality products than switch down to
lower priced, lower quality products. Furthermore, an intermediate default version led to the
lowest perceived complexity in the co-design process, perhaps because it came closest to most
customers’ ideal point. In contrast, Park et al. (2000) show empirically that customers engaged
in subtracting options from a fully loaded product (1) select more options, (2) pay more for the
options, (3) perceive a higher value from their choices, and (4) find the choice task more enjoyable. But these customers also perceive the choice decision as more difficult and take longer to make decisions. These findings may reflect a loss aversion effect: Customers are more sensitive to the losses in utility incurred by deleting an option than to the gains in utility by adding the same option (Kahnemann and Tversky 1982). However, the results may be contingent on the high level of customer commitment to the product category, in that this experiment used expensive, durable products, namely, cars. But when they extend the analysis to less expensive, nondurable products such as pizzas, Levin et al. (2002) also find that customers end up with more options and a higher price if they can scale down from more options. These contradictory findings make a consensus recommendation difficult. For maximum differentiation, mass customization firms should start with a fully loaded product as the default value in their configurators and ask customers to delete undesired options—an approach rarely implemented in practice. However, doing so creates the risk of alienating customers with the high starting price, such that they immediately switch to a competitor with a less expensive base model or decide not to buy a customized product at all. Before turning away from their mass customization business model, Dell successfully capitalized on this concept by presenting fully equipped PCs and laptops but allowing customers to replace high-end hard drives or graphic cards with cheaper components. Similarly, the low-cost airline Germanwings offers an intermediate default version; customers can either deselect options for luggage, seat reservation, and meals or add a flexibility option for rebooking/canceling the flight free of charge. Moreover, the ideal default values probably are not identical for all customers but can be adapted according to their user profile or configurations chosen previously (Piller et al. 2005, p. 13).

The sequence of product attribute presentations in the customization co-design process also can influence the bundle of attributes a customer finally purchases (Levav et al. 2010, p. 275). This reasoning is based on the “depletion effect” which implies that assessing the utility of an attribute requires effort that depletes a limited mental resource (Muraven and Baumeister 2000). A series of empirical studies indicate that depleted customers exhibit worse performance in subsequent tasks (for an overview, see Vohs 2006). For example, depleted customers cannot resist impulse buying temptations (Vohs and Faber 2007) and tend to choose extreme options (Pocheptsova et al. 2009). Obviously, mass customization firms can benefit
from these effects. As Levav et al. (2010) show empirically, customers who confront a high variety of choices early in the configuration process, followed by relatively low variety choices, suffer more depletion than customers who follow a reverse sequence. Depleted customers must simplify their decisions, so they tend to accept suggested default options. In this case, mass customization firms can increase their revenues by adjusting the placement of high-priced attributes. For example, if the engine choice appears early in a car configuration sequence, customers likely choose a more expensive option over the default one. In a reverse conclusion, that means that higher priced default alternatives should be placed at the end of the sequence. Customers then may accept the default system, even if it is the most expensive among the alternatives. However, this strategy entails the risk that, if customers recognize this strategy, they might quickly classify the vendor as undesirable. Nevertheless, most major car manufacturers have structured their configuration processes in this way.

Preference elicitation method
The solution searching approach of a configurator can be based on either technical parameters or needs (Randall et al. 2005, p. 72). With parameter-based preference elicitation, customers directly specify and manipulate design parameters (e.g., processor, display, and hard drive of a laptop), so it clearly is related to attribute-based product information presentation. Needs-based preference elicitation instead requires customers to express needs and their relative importance directly (e.g., portability, affordability, and performance of a laptop), and the manufacturer translates these needs into parameter choices, so product information should be presented by alternatives. This approach typically requires less knowledge about the underlying solution space. Randall et al. (2007) test the effect of parameter- versus needs-based preference elicitation in co-design interaction systems on outcome performance, measured in terms of the fit of the resulting product, the customer’s comfort with the co-design process, and speed of product design. In parameter-based preference elicitation, comfort and fit increase with the customer’s product expertise; for novice customers, the needs-based approach results in better fit, comfort, and speed. This finding implies that mass customization firms should distinguish expert from novice customers. Instead of letting both types complete the same configuration process, interaction systems should recognize the degree of customer expertise and accordingly offer different pathways to the customized design. Thus NIKEiD tells visitors on the start page of the configurator that designing a shoe
from scratch is not meant for everyone, so it offers a selection of design templates for novice customers.

**Visualization**

Because customers typically must order a customized product before having seen or tested it, rich illustrations are of paramount importance as a means to reduce perceived risk and uncertainty (Randall et al. 2005, pp. 80-81). Instant visualization (two- or three-dimensional) of the product after each configuration step, often combined with an ability to view the product from different angles, rotate it, or zoom in on details, gives customers a sense of participating in the design task, which should increase their process enjoyment. The visualization also should allow for side-by-side comparisons of different product alternatives, to facilitate a sensitivity analysis that relates to specific design parameters and product attributes (Randall et al. 2005, p. 79). As Dellaert and Dhabolkar (2009) show, visualization improves customers’ perceptions of product outcomes, process enjoyment, and control, while also decreasing perceived complexity, so it enhances their overall intention to use web-based mass customization.

**Salesperson interaction and customer collaboration**

Most customers lack experience designing their own products (e.g., Randall et al. 2005) and have limited insights into their own preferences (e.g., Simonson 2005). In traditional stores, customers can overcome these challenges by interacting with sales staff. In online mass customization settings, Dellaert and Dhabolkar (2009) similarly show that customers would benefit from interacting with company representatives about the products (e.g., support.dell.com). However, most small start-up firms find an exhaustive customer support system far too complex and costly.

Piller et al. (2005) propose a solution that fosters collaborative co-design in online communities instead of adhering to isolated, dyadic interaction processes between individual customers and mass customizers. A co-design community offers a platform on which customers can perform the co-design task and provide feedback and inspiration to others throughout the process, which reduces mass confusion. In addition, by bundling word-of-mouth communication from other customers who have already co-designed and ordered a customized product from a specific supplier, co-design communities can mitigate the
principal–agent problem. Previous research has demonstrated that users of toolkits are indeed willing to support each other even in absence of special incentives (Jeppesen 2005). Investigating this proposition in the context of mass customization, Franke et al. (2008) find that peer input has positive effects on both the development of the initial design idea and the evaluation of preliminary designs, in that it stimulates favorable problem-solving behavior. In turn, the process outcome is better, in terms of perceived preference fit, willingness to pay, and purchase intentions. Similarly, Ihl (2009) shows that opening the customization co-design process, such that it allows for direct, peer-to-peer interactions in communities and the exchange of design modules, is valued by customers. Co-design communities also may be beneficial simply because customers enjoy communicating with their peers or regard them as opportunities for extraversion and positive self-enhancement (Hennig-Thurau et al. 2004). Facebook, Twitter, and Pandora’s Internet radio increasingly enable customers to customize the information they see or hear; from there it is only a small step to tailored products (Gownder et al. 2011). Yet despite enormous growth in these communities, few mass customizers are capitalizing on the opportunity. They could establish their own community, as Spreadshirt or Threadless have, or leverage an existing platform. For example, Charmed by Ingrid Anne has embedded its configurator directly in a Facebook website, so customers can easily share their jewelry designs and get friends’ feedback. Mass customization firms also could empower customers to use their smartphones as measurement and rendering tools.

**Pricing and delivery time quotes**

Both price and delivery time elements have significant effects on customer perceptions of web-based mass customization (Dellaert and Dabholkar 2009, p. 60). By supplying products that better fit customer needs, firms generally can charge a higher price than they would for a standard product. As we outlined in Chapter 2.2, customers frequently show a higher willingness to pay for customized products (e.g., Franke and Piller 2004; Schreier 2006; Franke et al. 2009a). The decreasing comparability of individualized products also makes it possible to extract more of each customer’s willingness to pay through price discrimination (Dewan et al. 2003; Jiang et al. 2006). To attain this effect, mass customization firms price each customizable module individually (e.g., different laptop processors) and display these prices, along with the total product price; they alternatively might show only the total product price. In their study of PCs, Dellaert and Stremersch (2005) show that customers select less
expensive modules when they view individual module pricing, which lowers the quality of the final products and decreases their perceptions of product utility. Individual pricing makes prices more salient and creates a more disaggregated perception of the monetary losses associated with each module (for the loss aversion effect, see e.g., Tversky and Kahneman 1991). It also increases the complexity of using a configurator; customers must make separate cost–benefit trade-offs for each module. Moreover, very large assortments may make customers more promotion sensitive, because they use the promotion information to screen out unfavorable alternatives from the large assortment and reduce their consideration set to a manageable size (Kahn 1998). Mass customizers therefore should use overall prices and selected promotions to reduce customers’ perceived complexity.

Customers are prepared to wait longer for a customized product (Holweg and Miemczyk 2002, p. 830; Bardakci and Whitelock 2003, p. 470), though firms still need to consider waiting time, because extensive evidence from operations theory suggests strong customer satisfaction benefits from reducing it (e.g., Taylor 1994; Ho and Zheng 2004). When customers must wait too long, they might turn to a competitor or demand a discount (Waller et al. 2000, p. 141). The need to deliver highly differentiated products quickly is commonly referred to as the customization–responsiveness squeeze (e.g., McCutcheon et al. 1994; Salvador and Forza 2004; Trentin et al. 2011). Most extant approaches to this challenge adopt a functional focus, as we discussed in the context of robust process design (e.g., process modularity, postponement).

With a completely different perspective, Buell and Norton (2011) find that telling customers what takes so long can not only decrease the psychological costs of waiting but also increase service ratings, such that customers tend to value services more highly when they wait. These findings hold even when customers perceive a mere appearance of effort (labor illusion). To evoke such desirable feelings, firms should engage in operational transparency and make work done on behalf of the customers more salient. For example, when customers searching for flights online see a changing list of different airlines being searched, instead of a simple progress bar, this service earns higher ratings, even if the waiting time is longer. While Buell and Norton (2011) conducted their studies in the service domain, the results can be easily transferred to physical products. To illustrate this point, take the example of Domino’s Pizza, whose new Domino’s Tracker system shows customers whether their pizza is being prepared,
baked, quality checked, or already out for delivery. Customers appear to draw value inferences from their waiting time, so mass customization firms should strive to turn waiting time into an experience and leverage customers’ anticipation (Yeung and Soman 2007). Meyer and Blümelhuber (1998, p. 922) coin the term “queuetainment” to refer to this tactic. Waiting time seems shorter and less frustrating when customers know exactly how long they have to wait and are waiting for a more valuable product or service (Maister 1985). Therefore, mass customization firms should provide customers with an exact delivery date and strive to meet it by any means necessary. In addition, they should emphasize the functional and hedonic value of customized products compared with standard products in marketing communications. Why else would customers be willing to wait six to eight months for a self-configured car?

Figure 13 summarizes the effectiveness of various features in a configuration toolkit for reducing the three causes of mass confusion—namely, burden of choice, preference uncertainty, and principal–agent problem—while also creating an enjoyable co-design experience. The qualitative assessment is based on discussions with academic experts in the field of mass customization and personalization, although with the caveat that many of the findings presented in this chapter are very context-sensitive and may thus allow only limited generalization. For example, findings differed depending on whether customers were asked to configure a physical product or a service and whether durable or nondurable products were used in the experiments. We are also aware that a configuration toolkit encompassing all these features can turn out to be too costly. The final solution thus should be contingent on the company’s customer types, the customers’ level of expertise in the respective product category, the complexity level of the product, the total number of variants in the solution space, and whether the products are sold exclusively over the Internet or whether the online shop complements traditional brick-and-mortar distribution channels (Abdelkafi 2008, p. 269).

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16 See www.dominos.com/pages/tracker.jsp.
Customer co-design technologies will continue to grow richer and more plentiful (Gownder et al. 2011). To meet customers’ rising expectation and keep up with competitors, firms need to revise their configuration toolkits regularly, based on industry benchmarks, analyses of past configurations, and customer feedback. As previously mentioned, in connection with “listening in on the customer domain,” information generated during the customization co-design process also should feed back into the mass customizer’s strategy (e.g., Kotha 1995; Pine et al. 1995; Wind and Rangaswamy 2001). More specifically, data on past configurations can be used to update the solution space, add promising new variants to the standard product portfolio, revise pricing and delivery policies, improve production planning and sourcing, and plan future expansions of production capacity.
However, conventional configuration toolkits have been criticized in the past, because they mostly center on product features, without sufficiently enabling customers to learn about their own preferences during co-design processes (von Hippel 2001, p. 251), which makes them unsuitable for customers with little or no idea about product characteristics (Randall et al. 2007, p. 269). Therefore, the more advanced approaches of recommender systems and embedded toolkits are discussed in the following.

**Advanced methods for choice navigation: Recommender systems and embedded toolkits**

As more and more companies enter the markets for customized products, how can they differentiate themselves effectively? Personalizing the shopping experience might enable them to attract customers and build loyalty (Wind and Rangaswamy 2001; Kumar 2007). Personalization in general is about filtering or selecting objects, based on individual-level information (Piller 2007, p. 634). Customers thus should have an opportunity to create a user profile that reflects their individual preference information, gathered during the co-design process. Firms then can enhance this information with additional customer feedback, provided after the delivery of the customized product. For this purpose, they need to develop a dedicated learning relationship with customers and follow up on each sale. Doing so enables them to draw on detailed information about customers for the next sale and make the next customization co-design process quicker, simpler, and more focused (Berger et al. 2005). In such a personal relationship, switching costs increase for customers, decreasing their willingness to move to a new relationship (Riemer and Totz 2003, p. 37). Why would a customer switch to a competitor if one mass customizer already has all the measures necessary to supply his custom dress shirt?

Personalization can also support customers during the customization co-design process by providing personalized default configurations and limiting the number of customization options presented. Rather than letting customers design their own product, a mass customizer recommends a product that they can alter. This requires interactive decision aids (IDA), or recommender systems, that support customers when the variety and complexity of the product assortment exceeds their capacity to evaluate all alternatives and arrive at a decision (Felfernig et al. 2007, p. 18). Recommender systems enhance online shopping experiences by enabling customers to make better decisions with substantially less effort (Haeubl and Trifts 2000)

- **Collaborative filtering** makes automatic predictions about a customer’s interests by collecting preferences or taste information from a vast array of customers. It constitutes a digital representation of word-of-mouth promotion. The most prominent example is Amazon’s hint “Customers who bought this item also bought….”

- **Content-based filtering** instead uses features of the items that a user liked in the past to infer new recommendations; it does not incorporate information available from other customers. For example, Pandora, a personalized Internet radio service, helps listeners find new music based on their old and current favorites; listeners provide positive or negative feedback about songs recommended by the service, which gets taken into account for future selections.

However, in many situations, such approaches cannot produce the best choices. For more complex products and services such as cars, computers, or vacation packages, customers want to specify their requirements explicitly.

- **Knowledge-based systems** are highly interactive and calculate recommendations in the form of similarities between customer requirements and items or using explicit recommendation rules. The recommendations can reflect knowledge about the customers’ preferences for concrete features or more abstract needs, depending on customers’ familiarity with the product or service (Köhler et al. 2011, p. 234). For instance, needs-based recommendations for custom cereals would require answers to the following questions: “Are you allergic to nuts?” and “Is your goal to lose weight?”

   However, these recommender systems might exacerbate the principal–agent problem, in that customers assume that the recommendations aim solely to maximize the firm’s profit. To build trust in recommendations, the firm needs to tell customers why the system has recommended a certain feature (Felfernig et al. 2007, p. 20), as well as offer a means to share recommendations in social media and receive neutral feedback.

Pathak et al. (2010) show that providing value-added services, such as recommendations, improves sales and allows online retailers to charge higher prices. Although the configuration toolkit and the recommender system technically are separate systems, they should be
integrated to ensure a seamless customer experience. The recommender system facilitates company–customer interaction and maps customer inputs into product specifications; the configuration toolkit contains the product logic and generates variants within the solution space (Blecker et al. 2005, p. 153).

A number of firms are engaging in more innovative approaches to choice navigation as well. Traditional configuration toolkits provide flexibility and creativity for specifying the design parameters of a product, according to customers’ preferences during the co-design process. However, after the product has been manufactured, it cannot be adapted to changing customer requirements in the usage phase, which may represent a problem when customers have poorly defined preferences that are unstable over time (e.g., Thomke and Hippel 2002; Simonson 2005). As a consequence, what customers want at the time of purchase might not correlate with what they like when they go to use the product (Riquelme 2001). Needs and preferences also get drastically refined when customers first come in direct contact with a new product (Thomke 1997).

To remedy this problem, Piller et al. (2010) suggest *embedded open toolkits for co-design* that allow customers to customize products according to their individual needs in real time, after its manufacture. The key requirement is an intelligent design interface for manipulating the design parameters. With their multi-functionality and adaptability, products equipped with embedded toolkits qualify as smart products (Rijsdijk and Hultink 2009). For example, the Adidas One running shoe is equipped with a magnetic sensor, a tiny electric motor, and a microprocessor (Bajak 2005). After each stride, a sensor in the heel determines how much the heel is compressed, and the microprocessor decides the optimal amount of cushioning. Then the motor shortens or lengthens a cable, adjusting the compression characteristics of the heel to the wearer’s running style and pace, as well as to changes in terrain. Although this shoe was discontinued in 2006 after reliability issues caused too many repair requests, embedded toolkits remain a viable concept. Two examples demonstrate this viability.

- Mindstorms, a LEGO product line, combines the versatility of the LEGO building system with motors, sensors, an intelligent microcomputer brick, and intuitive drag-and-drop programming software.17 Mindstorms allows customers to build and program

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robots to do what they want, supported by a strong user community that shares designs and programming techniques.

- The Tasker application for Android allows smartphone users to define any task (e.g., loops, conditions) that triggers a specific action (e.g., built-in functions, apps) according to a particular context (e.g., time, date, location, event, gesture).\(^\text{18}\) For example, customers can specify that their phone automatically goes mute every day at midnight.

Paradoxically, when equipped with embedded toolkits, products become standard goods for the manufacturer, even as the customer experiences a custom solution. Using cars as an example, Piller et al. (2010) demonstrate customers’ general acceptance of embedded open toolkits for co-design. In this case, the enjoyment effect has a strong influence on purchase intentions, such that customers consider their interaction with the toolkit entertaining and are willing to purchase simply for hedonic reasons.

Figure 14 summarizes the effectiveness of recommender systems and embedded toolkits in reducing the three causes of mass confusion while creating an enjoyable co-design experience.

<table>
<thead>
<tr>
<th>Systems/tools</th>
<th>Objectives of choice navigation</th>
<th>Reduce burden of choice</th>
<th>Reduce preference uncertainty</th>
<th>Reduce principal-agent problem</th>
<th>Increase process enjoyment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommender systems</td>
<td>Reduce partially fulfilled</td>
<td>Reduce not fulfilled</td>
<td>Reduce partially fulfilled</td>
<td>Reduce not fulfilled</td>
<td></td>
</tr>
<tr>
<td>Embedded open toolkits for co-design</td>
<td>Reduce fully fulfilled</td>
<td>Reduce fully fulfilled</td>
<td>Reduce not fulfilled</td>
<td>Reduce not fulfilled</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 14: Effectiveness of Recommender Systems and Embedded Toolkits in Reducing Complexity and Creating Process Enjoyment**

### 4.3.3 Summary and Hypotheses

Customization requires close interaction between the manufacturer and its customers. Mass customization firms must effectively support customers in identifying their needs and preferences and translating them into concrete product specifications through choice navigation. Figure 15 summarizes the reasoning developed in this chapter.

\[^{18}\text{See www.market.android.com/details?id=net.dinglischt.android.taskerm&hl=en.}\]
To benefit from mass customization, firms should contemplate three questions that are fundamental to effective choice navigation:

- **What objectives must choice navigation fulfill to be effective?**
  To create a positive co-design experience, choice navigation must effectively reduce the three sources of *mass confusion*, namely, burden of choice, preference uncertainty, and principal–agent problem, while increasing the *process enjoyment*. This positive experience is then likely to carry over to the valuation of the co-designed product. But effective choice navigation requires adequate interaction systems that help customers navigate a mass customizer’s solution space. The capabilities of these interaction system are a main source of differentiation and critical to the success of this strategy.

- **Which system features should configuration toolkits contain?**
  The most widely used interaction systems in practice are configuration toolkits. These user-friendly design interfaces allow trial-and-learning processes and provide simulated feedback on design ideas. To effectively decrease configuration complexity and improve customer satisfaction, configurators should exhibit certain *basic* and *advanced features* related to product information presentation, preference elicitation, sequencing, pricing, and visualization. However, conventional configuration toolkits
may be criticized, because they focus on product features rather than support for customer learning about preferences.

- **Which alternative methods for choice navigation might mass customization firms employ?**

  Personalizing the shopping experience can be an effective way for mass customization firms to differentiate themselves from competitors in many product categories. In the most simple form, personalization offers customers the ability to create **user profiles** that facilitate their reorder process and increase switching costs. More advanced **recommender systems** provide personalized pre-configurations and limit the number of customization options presented, according to different information filtering techniques. **Embedded open toolkits** for co-design allow customers to customize a product according to their individual needs in real-time during the usage phase.

Developing a choice navigation capability thus enables mass customization firms to support customers in creating their own solutions, minimize perceived complexity, and maximize process enjoyment. In turn, providing enhanced choice navigation should reduce the search and evaluation costs that customers incur during the co-design process. We thus hypothesize:

**H3:** *Choice navigation capability is an essential facet of a firm’s overall mass customization capability.*

Most studies cited in this chapter rely on surveys of real customers to test their hypotheses. However, to be consistent with the firm perspective adopted with regard to the other two capabilities, we need valid measures for choice navigation the responding firms could easily provide, so we specify the following hypotheses:

**H3a:** *The cumulative financial investment into configurator technology is positively related to choice navigation capability.*

**H3b:** *The number of revisions of the configurator is positively related to choice navigation capability.*

**H3c:** *The diversity of information sources used for the revision process is positively related to choice navigation capability.*
Moreover, the design of the configuration toolkit and its system features determines whether choice navigation is effective. Most features are readily observable on mass customizers’ websites. We propose in turn:

\[ H3d: \text{Selected system features of the configuration toolkit relate positively to choice navigation capability.} \]

### 4.4 Performance Implications of Strategic Capabilities

#### 4.4.1 Single Effects on Company Performance

In order to deliver superior performance, a firm must gain and hold an advantage over its competitors (Porter 1985). There is a broad consensus that mass customization provides a suitable strategic framework to develop such a competitive advantage (e.g., Pine 1993; Hart 1995; Kotha 1995). When properly implemented, it offers improvements on all four competitive priorities: customization, responsiveness, costs, and quality (Piller and Kumar 2006, p. 42). Yet not all performance outcomes of mass customization are positive, as demonstrated by the failed examples of Levi’s, Procter & Gamble, and General Mills. It is therefore important that a firm’s management understands the nature of competitive advantage: A firm has a competitive advantage when some value-adding activities are performed in a way that leads to perceived superiority in the eyes of customers. For these activities to be profitable, the value perceived by the customers and the resulting price premium must exceed the added costs (Slater and Narver 2000, p. 120). Following Day and Wensley (1988, p. 3), we differentiate between sources of customer value and performance outcomes that result from delivering superior customer value. The sources of customer value creation reside in the capabilities and resources when mobilized by an effective strategy (Day and Wensley 1988, p. 5). The managerial challenge is to identify the handful of capabilities and resources that have the greatest impact on positioning and performance (Day and Wensley 1988, p. 7). Salvador et al. (2009) postulate that mass customization requires firms to develop three fundamental capabilities to create superior value for the customer—and ultimately for themselves. As demonstrated in Chapter 2.1, customers only recognize positive value in mass customization when the utility they derive from a customized product exceeds the acquisition costs and the search and evaluation costs. These are the levers targeted by strategic mass customization capabilities (Salvador and Piller 2009):
1. Solution space development capability helps firms to identify customers’ idiosyncratic needs and meet them with responsive product offerings; it should therefore have a positive impact on customers’ gross utility.

2. Robust process design capability implies that the firm reuses or recombines existing resources to mitigate the trade-off between variety and costs, such that it keeps customized product acquisition costs comparable to those of mass produced standard products.

3. Choice navigation capability supports customers in creating their own solutions while minimizing choice complexity, which significantly reduces search and evaluation costs during the customization co-design process.

Thus, each capability may independently contribute to the creation of superior customer value. The hypothesized effects are represented with arrows in Figure 16.

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**Figure 16: Developing Strategic Capabilities for Mass Customization: More Value to the Customer (adapted from Salvador and Piller 2009)**

We also consider two performance outcomes that result from delivering superior customer value—customer satisfaction and superior sales growth (Slater and Narver 2000, p. 121). Firms that deliver superior customer value likely enjoy high levels of customer satisfaction, which can be defined as the extent to which a product’s perceived performance fulfills a buyer’s expectations (Kotler et al. 2008, p. 37). This measure is widely accepted as a valid
predictor of behavioral variables, such as repurchase intentions, positive word of mouth, and loyalty (e.g., Oliver 1999; Bolton et al. 2006). After all, the cost of a repeat or additional sale to an existing customer is usually far less than the cost of acquiring a new one (Reichheld 1996). It is therefore not surprising that several researchers conclude that the main benefit of customization for the firm stems from greater customer satisfaction (e.g., Åhlström and Westbrook 1999, p. 266; Wind and Rangaswamy 2001, p. 18). However, the most accurate measure of customer value creation is probably sales growth relative to key competitors. Quite simply, a firm’s increase in sales will not outpace that of its competitors unless it delivers superior customer value (Slater and Narver 2000, p. 121).

Yet with a few exceptions, mass customization literature offers little evidence that pursuing such a strategy improves performance. Drawing on a case study in the bicycle industry, Kotha (1995, p. 34-36) finds that the analyzed mass customizer outperforms its competitors in terms of market share and reputation. Duray et al. (2000, pp. 622-623) also conclude that mass customization enhances overall firm performance in terms of profitability and market share, though the performance improvement differs across generic mass customization strategies. In an investigation of the link between mass customization capabilities and customer satisfaction, Tu et al. (2001, p. 213) argue that “firms with MC capabilities should be able to capture high sales volume and generate greater profits than competitors without them.” Along the same lines, Salvador et al. (2009, p. 76) suggest that even small improvements in a single capability can grant mass customization firms strategic differentiation and competitive advantages. We thus propose the following capabilities–performance relationship: Enhancing any of the strategic capabilities for mass customization, ceteris paribus, contributes to the creation of superior customer value through the previously outlined mechanisms. Delivering superior value in turn leads to higher levels of customer satisfaction and faster sales growth relative to key competitors, potentially resulting in increased market share and profitability. To the best of our knowledge, this relationship has not been empirically investigated previously in the context of mass customization. Thus, we propose the following hypotheses:

\[ H4a: \text{Solution space development capability has a positive direct effect on company performance.} \]

\[ H4b: \text{Robust process design capability has a positive direct effect on company performance.} \]
4 The Strategic Capabilities Framework

4.4.2 Complementarity of Strategic Capabilities

Resource constraints and powerful structural inertia might prevent companies embarking on mass customization from improving all three capabilities simultaneously, and instead focusing on one or two of them as a priority (Rungtusanatham and Salvador 2008). However, our analysis suggests that beyond their distinct functions in mass customization firms, the three capabilities are interdependent and mutually supportive. In order to implement a profitable and sustainable mass customization strategy, a business must integrate the different methods, tools, and routines described in this chapter. This reasoning leads us back to the concept of strategic fit (Porter 1996) discussed in Chapter 3.4, which implies that the competitive value of individual elements cannot be easily decoupled from the system or strategy. Attempting to explain superior company performance by focusing on individual elements could therefore be misleading (Porter 1996, p. 73).

To illustrate this point, consider the following causal chains: For instance, if a firm has systematically strengthened its robust process design capability to allow for high levels of volume and mix flexibility, but restricts its solution space to a limited number of customization options, it might fail to fully exploit the potential of its flexible production technologies. On the other hand, if a firm offers a broad solution space, but does not sufficiently support its customers in creating their own solutions by means of effective choice navigation, they might postpone their buying decisions or reallocate their budget to a different vendor. Finally, if the choice navigation system effectively guides customers in designing a product that perfectly matches their needs, but fulfilling these differentiated needs leads to a significant deterioration in the firm’s operations and supply chain, resulting in poor quality, long delivery times, and high price premiums, this will have a negative impact on repurchase intentions and customer loyalty. Hence, integrating SSD, RPD, and CN capabilities should lead to better company performance, being a complementary rather than a supplementary combination (Wernerfelt 1984, p. 175).

Complementary capabilities can create super-additive value synergies that are not captured by any single capability in isolation (Milgrom and Roberts 1995, p. 184). Therefore, the benefits
of the joint development of strategic capabilities for mass customization likely exceed the sum of the benefits obtained through isolated development of single capabilities. Conversely, the absence or weakness of one capability can diminish the value of the others as well. Moreover, whereas individual capabilities are neither idiosyncratic nor valuable resources in the RBV sense, bundles of complementary capabilities are more difficult to observe and imitate (Song et al. 2005, p. 262). Due to the complementarity, implementing a single capability without developing the others will fail to deliver the intended performance improvements (Porter 1996, p. 74); it may even produce negative performance effects (Milgrom and Roberts 1995, p. 191). In other words, competitors will gain little from imitation unless they successfully reproduce a firm’s entire system of mass customization capabilities (Porter 1996, p. 74).

Though anecdotal and case study evidence exists (e.g., Kotha 1995; Moser 2007; Salvador et al. 2009), we have yet to see large-sample studies that demonstrate how strategic elements and complementarities among them enhance a mass customization firm’s performance. Whittington et al. (1999, p. 585) state that complementarity analyses require “a simultaneously aggregated and disaggregated approach that compares the contribution of individual practices with the performance payoffs of them altogether.” Therefore, to assess the performance effects of complementary strategic capabilities, it is imperative to compare the effects of individual capabilities with the performance effect of the full system to define the conditionality of individual capabilities on one another and to ensure that overall effect outweighs the individual effects (Ichniowski et al. 1997). Accordingly, in addition to forwarding hypotheses concerning the individual capabilities, we propose:

\[ H5: \text{Complementarity of solution space development, robust process design, and choice navigation has a positive effect on company performance.} \]

### 4.4.3 Environmental Contingencies

In analyzing the performance effects of mass customization capability, it is important to consider environmental factors, because different environments imply different valuations of dynamic capabilities (Eisenhardt and Martin 2000, p. 1110). As uncertain and turbulent environments augment causal ambiguity, competitors’ ability to imitate a firm’s capabilities decreases, which in turn may help firms to achieve competitive advantage and superior performance based on their dynamic capabilities. On the other hand, if the business
environment is relatively stable and predictable, competitors can easily observe which configurations of resources and capabilities are most valuable and imitate them because time is not of the essence (Song et al. 2005, p. 262). Such environmental contingencies have been rather neglected in prior mass customization research, with the notable exception of the work of Tu et al. (2004a). This lack of attention is remarkable because firms often develop mass customization capabilities specifically in response to turbulent environments (Pine 1993, pp. 53-55). In the following discussion, we consider three contingency factors that likely moderate (i.e., increase or decrease) the relationship between mass customization capability and company performance: market turbulence, technological turbulence, and competitive intensity (Kohli and Jaworski 1990, pp. 14-15).

Market turbulence refers to the rate of change in the composition of customers and their preferences (Jaworski and Kohli 1993, p. 57). It is very similar to the market heterogeneity construct, which Miller (1987, p. 62) describes as the “change in diversity of production methods and marketing tactics required to cater to customers’ needs.” The mass production paradigm is based on stable business environments, in which customers do not demand much differentiation (Blecker and Abdelkafi 2006b, p. 5). As market turbulence increases, any hope of maintaining efficiency and controlling costs through mass production methods diminishes. Therefore, “the greater the market turbulence, the more likely that the industry is moving toward mass customization, and that the firm has to move in order to remain competitive” (Pine 1993, p. 54-55). In other words, mass customization capability is likely related more strongly to company performance in turbulent markets than in stable markets. Stated formally:

\[ H6a: \text{The greater the market turbulence, the stronger the positive effect of mass customization capability on company performance.} \]

Technological turbulence relates to the rate of technological change in an industry and covers the entire process of transforming inputs into outputs (Jaworski and Kohli 1993, p. 57). Mass customization capability is essentially a means to achieve a competitive advantage because it enables firms to understand customers’ idiosyncratic needs and offer responsive product offerings. While this is important, there may be alternative ways of gaining a competitive advantage, such as superior technology. Firms operating in industries characterized by rapidly changing technologies may be able to secure a competitive advantage through technological
innovation, thereby reducing—but not eliminating—the importance of mass customization capability. Apple, for instance, has successfully pursued this avenue over the past decade. By contrast, firms working with stable (mature) technologies are relatively poorly equipped to obtain a competitive advantage by leveraging technology and must instead rely more heavily on their mass customization capabilities to achieve differentiation in the eyes of customers (Jaworski and Kohli 1993, p. 58). This suggests:

\[ H6b: \text{The greater the technological turbulence, the weaker the positive effect of mass customization capability on company performance.} \]

The third environmental factor posited to moderate the linkage between mass customization capability and company performance is competitive intensity (Jaworski and Kohli 1993, p. 57). A firm with a monopoly in its market may perform well even without the ability to modify its offerings in response to heterogeneous customer needs, because customers are basically “stuck” with its products (Kohli and Jaworski 1990, p. 14). By contrast, in markets with intense competition, customers have multiple choices to satisfy their needs and wants. Consequently, firms must closely monitor customers’ changing needs and leverage their mass customization capabilities to create superior customer value through an improved fit with their preferences. Hence:

\[ H6c: \text{The greater the competitive intensity, the stronger the positive effect of mass customization capability on company performance.} \]
5 Empirical Research Design

5.1 Data Collection and Sample Description

This research is part of “The Customization 500,” an international benchmarking study on mass customization and personalization in consumer e-commerce initiated by the MIT Smart Customization Group, the Technology and Innovation Management Group of RWTH Aachen University, and the University of Applied Sciences in Salzburg.19

The unit of analysis in this study is the mass customization firm. To ensure comparability between respondents, we required companies in the sample to meet five criteria: First, they must sell their products directly to end consumers (B2C). Second, they must provide an online toolkit for customer co-design (web-based configuration). Third, they must market their products via the Internet (e-commerce). Fourth, the customization of the products must take place within the manufacturing processes (hard product customization). The opposite would be soft customization, where the product is personalized by the customers themselves (self-customization) or by retailers (point-of-sale customization). Soft customization can also result from secondary services provided with a standard product (service customization), which create the impression that the product itself is tailored to individual customers’ requirements (Piller 2006, p. 219). Fifth, customer co-design must be applied to change the physical characteristics of the products (tangible products). Especially in the entertainment industry, a growing number of companies offer customizable digital products (intangible products) such as movies, video clips, songs, or games (Anderson 2006). Due to the fact that the fulfillment process for digital products differs considerably from physical goods, these offerings were excluded from the analysis.

In total, we identified 620 mass customization firms that meet these criteria, using six Internet sources (milkorsugar.com, configurator-database.com, egoo-journal.com, egoo.de, mass-customization.blogs.com, and blogs.oneofakindpublishing.com). This can be regarded as a near exhaustive sample, as these firms represent virtually the entire mass customization universe in Western Europe and North America.

Our research applied a two-step data-gathering approach. First, a group of trained experts analyzed the website, the configurator, and the product offering of each of these 620 firms

19 For more details on the joint research project, see www.mc-500.com.
from a customer perspective. For a comprehensive overview of the results of this research, see Walcher and Piller (2011). This expert evaluation was followed by an extensive company survey conducted to gain deeper insights into the structures and practices of the players in today's mass customization market. The empirical results presented in this thesis are based exclusively on the data from this company survey.

For this survey, we developed a conceptual framework and formulated hypotheses based on the thorough literature analysis documented in Chapter 4. To ensure that our theoretical framework would be pertinent to our research context, we conducted a series of unstructured field interviews with managers of mass customization firms. We used these interviews to ensure that our theoretical understanding of the capabilities reflected managerial challenges in mass customization firms and that the experts could distinguish the three different capabilities. The interviews largely reiterated the insights from literature. We developed a draft of the survey on the basis of our interviews, academic literature, and discussions with academic experts in related disciplines and tested this instrument with managers from five mass customization firms and five domain experts in academia, who considered its wording, response formats, and clarity of instructions. We then made several changes to the survey instrument based on their feedback.

To ensure a satisfactory response rate, we administered the survey in four stages. First, we sent an e-mail with a personalized cover letter and a link to the online questionnaire to all 620 mass customization firms. The questionnaire was in English, primarily because the research on which the measurement scales were based was exclusively in English. Although not all respondents were native English speakers, many firms sold their products internationally and often had an English-language website. Extensive pretests also indicated that language issues did not compromise understanding of the questionnaire. As an incentive, we offered each respondent an individual capabilities profile, benchmarked against the mean value in their respective industry sector. Second, we sent reminder e-mails to the target respondents three weeks later. Third, to further boost the response rates, we made follow-up phone calls to the non-responding firms three weeks after the second mailing. Fourth, a final reminder went out to companies that had indicated their general interest in participating in the study during the phone calls. All in all, 118 mass customization firms responded, although we eliminated three responses due to excessive missing data, such that the overall response rate was 18.5%
For web surveys, response rates in excess of 10% are generally considered acceptable (Klassen and Jacobs 2001, p. 724).

Non-response bias is always a concern in large-scale survey research. We tested for it by comparing early and late respondents, with the assumption that late respondents were more likely to resemble companies that decided not to participate (Armstrong and Overton 1977). Responses received in the first six weeks, before the follow-up calls, represented the early respondents; the remainder were the late respondents. A comparison across all 46 scale items using a t-test showed no significant difference between early and late respondents (p = 0.05), so non-response bias does not appear to be an issue.

Descriptive statistics for the responding firms are provided in Table 4. As can be seen from the table, 82.6% of the firms were founded exclusively with the purpose of mass customization, while 17.4% run their mass customization business in a separate unit, in addition to their standard business. 27.8% of the responding firms launched their online mass customization offerings less than one year ago and can thus be considered typical start-ups. The majority of firms (56.5%) have operated their mass customization business between one and five years, while only 15.7% have been in the market for more than five years. This indicates the long time lag between the first description of the mass customization concept in the 1990s and its broader application. It is important to note, however, that the launch date of the online mass customization offerings and the founding date of the firm are not necessarily identical. Many of the established firms had been active in their respective industry sector for years before deciding to add customized products to their portfolio. Annual sales of the responding firms ranged from less than $100,000 to over $5 million in the fiscal year 2010, with the majority having sales of less than $1 million (83.5%). 53.9% of the firms have less than five employees; in many cases, these are also the founders. 20.9% of the firms are even operated as a one-person business. However, as customized products are often subject to strong seasonal effects (e.g., Christmas gifts), many firms reported that they employ additional temporary workers during peak times. The range of annual sales and number of employees indicates that the sample consists mainly of small and medium-sized enterprises (SMEs). This is consistent with our earlier observation that the current dynamism in mass customization is driven primarily by innovative SMEs that have built their business models from the ground up and focus entirely on the promises of mass customization.
Food customizers (23.5%) account for the largest product category in the sample, clearly reflecting the continuous trend toward mass customization of food products and beverages, which is enthusiastically covered by the press (Martell 2010). Companies offering custom shoes and accessories like bags and belts come second (18.3%). Customized apparel offerings, ranging from t-shirts to dress shirts, jeans and bridesmaids’ dresses, amount to 14.8%. The large category “Other” (17.4%) comprises a diverse range of custom offerings such as books, scooters, perfume, license plates, or tissues. According to a recent Forrester Research report, Germany is a clear intellectual and practical leader in mass customization due to its long tradition in innovative manufacturing (Gownder et al. 2011). This fact is well represented in our sample, with 59.1% of the respondents coming from Germany. As Table 4 shows, the majority of respondents in the surveyed firms were from the top management (87.0%). We are therefore confident that the respondents possess accurate knowledge with regard to the mass customization capabilities of their firm and the resulting performance effects.
<table>
<thead>
<tr>
<th>Metric</th>
<th>Frequency</th>
<th>Percentage</th>
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<tbody>
<tr>
<td><strong>Company type</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Company founded with the purpose of MC</td>
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<td>82.6%</td>
<td>82.6%</td>
</tr>
<tr>
<td>MC business unit of an established company with standard product range</td>
<td>20</td>
<td>17.4%</td>
<td>100.0%</td>
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<td><strong>MC offering online</strong></td>
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<td></td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>32</td>
<td>27.8%</td>
<td>27.8%</td>
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<tr>
<td>1 to 5 years</td>
<td>65</td>
<td>56.5%</td>
<td>84.3%</td>
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<tr>
<td>&gt; 5 years</td>
<td>18</td>
<td>15.7%</td>
<td>100.0%</td>
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<tr>
<td><strong>Sales in fiscal year 2010 (in USD)</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 100,000</td>
<td>57</td>
<td>49.6%</td>
<td>49.6%</td>
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<td>&lt; 500,000</td>
<td>23</td>
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<td>69.6%</td>
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<tr>
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<td>16</td>
<td>13.9%</td>
<td>83.5%</td>
</tr>
<tr>
<td>&lt; 5 million</td>
<td>10</td>
<td>8.7%</td>
<td>92.2%</td>
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<tr>
<td>&gt; 5 million</td>
<td>9</td>
<td>7.8%</td>
<td>100.0%</td>
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<tr>
<td><strong>Number of employees (FTEs)</strong></td>
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<td>5 to 24</td>
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<td>25 to 100</td>
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<td>&gt; 100</td>
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<td>23.5%</td>
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<td>Accessories and shoes</td>
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<td>18.3%</td>
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<td>Apparel</td>
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<td>11.3%</td>
<td>67.9%</td>
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<tr>
<td>Sportswear and equipment</td>
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<td>6.1%</td>
<td>74.0%</td>
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<td>4.3%</td>
<td>78.3%</td>
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<td>4.3%</td>
<td>82.6%</td>
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<td>100.0%</td>
</tr>
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<td>59.1%</td>
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<tr>
<td>USA</td>
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<td>27.0%</td>
<td>86.1%</td>
</tr>
<tr>
<td>Western Europe (excl. Germany)</td>
<td>13</td>
<td>11.3%</td>
<td>97.4%</td>
</tr>
<tr>
<td>Rest of world</td>
<td>3</td>
<td>2.6%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Position of informant</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Top management (e.g., Founder/CEO)</td>
<td>100</td>
<td>87.0%</td>
<td>87.0%</td>
</tr>
<tr>
<td>Middle Management</td>
<td>15</td>
<td>13.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 4: Descriptive Statistics for the Responding Mass Customization Firms
5.2 Measure Development

5.2.1 Mass Customization Capabilities and Performance Measures

Whenever possible, we used existing measurement instruments for the core constructs. All scales are presented in Appendix 8.2.1. The scale used to measure RPD was adapted from Zhang et al. (2003), using a combination of items from their volume and mix flexibility scales. As discussed above, while firms may apply different methods to increase the robustness of their process designs, the core objective of RPD is to ensure the required levels of volume and mix flexibility so that the firm can efficiently serve its customers individually.

However, established scales for SSD and CN were not available. We therefore generated them specifically for this study based on a rigorous process that focused on attaining content validity by reviewing relevant literature and consulting with company executives. For the pretest, the definitions of the capabilities and measurement items were examined by five academic experts from different universities who had expertise in mass customization, operations management, innovation management, and marketing. To further enhance the content validity, 15 attendees of an executive MBA program on mass customization at Instituto de Empresa, Madrid (Spain) participated in a Q-sort exercise. The managers acted as judges and were asked to independently sort the 15 measurement items into the three predefined and mutually exclusive measurement scales for the strategic capabilities (Rungtusanatham 1998). However, instead of using Cohen’s kappa as a measure of inter-rater reliability, which is only appropriate when assessing the agreement between two raters, we applied Fleiss’ kappa (Fleiss 1971). The resulting kappa value of 0.63 indicates a “substantial agreement” of the raters in assigning the items to the three capabilities (Landis and Koch 1977, p. 165). The results are presented in Appendix 8.2.2.

The scale for overall mass customization capability (MCC) was adapted and revised from Tu et al. (2001), such that the items adequately reflect the four competitive priorities of mass customization firms—namely, quality, responsiveness, scalability, and costs. The final scales for the three strategic capabilities and the overall mass customization capability were five-point Likert-type scales with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.
Business performance is a crucial indicator when comparing strategic configurations of firms (Ketchen et al. 1993). During the pretest, however, firms were rather reluctant to disclose their absolute sales and performance figures. We thus relied on the market performance scale proposed by Homburg and Pflesser (2000) to obtain a relative measure of performance while preserving the respondents’ privacy. Furthermore, because the market performance scale is oriented more toward customer success, we included “achieving sales growth” as an additional item to reflect economic success. We deliberately did not include any item relating to profitability (e.g., return on sales). Such a measure would not be meaningful for comparing performance among the companies in our sample because many of the recently founded companies were still experiencing the usual start-up losses. As previously discussed, developing the strategic capabilities for mass customization often requires substantial upfront investments (e.g., in configuration technology or flexible automation systems) that must be recovered in the following years. The performance scale was five-point Likert-type with the anchor points 1 = “much worse relative to main competitors,” to 5 = “much better relative to main competitors.”

### 5.2.2 Antecedents, Contingency Factors, and Controls

Within our conceptual framework, we have derived different sources of information used to develop product offerings and the presence of a formal revision process as possible antecedents for SSD. For the revision process we included a dummy variable (SSD_REV), where firms were assigned the value 1 if they stated that they have a formal process to revise, trim, or extend their solution space. Concerning the sources of information used to develop the product offerings and improve the solution space during the revision process, we differentiate between (1) opportunity recognition heuristics (SSD_OPP), (2) secondary knowledge sources (SSD_SEC), and (3) information obtained directly from customers (SSD_CUST). The use of opportunity recognition heuristics refers to statements such as “we relied on our experience” and “we translated our own unsatisfied needs into a product offering.” Secondary knowledge sources comprise trend reports, external consultants, analysis of purchase data, and benchmarking of competitors’ assortments. Information can also be obtained directly from customers through personal interviews, focus groups and surveys. Firms were asked to indicate on a five-point scale anchored at 1 = “never” and 5 = “frequently” whether they use
the respective sources. The three variables simply represent the average of the firms’ ratings in each category.

To measure the antecedents of RPD, we relied exclusively on existing scales. The scales for product (PDM) and process modularity (PCM) were adapted from Tu et al. (2004b). For flexible automation (FA), we generated one item for each of the four flexibility dimensions (range-number, range-heterogeneity, mobility, and uniformity) of the machine flexibility scale proposed by Koste et al. (2004). Finally, to measure human resources flexibility, we adapted the skill flexibility (SF) scale of Bhattacharya et al. (2005).

With regard to the antecedents of CN, we took a twofold approach. First, we developed three measures that firms were asked to indicate directly in the survey. These were (1) the cumulative financial investment in configuration technology (INVEST), (2) the number of revisions of the configurator (CN_REV) to date, and (3) the diversity of information sources used for the revision (CN_INFO). The potential information sources were market studies on configuration technology, industry benchmarking of other configurators, external consultants, analysis of past configurations, customer feedback, and logfile analysis; the respective source was counted if it was ranked 4 or 5 on a five-point scale with the anchors 1 = “very unimportant” to 5 = “very important.” Second, we analyzed the online configurator of each of the 115 firms in the final sample with regard to specific features critical to effective choice navigation that were derived from Randall et al. (2005) and our literature review in Chapter 4.3. These features are needs-based preference elicitation (NEEDS), a default configuration as starting point (DEFAULT), the option to save the configuration and continue at a later time (SAVE), and the possibility to visually compare two configured products side by side (COMPARE). We also tracked whether the configurators provide a shortcut to the shopping cart without running through the entire configuration process (SHORT), have a help function (HELP), offer explanations on the product attributes (EXPLAIN), and show recommendations based on other customers’ selections (PEER). Furthermore, the richness of the visualization (3D) with the possibility to zoom in on objects, rotate them, or view them from different angles (ZOOM) was assessed. Finally, we checked whether each module is priced separately during the configuration process (MODPRICE) as opposed to overall prices and whether customers can share their creations in social networks (COMMUN). For all features we
included a dummy variable where firms are assigned the value 1 if their configurator has the respective features.

The scales for technological turbulence (TT), market turbulence (MT), and competitive intensity (CI) are based on Jaworski and Kohli (1993), and many other studies have used these scales (e.g., Sethi and Iqbal 2008; Lichtenthaler 2009). Moreover, we controlled for a firm’s experience in the market for mass customized products (AGE) which was measured as the period since the launch of the online mass customization offering. Additionally, firm size may also affect mass customization capability. Larger firms usually have a larger resource base, which enables them to develop the three capabilities simultaneously, while smaller firms instead may focus on one or two of them as a priority due to resource constraints. We therefore also controlled for firm size measured as the logarithm of the average number of full-time equivalents (FTE) employed in the fiscal year 2010. Finally, we differentiated between firms that were founded exclusively with the purpose of mass customization and established companies that run their mass customization business in a separate unit, in addition to their standard business (TYPE). The scales are presented in Appendix 8.2.3.

5.2.3 Descriptive Statistics for Antecedents

Before validating the measures, we performed a descriptive analysis of some of the antecedents of SSD and CN to develop a better understanding of the responding firms’ revision cycles, investment expenditures and customer interface designs. The results are provided in Table 5. It can be seen that 36.6% of the mass customizers have implemented a formal process to revise, trim, or extend their solution space at regular intervals. The average cumulative investment in configuration technology across all respondents since the launch of their online mass customization offering amounts to $114,000. During this time, the configurator was revised 2.8 times on average. While the effectiveness of different configurator features in reducing complexity and creating an enjoyable co-design experience is well founded in the mass customization literature, their implementation in practice seems to be lagging behind. Only 1.8% of firms base their solution searching approach on needs, whereas the overwhelming majority still adheres to parameter-based preference elicitation. Only 33.0% of firms provide a rich 3D visualization, and a mere 34.8% allow their customers to turn/rotate the configured product or zoom in on details, which are important facets of process enjoyment.
Only 42.0% offer their customers the possibility to save their configurations and continue at a later time; in the other cases, the customers must start the tedious configuration process from scratch. An explicit help button or hotline could be found only on 22% of the websites. Most firms (58.9%) rely on individual module pricing, although empirical research has demonstrated that it increases the complexity of using a configurator; customers also tend to select less expensive modules, as individual pricing makes prices more salient (Dellaert and Stremersch 2005). However, mass customizers seem to increasingly recognize the potential of social media. 66.1% of the respondents offer customers the possibility to connect with other customer via social networks such as Facebook or Twitter and share product visualizations for critique and collaboration.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Frequency/Value</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antecedents of SSD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formal revision process (SSD_REV)</td>
<td>41</td>
<td>36.6%</td>
</tr>
<tr>
<td>Antecedents of CN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. cumulative investment in configurator in USD (INVEST)</td>
<td>114,000</td>
<td>--</td>
</tr>
<tr>
<td>Avg. no. of revisions of configurator since launch (CN_REV)</td>
<td>2.8</td>
<td>--</td>
</tr>
<tr>
<td>Configurator features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Needs-based preference elicitation (NEEDS)</td>
<td>2</td>
<td>1.8%</td>
</tr>
<tr>
<td>Default configuration (DEFAULT)</td>
<td>94</td>
<td>83.9%</td>
</tr>
<tr>
<td>3D view (3D)</td>
<td>37</td>
<td>33.0%</td>
</tr>
<tr>
<td>Zoom/turn/rotate (ZOOM)</td>
<td>39</td>
<td>34.8%</td>
</tr>
<tr>
<td>Visual side-by-side comparison (COMPARE)</td>
<td>51</td>
<td>45.5%</td>
</tr>
<tr>
<td>Possibility to save configuration (SAVE)</td>
<td>47</td>
<td>42.0%</td>
</tr>
<tr>
<td>Help function (HELP)</td>
<td>35</td>
<td>31.3%</td>
</tr>
<tr>
<td>Explanation of product attributes (EXPLAIN)</td>
<td>58</td>
<td>51.8%</td>
</tr>
<tr>
<td>Shortcut to the shopping cart (SHORT)</td>
<td>65</td>
<td>58.0%</td>
</tr>
<tr>
<td>Recommendations based on selections of others (PEER)</td>
<td>25</td>
<td>22.3%</td>
</tr>
<tr>
<td>Module pricing (MODPRICE)</td>
<td>66</td>
<td>58.9%</td>
</tr>
<tr>
<td>Connection to social media (COMMUN)</td>
<td>74</td>
<td>66.1%</td>
</tr>
</tbody>
</table>

Table 5: Descriptive Statistics for Selected Antecedents of SSD and CN

5.3 Measure Validation
In the literature, there is general agreement that tests of unidimensionality (convergent validity), reliability, and discriminant validity are important for establishing construct validity (e.g., Gerbing and Anderson 1988; Bagozzi et al. 1991; Sethi and King 1994; Ahire et al. 1996; Homburg and Giering 1996). Unidimensionality exists if there is a single latent variable
underlying a set of measurement items (Anderson 1987). To check for unidimensionality, an exploratory factor analysis with varimax rotation and Kaiser normalization (Kaiser 1974) was first performed separately for each of the three capability constructs, using SPSS 19.0. A single factor emerged for each capability with all factor loadings above 0.50. Next, the 15 strategic capability items were submitted to a joint exploratory factor analysis. Three clear factors reflecting the three capabilities emerged from the factor analysis. Item CN5 did not belong to any of these factors and was therefore removed from further analysis (for this approach, see Gerbing and Anderson 1988, p. 88). All factor loadings were above 0.50 and no cross-loading above 0.40 was observed; thus, there was no need for further item revision. The construct-level factor analysis results for the three strategic capabilities are shown in Appendix 8.2.4. The direct mass customization capability construct (MCC) was conceptualized as having one dimension comprising five items. To check for unidimensionality of the MCC construct, exploratory factor analysis was performed and one single factor emerged with all factor loadings above 0.60 (see Appendix 8.2.5).

The market performance construct (MP) was conceptualized as having one dimension and seven items. However, an exploratory factor analysis revealed that the market performance construct was not unidimensional and instead supported a two-factor structure with no cross-loadings above 0.40 and all factor loadings above 0.70 (see Appendix 8.2.6). Upon closer examination, there is a similarity of content between items MP1, MP5, MP6, and MP7. The first three items make up growth of the customer base, which is typically connected to growth in sales (MP7). By contrast, the other three items have a customer focus, measuring causes of customer loyalty, positive word of mouth, and repurchase intentions. We thus distinguish between “market growth (MG)” and “customer success (CS)” as performance measures in further analysis.

Reliability analysis was performed for each of the three strategic capabilities (SSD, RPD, CN), mass customization capability (MCC), and the two performance measures (MG, CS) using Cronbach’s (1951) alpha. Alpha values above 0.7 are generally considered acceptable for basic research (Nunnally 1978, p. 245). As shown in Appendix 8.2.7, alpha values are 0.816, 0.758, 0.730, and 0.839 for SSD, RPD, MCC, and MG, respectively. The alpha values of CN (0.693) and CS (0.667) are slightly below the minimum value of 0.7. In this case, eliminating items with a low corrected item-to-total correlation can lead to an increase of Cronbach’s
alpha (Churchill 1979, p. 68). Thus CN2, CS2, and CS3 were considered for deletion. Removing CN2 improved the alpha value of the CN scale to 0.702. However, the “alpha if deleted” score indicated that alpha could not be substantially improved if CS2 and CS3 were deleted, and the items were thus retained for further analysis. Moreover, for novel constructs, minimum alpha values of 0.6 can be justified, which applies to CS (Nunnally 1967, p. 226; Malhotra 1993, p. 308). For all six constructs, the average variance extracted (AVE) was in excess of the recommended 0.5 (Bagozzi and Yi 1988, p. 80). Thus, overall, the scales demonstrated satisfactory reliability.

Reliability and exploratory factor analysis was also conducted for the reflective constructs product modularity (PDM), process modularity (PCM), flexible automation (FA), skill flexibility (SF), market turbulence (MT), technological turbulence (TT), and competitive intensity (CI). From the exploratory factor analysis, a single factor emerged for each construct with all factor loadings above 0.70. After purification of the scales through examination of the corrected item-to-total correlation, all alpha values were above the threshold of 0.7, with the exception of MT (0.660). For all seven constructs, the average variance extracted (AVE) exceeded the recommended cut-off value of 0.5 (see Appendix 8.2.7).

All purified constructs discussed in this chapter were finally jointly submitted to a construct-level factor analysis. Eleven clear factors emerged from factor analysis, with no cross-loadings above 0.40 and all factor loadings above 0.5. The final results are shown in Appendix 8.2.8.

In a next step, we used a confirmatory factor analytic approach within AMOS to establish the validity of the measurement model prior to testing the structural model (Brown 2006). A five-factor correlated model representing SSD, CN, RPD, CS, and MG was specified and is shown schematically in Figure 17. Doing so minimizes the misfit in the measurement model so that any misfit in the overall structural model can be attributed to structural relationships. The results of the confirmatory factory analysis are summarized in Appendix 8.2.9.
Three items (blackened in Figure 17) were deleted because they showed indicator reliabilities below the recommended value of 0.4 (Homburg and Giering 1996, p. 13). Although its reliability was marginally below 0.4, item CS3 (“Providing value for customers”) was retained for further analysis because it is a key performance indicator for mass customization firms (see Chapter 4.4). This is in line with the reasoning of Little et al. (1999), who note that an overly strong focus on indicator reliability might negatively affect content validity of the measurement model. The resulting construct reliability was in the range between 0.67 and 0.84, and thus above the required threshold of 0.6 (Bagozzi and Yi 1988, p. 82). The average variance extracted ranged from 0.50 to 0.57, and thus met the threshold of 0.5. We also examined discriminant validity among the five elements, using Fornell and Larcker’s (1981, p. 46) test. This test shows the uniqueness of the constructs for the five dimensions by comparing the AVE of any two constructs with the shared variance between those two constructs. If the AVE for each construct is greater than its shared variance with any other construct, discriminant validity is supported. All calculated Fornell-Larcker ratios were below the required value of 1.0, suggesting that there is good discriminant validity between the factors.

To assess the fit between the hypothetical model and the sample data, we used relative chi-square ($\chi^2$/df), root mean square error of approximation (RMSEA), Tucker-Lewis index (TLI), and comparative fit index (CFI). The threshold values for reasonable model fit are $\chi^2$/df $\leq$ 3.0 (Carmines and McIver 1981, p. 80), RMSEA $\leq$ 0.08 (Browne and Cudeck 1993, p. 144), TLI $\geq$ 0.9 (Hair et al. 2006, p. 672), and CFI $\geq$ 0.9 (Sharma et al. 2005, p. 936). In the past, the model fit was frequently assessed using the goodness-of-fit index (GFI) and the adjusted goodness-of-fit index (AGFI). However, both indices are very sensitive to the sample size;
their values decrease for small samples with increasing model complexity. With regard to our relatively small sample size, we thus followed recent recommendations in the literature that the use of GFI and AGFI should be discouraged (Sharma et al. 2005, p. 941). A simulation study by Sharma et al. (2005, pp. 941-942) that investigates the use of different indices with cut-off values for assessing model fit instead suggests that RMSEA and TLI are very reliable criteria in identifying misspecified models for small samples. Overall, the CFA model showed a good fit ($\chi^2/df = 1.329$, RMSEA = 0.054, TLI = 0.925, CFI=0.940).

Due to the relatively small sample size, it was not possible to perform confirmatory factor analysis for all 37 constructs and variables simultaneously using the structural modeling method. We therefore examined the correlation matrix of these constructs and variables for evidence of discriminant validity. Mass customization capability (MCCAP), calculated as the arithmetic mean of the constructs for SSD, RPD, and CN, has significant and positive correlations with both market growth (MG) and customer success (CS) which is in line with our conceptual framework. Furthermore, in the majority of cases we find significant and positive correlations between the three strategic capabilities and their hypothesized antecedents. However, we do not find exceptionally high correlations between any variables where no causal relationship exists. For all variables, we also calculated the variance inflation factor (VIF) to check for potential multicollinearity. The highest VIF found, 2.75 for SSD, was well below the threshold of 10.0 (Hair et al. 2006, pp. 290-291). The descriptive statistics and correlations among the variables are summarized in Appendix 8.2.10.
6 Hypotheses Testing

In our analyses, we used covariance-based structural equation modeling (SEM) as implemented in AMOS to test the hypotheses. Given that the estimation algorithms are based on asymptotic theory, the number of observations has to exceed the number of parameters to be estimated by at least 50 (Bagozzi and Yi 1988, p. 80). This minimum requirement was fulfilled by all models (115 observations and a maximum of 43 distinct parameters). Furthermore, multiple regression analyses were used to analyze the impact of various correlates and contingency factors.

6.1 Validation of Mass Customization Capability as Second-Order Construct

To establish the dimensional structure of strategic capabilities for mass customization, we specified various alternative measurement models at the first-order and second-order levels and assessed their relative fits (Law et al. 1998). The fit statistics for these models are reported in Table 6.

<table>
<thead>
<tr>
<th>Models</th>
<th>χ² (df)</th>
<th>Normed χ²</th>
<th>RMSEA</th>
<th>TLI</th>
<th>CFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic capabilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1 (one-factor model)</td>
<td>166.053 (35)</td>
<td>4.744</td>
<td>0.181</td>
<td>0.470</td>
<td>0.588</td>
</tr>
<tr>
<td>Model 2 (3 uncorrelated factors)</td>
<td>51.786 (35)</td>
<td>1.480</td>
<td>0.065</td>
<td>0.932</td>
<td>0.947</td>
</tr>
<tr>
<td>Model 3 (3 correlated factors)</td>
<td>38.197 (32)</td>
<td>1.194</td>
<td>0.041</td>
<td>0.973</td>
<td>0.981</td>
</tr>
<tr>
<td>Model 4 (one second-order factor)</td>
<td>38.197 (32)</td>
<td>1.194</td>
<td>0.041</td>
<td>0.973</td>
<td>0.981</td>
</tr>
<tr>
<td>Performance measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 5 (one-factor model)</td>
<td>66.960 (14)</td>
<td>4.783</td>
<td>0.182</td>
<td>0.689</td>
<td>0.793</td>
</tr>
<tr>
<td>Model 6 (two-factor model)</td>
<td>20.128 (13)</td>
<td>1.548</td>
<td>0.069</td>
<td>0.955</td>
<td>0.972</td>
</tr>
</tbody>
</table>

Table 6: Measurement Models and Fit Statistics

Model 1 has a unidimensional factor that accounts for the variance among all 10 items, which is also known as Harman’s single-factor test (Podsakoff et al. 2003, p. 889). Not surprisingly, model 1 has a very poor fit. In model 2, we conceptualize that the 10 items form three distinct and uncorrelated first-order factors, corresponding to SSD, RPD, and CN. Comparison of the fit indices for model 1 and model 2 shows that model 2 is the better-fitting model, indicating that a multidimensional model composed of three uncorrelated first-order factors is superior to a unidimensional first-order factor model. The chi-square difference (Δχ² = 114.267, p < 0.01) across the two models is significant, providing further evidence in support of model 2.
Model 3 conceptualizes that the three first-order factors are free to correlate with each other. A comparison between the fit measures of models 2 and 3 indicates that model 3 represents the data considerably better than model 2; the chi-square difference between the two models relative to their degrees-of-freedom difference is also significant ($\Delta \chi^2 = 13.589$, $\Delta df = 3$, $p < 0.05$). Moreover, we examined additional models that are similar to model 3 because they have the 10 items forming two, four, and five correlated first-order factors. As model 3 exhibited a better fit than these additional models, they are not described in further detail. Finally, model 4 posits mass customization capability (MCC) as a reflective second-order construct that accounts for the relationships between the three strategic capabilities. However, when two nested models have exactly the same chi-square and degrees of freedom, as do models 3 and 4, comparing goodness of fit statistics for the two models is not meaningful. In this case it is also not possible to calculate the target coefficient, which is the percent of variation in the first-order factors that can be explained by the second-order construct (Marsh and Hocevar 1985). The superiority of one model is instead established by examining the significance of the second-order factor loadings in the measurement model (Venkatraman 1990; Tippins and Sohi 2003) on one hand and significance of the structural links that link the measurement model to a criterion variable of interest such as company performance on the other (Venkatraman 1990). All the second-order factor loadings in model 4 are significant ($p < 0.05$). Further, as will be discussed in Section 6.3, only the second-order factor model has a significant impact on company performance. Collectively, these results suggest that the second-order factor structure is a better statistical specification for modeling mass customization capability, supporting our hypotheses H1, H2, and H3 of mass customization capability encompassing SSD, RPD, and CN.

The dimensional structure for the performance measures was assessed in a similar manner by comparing two measurement models. Model 5 consists of seven measures forming a unidimensional factor, whereas model 6 consists of two distinct yet correlated factors representing market growth (MG) and customer success (CS). Table 3 presents the fit statistics for these two models. We retain model 6 because of its superior fit to the data; its fit measures surpass the fit statistics associated with model 5 and exceed the critical cut-off values. The chi-square difference across the two models was also found to be significant relative to the corresponding change in degrees of freedom ($\Delta \chi^2 = 46.832$, $\Delta df = 1$, $p < 0.01$).
To further assess the content validity of the second-order mass customization capability construct (MCC second-order) comprising three strategic capabilities, we compare it with a predefined direct measure of mass customization capability (MCC direct). For this purpose, the adapted MCC measure from Tu et al. (2001) is used as a possible criterion. A positive and significant path coefficient between the two measures would suggest that the indirect measurement of MCC through SSD, RPD, and CN is a valid representation of the direct MCC measure. The corresponding model is shown in Figure 18. Within the model, we conducted confirmatory factor analysis (CFA) for the direct MCC measure. MCC1, MCC2, and MCC5 were removed from further analysis because they showed indicator reliabilities below the recommended value of 0.4. The resulting factor reliability was 0.67 and the average variance extracted 0.50, and thus above the cut-off values of 0.6 and 0.5, respectively (see 8.2.9).

![Figure 18: Relatedness of Strategic Capabilities to Mass Customization Capability](image)

Overall, estimation of the model produced a good fit ($\chi^2/df = 1.368$, RMSEA = 0.057, TLI = 0.938, CFI = 0.953). In line with our reasoning, the path coefficient between the indirect and the direct measurement of MCC is positive and highly significant (0.866, p < 0.001). Moreover, the MCC second-order construct explains 75% ($R^2 = 0.749$) of the variance in the direct MCC measure, meaning that it captures the major facets of observable mass customization capability. Finally, according to Fornell and Larcker’s (1981) test, the discriminant validity between the latent construct and the direct measurement of MCC is not
sufficient (1.49). That implies that the MCC second-order construct measures the same content as the intended direct measurement of MCC.

6.2 Antecedents of Strategic Capabilities

Much of the discussion in Chapter 4 centered on how the proposed capabilities can be developed in practice; that is, which proven tools, methods, and routines companies can deploy to mass customize their offerings. To examine the correlation of these practices with the respective capabilities, multiple regression analyses were performed (see Table 7). In all regressions, we controlled for the type of business (TYPE), the period since the launch of the online mass customization offering (AGE), and the firm size in terms of the logarithm of the average number of FTEs employed in 2010 (FTE).

The results indicate that the use of opportunity recognition heuristics (SSD_OPP) and customer information (SSD_CUST) to develop the product offerings and improve the solution space relate positively to SSD capability. The same applies to the implementation of a formal revision process (SSD_REV). This confirms hypotheses H1a, H1c, and H1d; the other hypotheses are not supported.

Product modularity (PDM), process modularity (PCM), and skill flexibility (SF) are significant and positively related to RPD capability, providing evidence for hypotheses H2a, H2c, and H2d. However, we do not find a positive relationship between flexible automation (FA) and RPD capability as proposed in H2b; this result may be ascribed to specific characteristics of the mass customizers in the sample who apparently do not rely heavily on automated machinery for customizing their products.

With regard to choice navigation, we do not find any positive and significant relationship; hypotheses H3a to H3d are thus rejected.
### SSD Antecedents

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>.897†</td>
<td>.472</td>
</tr>
<tr>
<td>SSD_REV</td>
<td>.340*</td>
<td>.153</td>
</tr>
<tr>
<td>SSD_OPP</td>
<td>.194*</td>
<td>.081</td>
</tr>
<tr>
<td>SSD_SEC</td>
<td>.103</td>
<td>.079</td>
</tr>
<tr>
<td>SSD_CUST</td>
<td>.231**</td>
<td>.087</td>
</tr>
<tr>
<td>PDM</td>
<td>.053</td>
<td>.054</td>
</tr>
<tr>
<td>TYPE</td>
<td>-.089</td>
<td>.217</td>
</tr>
<tr>
<td>AGE</td>
<td>-.002</td>
<td>.008</td>
</tr>
<tr>
<td>FTE</td>
<td>.046</td>
<td>.058</td>
</tr>
</tbody>
</table>

R² = .255  Adjusted R² = .199  F = 4.55***

### RPD Antecedents

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>PDM</td>
<td>.113*</td>
<td>.064</td>
</tr>
<tr>
<td>PCM</td>
<td>.212**</td>
<td>.080</td>
</tr>
<tr>
<td>FA</td>
<td>.055</td>
<td>.063</td>
</tr>
<tr>
<td>SF</td>
<td>.214*</td>
<td>.082</td>
</tr>
<tr>
<td>TYPE</td>
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<td>.221</td>
</tr>
<tr>
<td>AGE</td>
<td>.010</td>
<td>.009</td>
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<tr>
<td>FTE</td>
<td>-.067</td>
<td>.064</td>
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</tbody>
</table>

R² = .192  Adjusted R² = .125  F = 2.85*

### CN Antecedents

<table>
<thead>
<tr>
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<th>Coefficients</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
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<td>.005</td>
</tr>
<tr>
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<td>.020</td>
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<tr>
<td>CN_INFO</td>
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<td>NEEDS</td>
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<td>.588</td>
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<tr>
<td>DEFAULT</td>
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<td>.218</td>
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<tr>
<td>SAVE</td>
<td>-.099</td>
<td>.162</td>
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<tr>
<td>COMPARE</td>
<td>-.037</td>
<td>.164</td>
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<tr>
<td>3D</td>
<td>.032</td>
<td>.159</td>
</tr>
<tr>
<td>ZOOM</td>
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<td>.170</td>
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<td>TYPE</td>
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<td>.245</td>
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<tr>
<td>AGE</td>
<td>-.000</td>
<td>.010</td>
</tr>
<tr>
<td>FTE</td>
<td>-.047</td>
<td>.085</td>
</tr>
</tbody>
</table>

R² = .075  Adjusted R² = -.105  F = 0.42  ***p < 0.001; **p < 0.01; *p < 0.05; †p < 0.10

Table 7: Regression Results for Antecedents of Strategic Capabilities
6.3 Performance Implications of Strategic Capabilities

Our conceptual framework suggests that enhancing any of the three strategic capabilities for mass customization has a positive effect on company performance. The model in Figure 19 includes the three strategic capabilities and models their pairwise covariance. We label this the *direct effects model* because it suggests that the strategic capabilities have independent direct effects on market growth and customer success.

![Figure 19: Direct Effects Model](image)

The fit indices for the direct effects model exceed the critical cut-off values ($\chi^2/df=1.366$, RMSEA = 0.057, TLI = 0.917, CFI=0.933). However, only the structural link from SSD to market growth is positive and significant (0.260, $p < 0.05$), whereas the other five relationships are insignificant, indicating poor model specification. Therefore, H4a is partially supported, while we do not find support for H4b and H4c. Overall, the results suggest that mass customization firms cannot achieve strategic differentiation and competitive advantage by improving along only one capability dimension. This finding is somewhat surprising, but it further highlights the importance of examining whether the individual capabilities may affect market growth and customer success through their complementarity in mass customization capability.
Complementarity theory implies that the magnitude of the effect of overall mass customization capability is greater than the sum of marginal effects from developing each capability individually (Milgrom and Roberts 1995). To examine complementarity, we model overall mass customization capability (MCC) as a reflective second-order factor to capture complementarities arising from the three capabilities. This reflective second-order factor accounts for multilateral interactions between the three capabilities and is thus a superior statistical specification compared to pairwise interactions (Whittington et al. 1999). The use of a reflective second-order factor to represent complementarities among first-order factors is consistent with recent examinations of complementarity (Tanriverdi and Venkatraman 2005; Ettlie and Pavlou 2006; Shah and Ward 2007; Lichtenthaler 2009; Mishra and Shah 2009). A formative second-order factor modeling approach is not appropriate for capturing complementarities because it does not assume any interactions or covariance among the first-order factors (Tanriverdi 2006). The complete structural model representing our conceptual framework is shown in Figure 20. It includes the second-order mass customization capability construct and the two structural links to the performance measures. We label this the complementarity model.

![Figure 20: Complementarity Model](image)

χ²/df = 1.314, RMSEA = 0.052, TLI = 0.929, CFI = 0.941

*p < .05

**p < .01

***p < .001
In assessing the performance effects of complementary strategic capabilities, the complementarity model must be compared with the direct effects model (Whittington et al. 1999): First, the complementarity model with its second-order factor is more parsimonious than the direct effects model because it requires fewer parameters to be estimated and accounts for the covariance among first-order factors. Second, the fit statistics for the complementarity model are also better than those of the direct effects model ($\chi^2/\text{df} = 1.314$, RMSEA = 0.052, TLI = 0.929, CFI=0.941). More importantly, all structural links in the complementarity model are positive and significant, whereas only one structural link was significant in the direct effects model. Finally, we also compare the variance explained in the two performance measures by the complementarity and direct effects models. The complementarity model explains 26% ($R^2 = 0.263$) of the variation in market growth compared to 12% ($R^2 = 0.115$) explained by the direct effects model. The variation explained in customer success is 16% ($R^2 = 0.159$) for the complementarity model and 7% ($R^2 = 0.066$) for the direct effects model. This result clearly demonstrates the superiority of the complementarity model over the direct effects model in explaining the variation in company performance of mass customization firms. Hypothesis 5 proposed that the three strategic capabilities are complementary and have a major impact on market growth and customer success through mass customization capability; our results provide significant support for this proposition.

Common method variance is a potentially serious concern in survey-based research, especially where the predictor and criterion variables are perceptual and obtained from the same source (Podsakoff and Organ 1986). Common method variance is “variance that is attributable to the measurement method rather than to the constructs the measures represent” (Podsakoff et al. 2003, p. 879), which creates false internal consistency. Because the capability measures and performance evaluations were both obtained from the same respondents (i.e., founders or managers of mass customization firms) and in the same measurement context (i.e., an online survey), there is a possibility that common method variance may have inflated or deflated the strength of the observed relationships between the constructs. To assess the potential impact of this form of bias in the present study, we follow the recommendation of Podsakoff et al. (2003, p. 894) and add a latent common method variance factor with all of the measures as indicators to the complementarity model shown in Figure 20. This procedure, which has been used in a number of studies (e.g., Podsakoff and MacKenzie 1994; MacKenzie et al. 1999;
Carlson and Kacmar 2000), has the effect of controlling for the portion of variance in the indicators that can be attributed to the fact that the measures were obtained from the same source. The standardized parameter estimates for the reestimated model are reported in the second column of Table 8. The chi-square difference between the two models relative to their degrees of freedom is significant ($\Delta \chi^2 = 38.308, p < 0.01$). However, the overall pattern of significant relationships was not affected by common method variance: All of the paths that were significant without controlling for common method variance remained significant when controlling for common method variance. Furthermore, when controlling for common method variance, the variance explained in market growth even increases from 26.3% to 33.3%, whereas the variance explained in customer success decreases slightly from 15.9% to 13.0%.

<table>
<thead>
<tr>
<th>Description</th>
<th>Not Controlling for Common Method Variance</th>
<th>Controlling for Common Method Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2$ (df)</td>
<td>149.788 (114)</td>
<td>111.480 (97)</td>
</tr>
<tr>
<td>SSD $\rightarrow$ MCC</td>
<td>.596***</td>
<td>.623***</td>
</tr>
<tr>
<td>RPD $\rightarrow$ MCC</td>
<td>.483**</td>
<td>.470**</td>
</tr>
<tr>
<td>CN $\rightarrow$ MCC</td>
<td>.363*</td>
<td>.368*</td>
</tr>
<tr>
<td>MCC $\rightarrow$ CS</td>
<td>.399*</td>
<td>.361*</td>
</tr>
<tr>
<td>MCC $\rightarrow$ MG</td>
<td>.531***</td>
<td>.574***</td>
</tr>
<tr>
<td>R² (in CS)</td>
<td>.159</td>
<td>.130</td>
</tr>
<tr>
<td>R² (in MG)</td>
<td>.263</td>
<td>.330</td>
</tr>
</tbody>
</table>

Table 8: Standardized Parameter Estimates With and Without Controlling for Common Method Variance

### 6.4 Moderator Effects of Environmental Contingencies

The moderator effect implies that the moderator variable affects the relationship (i.e., the slope of the regression line) between the predictor variable (e.g., mass customization capability) and the criterion variable (e.g., company performance). To test for moderator effects, we apply moderated regression analysis (Sharma et al. 1981; Irwin and McClelland 2001) and create three multiplicative interaction terms by multiplying the values for mass customization capability (MCCAP), computed as the arithmetic mean of the constructs for SSD, RPD, and CN, with the values for the hypothesized environmental contingencies MT, TT, and CI. Following recommendations by Jaccard et al. (1990) and Aiken and West (1991), we mean-
center all independent variables that constitute an interaction term to mitigate the potential risk of multicollinearity. Next, we simultaneously regress company performance on mass customization capability, the environmental dimensions, the interaction terms, and three control variables. As in the previous analyses, company performance is measured as market growth (MG) and customer success (CS) relative to competitors.

Technological turbulence positively moderates the effects of mass customization capability on market growth, whereas the multiplicative terms for market turbulence and competitive intensity are insignificant. Contrary to H6b, however, the results indicate that mass customization capability could be more important in environments with high technological turbulence. The results are reported in Table 9. It is important to note that we also found some evidence of a moderator effect for market turbulence in more parsimonious regression models without controls. Hence, while the effect does not seem to be very robust, it was consistently negative in all analyses. This finding suggests that mass customization capability is potentially more strongly related to market growth in stable markets than in turbulent markets.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Standard Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>2.930***</td>
<td>.127</td>
</tr>
<tr>
<td>MCCAP</td>
<td>.473**</td>
<td>.151</td>
</tr>
<tr>
<td>MT</td>
<td>.154</td>
<td>.098</td>
</tr>
<tr>
<td>TT</td>
<td>-.169†</td>
<td>.082</td>
</tr>
<tr>
<td>CI</td>
<td>-.125*</td>
<td>.067</td>
</tr>
<tr>
<td>MCCAP x MT</td>
<td>-.332</td>
<td>.228</td>
</tr>
<tr>
<td>MCCAP x TT</td>
<td>.320*</td>
<td>.164</td>
</tr>
<tr>
<td>MCCAP x CI</td>
<td>.166</td>
<td>.134</td>
</tr>
<tr>
<td>TYPE</td>
<td>.668**</td>
<td>.225</td>
</tr>
<tr>
<td>AGE</td>
<td>-.005</td>
<td>.009</td>
</tr>
<tr>
<td>LN_FTE</td>
<td>.209**</td>
<td>.060</td>
</tr>
</tbody>
</table>

R² = .331  Adjusted R² = .267  F = 5.15***  ***p < 0.001; **p < 0.01; *p < 0.05; †p < 0.10
Dependent Variable: Market Growth (MG)

Table 9: Moderated Regression Analysis with Market Growth as Dependent Variable

The three environmental contingencies do not significantly affect the relationship between mass customization capability and customer success. In other words, the positive effect of mass customization capability on customer success is equally high at different levels of market and technological turbulence, and competitive intensity. The results are shown in Table 10.
### Table 10: Moderated Regression Analysis with Customer Success as Dependent Variable

The simple slope analysis in Figure 21 illustrates these findings; it shows that mass customization capability has a strong positive effect on company performance under conditions of high technological turbulence, but that the strength of this effect is weakened in relatively stable environments. The significance of these findings for managers and academics is discussed in the next chapter.

![Figure 21: Illustration of Simple Slope Analysis for Technological Turbulence](image)
chapter, our empirical results provide strong significant support for 10 of these hypotheses, while another, H4a, is partially confirmed, as one of the structural links from SSD to the performance measures is positive and significant. Table 11 summarizes the results.

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensional Structure of Mass Customization Capability</strong></td>
<td></td>
</tr>
<tr>
<td>H1: Solution space development capability is an essential facet of a firm’s overall mass customization capability.</td>
<td>✓</td>
</tr>
<tr>
<td>H2: Robust process design capability is an essential facet of a firm’s overall mass customization capability.</td>
<td>✓</td>
</tr>
<tr>
<td>H3: Choice navigation capability is an essential facet of a firm’s mass customization capability.</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Antecedents of SSD</strong></td>
<td></td>
</tr>
<tr>
<td>H1a: Systematic analysis of customer information relates positively to solution space development capability</td>
<td>✓</td>
</tr>
<tr>
<td>H1b: Systematic analysis of secondary information relates positively to solution space development capability.</td>
<td>−</td>
</tr>
<tr>
<td>H1c: Opportunity recognition abilities relate positively to solution space development capability.</td>
<td>✓</td>
</tr>
<tr>
<td>H1d: A formal revision process relates positively to solution space development capability.</td>
<td>✓</td>
</tr>
<tr>
<td>H1e: Product modularity relates positively to solution space development capability.</td>
<td>−</td>
</tr>
<tr>
<td><strong>Antecedents of RPD</strong></td>
<td></td>
</tr>
<tr>
<td>H2a: Process modularity relates positively to robust process design capability.</td>
<td>✓</td>
</tr>
<tr>
<td>H2b: Flexible automation relates positively to robust process design capability.</td>
<td>−</td>
</tr>
<tr>
<td>H2c: Flexible human resources relate positively to robust process design capability.</td>
<td>✓</td>
</tr>
<tr>
<td>H2d: Product modularity relates positively to robust process design capability.</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Antecedents of CN</strong></td>
<td></td>
</tr>
<tr>
<td>H3a: The cumulative financial investment into configurator technology is positively related to choice navigation capability.</td>
<td>−</td>
</tr>
<tr>
<td>H3b: The number of revisions of the configurator is positively related to choice navigation capability.</td>
<td>−</td>
</tr>
<tr>
<td>H3c: The diversity of information sources used for the revision process is positively related to choice navigation capability.</td>
<td>−</td>
</tr>
<tr>
<td>H3d: Selected system features of the configuration toolkit relate positively to choice navigation capability.</td>
<td>−</td>
</tr>
<tr>
<td><strong>Performance Implications of Strategic Capabilities</strong></td>
<td></td>
</tr>
<tr>
<td>H4a: Solution space development capability has a positive direct effect on company performance.</td>
<td>(✓)</td>
</tr>
<tr>
<td>H4b: Robust process design capability has a positive direct effect on company performance.</td>
<td>−</td>
</tr>
<tr>
<td>H4c: Choice navigation capability has a positive direct effect on company performance.</td>
<td>−</td>
</tr>
<tr>
<td>H5: Complementarity of solution space development, robust process design, and choice navigation has a positive effect on company performance.</td>
<td>✓</td>
</tr>
<tr>
<td>H6a: The greater the market turbulence, the stronger the positive effect of mass customization capability on company performance.</td>
<td>−</td>
</tr>
<tr>
<td>H6b: The greater the technological turbulence, the weaker the positive effect of mass customization capability on company performance.</td>
<td>−</td>
</tr>
<tr>
<td>H6c: The greater the competitive intensity, the stronger the positive effect of mass customization capability on company performance.</td>
<td>−</td>
</tr>
</tbody>
</table>

Table 11: Summary of Results Concerning the Proposed Hypotheses
7 Discussion of Results

The goal of this work was to establish a model of the capabilities required to implement a profitable and sustainable mass customization business. This chapter summarizes our key findings and contributions. In a first step, the results of the empirical study are discussed and interpreted with regard to the research questions developed in Chapter 1.4 (see Section 7.1). Second, the managerial implications are derived (see Section 7.2). Third, we point out limitations of this study and outline potential avenues for future research (see Section 7.3). In the final section, we present our conclusion and outlook on the future of mass customization (see Section 7.4).

7.1 Theoretical Discussion and Contributions

In the 21st-century economy, the role of the customer in the value creation process is evolving—from that of a passive recipient to that of an active co-creator (Prahalad and Ramaswamy 2004). As a consequence, mass customization has become a strategic imperative for many companies to compete in the developing marketplace (Piller and Kumar 2006). In the introductory chapter of this work, however, we noted that many companies continue to struggle to scale up their mass customization business and break even on their investment. Looking into some prominent cases of mass customization business failures, we ascertained that these failures were exclusively failures of execution, not of concept. This should come as no surprise, given that academic literature provides managers with little guidance on which strategic capabilities firms need to realize mass customization and how these capabilities might be developed in practice. Most current research instead focuses on formalizing specific problems associated with the pursuit of mass customization (Salvador et al. 2008). To address this gap, we formulated five concrete research questions concerning strategic capabilities for mass customization and their performance implications. All research questions were answered by the presented empirical study. The following discussion summarizes the main results:

(1) What are the strategically relevant capabilities for mass customization?

From a customer perspective, mass customization can potentially create value by increasing the utility of the product, but it also raises both acquisition costs and search and evaluation costs; the net effect is a priori uncertain. However, firms can positively influence the customer value creation levers by developing certain core capabilities. From a firm perspective, these
capabilities are strategically relevant if they are distinctive, supporting a market position that is both valuable and difficult to imitate. Combining the two perspectives, Salvador et al. (2009) propose that a firm should develop three fundamental capabilities to reap the benefits of mass customization:

- Solution space development (SSD)
- Robust process design (RPD)
- Choice navigation (CN).

Based on an extensive literature review, we demonstrated that the capabilities framework of Salvador et al. (2009) allows for an integration of much of the conceptual and empirical research on mass customization currently taking place independently in different fields. We then extended the work of Salvador et al. (2009) in three ways: First, we synthesized concepts and findings from related research disciplines, including operations management, innovation management, strategic management, marketing, and psychology, to build a richer theory of the development of mass customization capabilities. Second, we disentangled the capabilities in accordance with their antecedents, that is, the specific methods, tools, and routines firms may deploy to implement them in practice. Third, we provided theoretical justification for a research model that relates the strategic capabilities for mass customization to company performance. The aim of this work was not to present an overview of all potentially relevant capabilities for mass customization; instead, we focused on identifying the capabilities that grant firms strategic differentiation and competitive advantages.

(2) How do the strategic capabilities relate to one another?

To date, the re-conceptualization of mass customization as comprising three distinctive strategic capabilities has only been motivated theoretically. To empirically validate the dimensional structure of strategic capabilities for mass customization, we analyzed several alternative measurement models representing plausible specifications of the relationships between the variables and compared their fit statistics. The comparison produced two main findings: First, a multidimensional model composed of three uncorrelated first-order factors fits the data better than a unidimensional first-order factor model. The three capability dimensions are thus not only theoretically but also empirically distinguishable, which emphasizes the multidimensional nature of mass customization. Second, the superiority of the second-order factor model (model 4) compared to the model of three correlated factors
(model 3) confirms that multiple capability configurations are all driven by a cohesive yet unobservable underlying competence—namely, mass customization capability. To establish the content validity of the second-order mass customization capability construct, we compare it with a direct measure of mass customization capability. According to Fornell and Larcker’s (1981) test, the two measures are indistinguishable, which implies that the second-order construct comprises all major facets of the direct measurement of mass customization capability. In summary, the results provide strong empirical evidence for the proposed re-conceptualization of mass customization as a multidimensional, higher-order construct encompassing solution space development, robust process design, and choice navigation.

(3) Which activities are positively related to the development of these capabilities?

When developing the strategic capabilities, managers want to know which practices are important for success. The results of our study indicate that, in addition to conventional market research, opportunity recognition heuristics are particularly effective in determining the solution space. This finding reinforces our belief that many entrepreneurs started their mass customization businesses simply by translating their own unsatisfied needs into a custom product offering. It is generally advantageous when entrepreneurs have deep domain expertise in the space where they are innovating. Furthermore, the implementation of a formal revision process to revise, trim, or extend the solution space at regular intervals is also positively related to solution space development capability. As previously discussed, customer preferences are generally not static—what customers want today may differ from what they will want tomorrow (Simonson 2005).

We also find that product modularity and process modularity are positively related to robust process design capability. Modularity is an inevitable strategic choice for firms if they are to cope with the demand for individually customized products (e.g., Pine 1993; Feitzinger and Lee 1997; Duray et al. 2000). The results are consistent with earlier findings of Tu et al. (2004b), who demonstrate that modularity-based manufacturing practices have a positive impact on mass customization capability. However, the data do not support the proposition that flexible automation is an essential element of robust process design. This may be due to the fact that, among the mass customizers in the sample, the degree of automation is in general quite low. Follow-up interviews with selected firms in the sample confirmed that customization sub-processes such as material printing or ingredient mixing are often
performed manually, or at most semi-automatically. Entrepreneurs typically prefer to wait and see whether their custom products will sell before investing in flexible automation technologies to scale up their business. However, the labor-intensive production of custom products places high demands on the workforce in terms of flexibility. Companies must break down bureaucratic organizational structures and instead deploy adaptable, highly skilled teams that can be easily reconfigured to meet the ever changing customer needs (Pine et al. 1993). Not surprisingly then, we find a significant and positive relationship between skill flexibility and robust process design capability.

With regard to choice navigation, we do not find any positive and significant correlation with the three measures that firms were asked to indicate directly in the survey. Neither the cumulative financial investment in configuration technology, nor the revision frequency, nor the diversity of information sources used for the revision seem to be decisive factors in enhancing choice navigation capability. The results suggest that, once a basic solution has been implemented, mass customization firms should focus their resources on optimizing the solution space and increasing the robustness of the process design. Furthermore, the individual effects of selected system features of the configuration toolkit are also insignificant. It is important to note, however, that we simply verified whether a configuration toolkit has the respective features or not. We did not attempt to match the features with customers’ evaluations of the configuration toolkit in terms of visual realism, usability, and enjoyment of the configuration process.

In summary, the fact that we found several positive correlations between these capabilities and proven mass customization practices applied in multiple firms provides further evidence that they are indeed distinctive mass customization capabilities.

\textit{(4) What are the performance implications of strategic capabilities for mass customization?}

In a sample of 115 mass customization firms, we find that the three strategic capabilities on their own do not improve company performance. Only the structural link between solution space development and market growth is positive and significant. However, our analysis shows that, compared to the direct effects model, the complementarity model yields statistically stronger results that are valid in practice. Specifically, the extent of variance in the two performance measures explained by the second-order latent construct is higher than that
This finding suggests that it is the complementary and synergistic effects of the three distinct but highly inter-related capabilities that enable firms to achieve multiple performance goals. Accordingly, firms that are able to implement the complete set achieve superior performance outcomes, which may result in sustainable competitive advantage. The sustainability of this advantage follows from the difficulty of simultaneously implementing multiple aspects of mass customization. Because simultaneous implementation of so many elements is difficult to achieve, it is also difficult for competitors to imitate (Porter 1996).

(5) Which contingency factors moderate their impact on performance?

The results show that the impact of mass customization capability on a firm’s performance differs depending on the level of environmental uncertainty. On the one hand, the positive effect of mass customization capability becomes stronger in environments with high technological turbulence. This finding underscores the particular importance of dynamic capabilities under turbulent conditions (Teece 2007). On the other hand, there is some evidence that mass customization capability could be more important in environments with low market turbulence. The sign of the moderator effect for market turbulence is consistently negative, although it is significant only in more parsimonious regression models. Finally, the link between mass customization capability and company performance appears to be robust independent of the level of competitive intensity. In summary, these mixed results raise the fundamental question of why a mass customization firm should necessarily be influenced by environmental contingencies.

As an important contribution to theory, this study synthesizes the resource-based view (RBV) and the economic theory of complementarities. Unlike most previous quantitative RBV studies (see Barney 2001, for a review), this study does not limit itself to analyzing the impact of one resource or capability on company performance. Rather, it demonstrates how multiple core elements of a mass customization strategy enhance company performance, either independently or collectively. In a sample of 115 mass customization firms, the study finds that the strategic capabilities do not improve corporate performance on their own; they seem to be neither idiosyncratic nor valuable resources in the RBV sense. However, conceptualizing individual dimensions of a multi-dimensional construct such as mass customization capability as independent may lead to inconsistent or ambiguous results. If we had assessed each
capability separately, we might have incorrectly concluded that they have no significant effect on company performance, even though they contribute to customer success and market growth through mass customization capability. By modeling their complementarity using a second-order construct, we discovered super-additive synergies arising from the simultaneous implementation of the three strategic capabilities for mass customization. In other words, the “marginal productivity” of each capability increases with the values of all other strategic capabilities. Other researchers report similar findings for analyses of organizational learning processes of absorptive capacity (Lane et al. 2006; Lichtenthaler 2009) and routines used for collaboration in new product development (Mishra and Shah 2009). Thus, the results confirm that no company is likely to outperform its rivals based on a single strategic resource; gaining and preserving superiority in competitive environments is instead dependent on a set of mutually enhancing strategic elements (Carmeli and Tishler 2004). Overall, this study is a step toward providing a more nuanced and realistic perspective on the integrated nature of mass customization.

Methodologically, this study makes two important contributions. Several authors (e.g., Da Silveira et al. 2001; Tu et al. 2004a; Kumar et al. 2007; Moser 2007; Huang et al. 2010) lament the lack of empirical evidence in mass customization research on the firm level; many works still rely on case descriptions and concept development. One important reason for this might be the substantive disagreement about what constitutes mass customization and how it can be measured operationally. As Kaplan and Haenlein (2006, p. 180) put it: “Since it is obviously not appropriate to proceed to theory testing as long as the measurement properties of the key constructs prove to be inadequate, focusing on developing a scale for measuring … mass customization is strongly recommended.” Therefore, as a first contribution, this study develops a set of valid and reliable instruments to measure the three sub-dimensions of mass customization capability, namely solution space development, robust process design, and choice navigation. These instruments were developed through a carefully designed large-scale data collection process applying rigorous instrument development methods. A literature search generated potential scale items, which were supplemented by newly proposed ones. Extensive efforts were then made during pre-testing and pilot study testing to ensure the instruments’ content validity. In an empirical test, the measures showed strong evidence of unidimensionality, reliability, convergent validity, and discriminant validity. The scales thus
represent substantial progress towards the establishment of standard instruments for measuring mass customization capability and its sub-dimensions. These instruments will allow researchers to assess the state of mass customization implementation in firms and test hypotheses about relationships between mass customization capabilities and other firm characteristics affecting firm performance. Additionally, the study provides a tool for managers to self-evaluate their progress in implementing capabilities-based mass customization and compare mass customization readiness among various divisions of the same company or across organizations.

The few empirical-statistical studies on mass customization can be divided into two groups (Kaplan and Haenlein 2006, p. 179): (1) surveys and experiments with end customers, addressing questions such as how customers handle choice complexity and experience the integration into the value creation process (e.g., Dellaert and Dabholkar 2009; Franke et al. 2010; Merle et al. 2010); and (2) large-scale empirical studies that approach mass customization from a company perspective, analyzing primarily the effectiveness of various practices (e.g., modularity, flexible manufacturing, quality management) in enhancing mass customization capability (e.g., Tu et al. 2004a; Squire et al. 2006b; Kristal et al. 2010). However, the latter group of studies tested their hypotheses mostly using survey data collected from a convenience sample of medium- to large-sized mass manufacturers that merely apply some mass customization practices. The respondents can thus rarely be considered full mass customizers, and the findings therefore have limited generalizability for innovative start-ups and SMEs such as Mymuesli, Chocri, or Zazzle, which built their business models from the ground up and bet fully on the promises of mass customization. Therefore, as a second contribution, this study returns to the intellectual foundations of mass customization by enforcing strict criteria in terms of the selection of respondents. With their clear focus on end customers, customization of tangible products, online elicitation of needs, and flexible on-demand production, the companies in the sample come close to the visionary “anything-at-any-time” definition of mass customization articulated by Davis (1987). To the best of our knowledge, this study represents one of the first large-scale empirical investigations of a relevant sample of pure-play mass customizers to determine how organizational elements, independently and complementarily, may or may not enhance an organization’s performance.
7.2 Managerial Implications
In addition, this study has important managerial implications. Due to the sample characteristics, however, it is imperative that any concrete recommendations we provide differentiate between pure-play mass customizers and traditional mass producers embarking on mass customization. Our goal was to establish a model of the requisite capabilities for implementing a profitable and sustainable mass customization strategy focusing exclusively on B2C relations. We therefore mainly surveyed innovative start-ups and SMEs that built their mass customization business model from the ground up to determine what distinguishes successful mass customizers from less successful ones. As a result, our findings have only limited significance for traditional mass producers and B2B mass customizers.

The most important finding of this study is that firms pursuing mass customization as their core business must have all three capabilities in place to achieve an above-average performance relative to their competitors. The present data clearly show that performance effects are contingent on the complementarity of the three strategic capabilities for mass customization. While the capabilities are distinct, they are also interdependent and mutually reinforcing. Thus, improving one capability may not result in a positive effect independent of the other capabilities. For example, if a firm has continuously invested in the robustness of its process design but restricts its solution space to a limited number of customization options, it might fail to fully exploit the potential of its flexible production technologies. Likewise, if a firm has thoroughly defined its solution space, but offers its customers poor choice navigation, they might postpone their buying decisions or reallocate their budget to a competitor. Lastly, if the choice navigation system effectively guides customers in finding a product that perfectly matches their needs, but fulfilling these differentiated needs significantly impairs the firm’s operational processes, resulting in poor quality, long delivery times, or high price premiums, this will likely have a negative impact on customer satisfaction.

The lack of significance of the individual direct effects on company performance suggests that the likelihood of compensating for limitations in one capability by excelling at the other capabilities is low. We therefore advise managers not to place too much emphasis on any single particular capability, and rather encourage them to balance the development of the three capabilities in such a way that they achieve a whole that is greater than the sum of its parts (Makadok 2003). This notion is especially important given the findings of previous studies
that an excessive focus on a particular good activity will likely have negative consequences by creating an imbalance within the system as a whole (e.g., Barnett and Freeman 2001; Lane et al. 2006).

However, firms should not become mired in the complexity of developing the three mass customization capabilities simultaneously. Experience shows that developing dynamic capabilities ties up substantial management attention and resources (Helfat et al. 2007). This presents a special challenge for the many privately funded start-ups in the field of mass customization that have very limited financial and human resources. As stated above, 53.9% of the firms in our sample have fewer than five employees. Moreover, mass customization capabilities are often a combination of specific methods, tools, and routines, some of which may be a necessary prerequisite for others and must therefore be developed first. Brown and Eisenhardt (1997) termed this property “sequenced steps.” Therefore, we recommend that mass customization firms adopt a sequential approach to capability development.

In the structural model, solution space development shows the strongest factor loadings, which emphasizes the importance of this capability for the successful management of mass customization. Companies devising a new mass customization business must first understand the idiosyncratic needs of their customers. Once these are understood, the companies can define their solution space and clearly decide where they want to give customers a choice—and where they do not. The tricky task is to identify the few customization dimensions that will yield the most value for customers—and ultimately for the firm. The empirical results indicate that conventional market research techniques and opportunity recognition heuristics are particularly helpful in determining the initial solution space.

Next, mass customization firms must develop adequate interaction systems that help customers navigate their solution space. In this work, we presented a set of basic and advanced features related to the information presentation format, preference elicitation, pricing, and visualization, with which managers can build the configurator solution that best suits their specific business model. While we do not find any significant relationships between single system features and choice navigation capability, we believe that it is the unique combination of these features that facilitates effective choice navigation in practice and helps firms to achieve differentiation in the eyes of their customers. However, we advise entrepreneurs not to
invest too many resources in designing the configurator before launching their business and instead recommend that they start with a basic solution. Quite interestingly, customers do not always seem to appreciate advanced 3D visualization—apparently, there can also be too much of a good thing (Walcher and Piller 2011). The perceived usability of a configurator is instead driven by basic features such as a help function, a progress bar, or the possibility to save a configuration and continue working on it later. Getting these basics right should be the first goal for mass customization start-ups.

By improving choice navigation, mass customization firms considerably increase their sales capacity, because a larger number of customers will be more likely to find a product configuration that perfectly matches their needs within the predefined solution space. This should ideally result in higher sales conversion rates. However, selling more can easily become selling out if the installed production capacity cannot keep up with the growing demand. To ensure the required levels of volume and mix flexibility, mass customization firms must invest in the robustness of their process designs. One of the main enablers of any mass customization strategy is modularity, because it allows companies to gain scale. In our study, both product and process modularity are positively related to robust process design capability. Human resource flexibility was established as another key success factor of a mass customization system, because even the most flexible technologies have trouble adapting quickly enough to ever changing customer needs.

Once firms have a stable mass customization system up and running, they can start gradually improving their capabilities. For this purpose, information generated during the customization co-design process should be fed back into the mass customizer’s strategy. It would be a mistake to view a configurator as a tool merely for sales. For instance, data on past configurations can be used to eliminate from the solution space customization options that are rarely viewed or selected by customers, to add more variants for popular modules, or to revise pricing and delivery policies. In our study, we were able to demonstrate that revising the solution space at regular intervals is positively related to solution space development capability. Data on customers’ past purchases and behaviors can also be utilized to improve production planning and sourcing and plan future production capacity expansions. As the mass customization business matures, concepts like total quality management (TQM) and continual improvement processes (CIP) may help firms to further enhance the robustness of their
process designs and increase customer satisfaction. And lastly, the configuration toolkit itself should also be continuously improved based on industry benchmarks, analyses of past configurations, and customer feedback. As part of new releases, firms might contemplate adding more advanced system features, such as needs-based configuration, to their configuration toolkit; although the effectiveness of needs-based configuration has been proven empirically, only 1.8% of the firms in our sample have adopted this approach. This would therefore appear to be a good opportunity for differentiation, especially in popular product categories such as customized apparel or food, where competition has greatly intensified recently.

The empirical results clearly indicate that, if mass customization business ventures are to be successful, they must learn or acquire all three strategic capabilities. Therefore, to evaluate their progress in implementing capabilities-based mass customization, firms should define key performance indicators (KPIs) for each capability and regularly benchmark them against best practices from their own or other industries. This will allow them to identify the strengths and weaknesses of their current mass customization system and allocate their limited resources more efficiently. The scales and measures used in this study may provide a good starting point for developing meaningful KPIs. What is important is that the management has a clear vision of the desired performance level of the mass customization system and a strategic roadmap for how to achieve this goal.

However, instead of developing the capabilities fully autonomously, start-ups can also leverage the best practices and technical foundations of mass customization platforms such as Zazzle, Shapeways, or Fluid to fill gaps in their capabilities configuration. For example, if a company has properly defined its solution space and developed a good configuration toolkit, but still lacks flexible production capacity, it might draw on Shapeways’ 3D printing services to manufacture its custom products. For companies that wish to avoid the effort of building a custom configuration toolkit, Fluid Configure offers a sophisticated platform for managing online product customization, with direct integration in e-commerce and manufacturing systems. Going even further, Zazzle’s platform covers the entire mass customization value chain—their proprietary technology enables individuals to design, visualize, manufacture on demand, and distribute unique products to customers worldwide with low investment costs.
Different recommendations apply for traditional mass producers that have an established and functioning business model. Many mass producers do not pursue mass customization for profit; its impact on company performance is therefore of secondary importance. They instead utilize mass customization as (1) a symbol to the industry to enhance their standing or brand, (2) a vehicle for learning, or (3) a vehicle for increasing operational efficiency (Spring and Dalrymple 2000; Moser 2007). To achieve these business goals, incremental improvement along one capability dimension is often sufficient. For example, Coca-Cola dramatically expanded its solution space by launching the Freestyle soda dispenser that lets customers create their own personal mix from 125 drink choices.20 This savvy move drew extensive media attention and gave Coca-Cola an edge over its competitor PepsiCo. McDonald's already had very modular products and flexible processes; all it needed to start a truly interactive process with its customers was a customer interface. Hence, it created an online burger configurator allowing customers to create their very own burger from a huge variety of ingredients.21 Other customers then voted on the creations, and the best were introduced in restaurants all over Germany. McDonald's thus gained a wealth of information about its customers' preferences, which it applied in its new product development efforts. Other mass producers like IKEA, Deutsche Telekom, APC, or Schmitz Cargobull employ various elements of a robust process design to be better prepared to deal with production peaks, temporary breakdowns, and unpredicted swings in customer demand (Moser 2007). As demonstrated by the examples above, developing strategic mass customization capabilities can be an effective means for mass producers to better align with their customers’ needs and set them apart from their competitors (Salvador et al. 2009).

In summary, a complementary set of mass customization capabilities provides unique value to both pure-play mass customizers and traditional mass producers because it is difficult to disentangle from a purely outside perspective and therefore hard to imitate (Porter 1996)—and even if competitors successfully detect the complementarities, they will have difficulties replicating them. Due to the complementarities, an unsuccessful implementation in one dimension will negatively affect the implementation of other dimensions, leading to the failure of the entire imitation effort (Milgrom and Roberts 1995). This implies that a firm embarking on mass customization should not blindly copy the business models of successful mass

21 See www.mcdonalds.de/meinburger.
customizers. Instead, it should define its own specific mass customization strategy based on idiosyncratic customer requirements, the competitive intensity in the industry, and the available technology (Salvador et al. 2009).

However, we find little support for the proposition that environmental contingencies have an effect on the nature and strength of the capabilities-performance relationship. As noted previously, mass customization should no longer be regarded merely as a business model or a competitive strategy—it is first and foremost an effective approach to achieve customer centricity by deploying the three strategic capabilities (Piller 2005a; Salvador et al. 2009). However, this raises an even more fundamental question: Why should a customer-centric business necessarily be influenced by environmental contingencies? The concept of customer-centric businesses is to treat customers as individuals, develop products in accordance with individual customers’ preferences, and efficiently produce and distribute these offerings (Sheth et al. 2000; Tseng and Piller 2003). Instead of trying to influence customers in terms of what to buy and when to buy, customer-centric firms continuously adjust their capabilities, including product design, production, sales, and supply chain design, in response to customer demand. This makes them largely independent of current market conditions. Therefore, we postulate that customer-centric firms with high levels of mass customization capabilities are best positioned to achieve and sustain competitive advantage in any environmental situation.

Recently, increasing numbers of financial investors are discovering mass customization as an interesting business opportunity. CafePress, which allows its customers to configure a wide range of products and also employs a "marketplace" model where designers can offer their products for sale, successfully made its market debut in March 2012. This was the first-ever initial public offering (IPO) of a pure-play mass customizer that built its business model from the ground up and reached profitable scale operations, with revenues of $175M in 2011.22 Innovative mass customization business models also enjoy great popularity on crowdfunding platforms. For example, kickstarter.com raised over $10M to develop a customizable watch that connects to the iPhone and Android smartphones.23 We believe that the capabilities framework provides a useful tool for investors to assess the competitiveness and sustainability

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7 Discussion of Results

of a mass customization business model beyond the market prospects. This is especially important because good ideas for custom products are often copied quickly and the entry barrier for many products is rather low (Walcher and Piller 2011). Only firms that have developed all three capabilities are likely to benefit from mass customization and resist imitation in the long run. On the other hand, investors may also consider the opportunity to cherry-pick undervalued companies that score high on most capabilities, but have a deficiency along one capability dimension. By systematically developing this capability, they can build a profitable business with attractive exit options.

7.3 Limitations and Directions for Future Research

Before we conclude, we would like to point out some limitations of this study and offer them as interesting avenues for future research. First, it is important to recognize that a single study cannot provide valid measures in the true spirit of instrument development (Zhang et al. 2003). Future studies should collect additional data to confirm both the strategic capabilities measures and the structural model results. This would provide further evidence for the validity and reliability of the instruments and would accelerate the diffusion of standard instruments for measuring mass customization capabilities among the academic community.

The second concern is the generalizability of the study, which may be limited due to the sample characteristics. The sample consists mainly of innovative SMEs employing business models predicated completely on mass customization. Therefore, the results may not be directly transferable to traditional mass producers moving into customization, who are accustomed to operating in accordance with traditional management concepts. Accordingly, we encourage future studies to investigate traditional mass producers’ managerial challenges in developing the three strategic capabilities. Moreover, all of the mass customizers in the study sell their custom products directly to end consumers, which means that the capabilities framework of Salvador et al. (2009) is relevant for business-to-consumer (B2C) relations. This does not mean that the capabilities framework is not applicable to business-to-business (B2B) relations. A study that focuses on B2B relationships could therefore be useful. For instance, we would expect to find a higher degree of flexible automation and more technically oriented configuration toolkits among B2B mass customizers.
Third, we relied solely on subjective performance measures related to market growth and customer success. Yet company performance is a multidimensional construct and can be characterized in a number of ways; the impact of the mass customization capabilities on other performance measures could potentially be different from what we determined in this study. Furthermore, performance in one dimension may run counter to performance in another dimension. Therefore, it would be worthwhile to explore the impact on alternative performance dimensions in future studies, including widely used objective measures of firm performance such as return on sales (ROS) and return on investment (ROI).

Fourth, we obtained the measures of both predictor and criterion variables from a single key informant; while this is currently the standard approach in empirical research, it is associated with common method bias. We therefore followed the recommendation of Podsakoff et al. (2003) and controlled for common method variance in the structural model. We were able to demonstrate that the overall pattern of significant relationships is not affected by common method variance. Nevertheless, future studies might use multiple data sources to limit common method variance ex ante.

Fifth, we did not examine how firms coordinate the three mass customization capabilities to achieve complementarities. Which organizational structures and processes can be designed to leverage a complementary set of capabilities? Do certain characteristics of entrepreneurs and employees (e.g., personality, attitudes) help or hinder the development of strategic mass customization capabilities? Further work on such central questions may allow us to better understand how organizations should be designed to capture value from capabilities-based synergies.

Sixth, we did not take into account the cost of capability development (or acquisition) and utilization. Achieving a capability involves integrating tangible assets, knowledge, and skills, which makes it difficult to possess a capability without incurring some costs (Helfat et al. 2007, p. 11). For example, a robust process design capability utilizes shop floor employees, engineers, and their knowledge, as well as physical assets such as flexible manufacturing and design technologies. This means that capability performance has two dimensions: quality and cost; that is, how well the capability performs its intended function and how much it costs to perform at a certain level (Helfat et al. 2007, p. 7). Thus, future studies may address the costs
of capability development and examine potentially declining marginal returns to the three strategic capabilities for mass customization.

Seventh, the strategic capabilities were analyzed only from a vendor’s point of view; they were not examined from an external perspective. However, Zhang (2003, p. 187) emphasizes that customers do not value the capabilities directly. They are unwilling to pay more because a firm scores high on the respective capability dimensions. Customers rather value the manifestation of these capabilities, which is the ability of a firm to supply a high variety of products in good quality, at a reasonable cost, and at the right time. It would therefore be insightful to apply a dyadic research design and contrast the self-assessments of the firms in the sample with customer evaluations of the manifestations of the three capabilities.

Eighth, we did not look for groups or subtypes of cases in the data. However, Moser (2007) states that companies have very different motives for pursuing mass customization (e.g., profit taker, market entry vehicle, entry barrier), which presumably correspond to different capability configurations. Similarly, Salvador et al. (2009, p. 77) assume that not all mass customizers achieve their capabilities with the same approaches. They suggest instead that companies should define their mass customization strategy depending on the requirements of their customer base, the competitive intensity in the industry, and the available technology. Thus, it could be worthwhile to apply some kind of clustering technique (e.g., latent class cluster analysis) to the data to search for patterns of conditional probabilities. These techniques mostly require larger sample sizes than those available for this study.

Finally, this study employs a cross-sectional analysis of a large number of mass customization firms. While this provides important insights into the determinants of a mass customization capability, it does not allow any conclusions about the sustainability of the capability configuration. This is particularly true given the fact that the majority of companies (84.3%) in the sample are younger than five years. An important step for further research is thus the collection and analysis of longitudinal data. The cross-sectional design also fails to shed much light on the change process involved in developing and improving mass customization capabilities. For example, a relatively low level of robust process design capability may in fact lead managers to alter certain antecedents such as process architectures, manufacturing technologies, or qualification of the workforce, which in turn may increase the level of robust
process design capability. In this regard, it would be useful to conduct in-depth studies of a few organizations so as to better understand the factors that drive the change efforts directed at improving the mass customization capabilities of a business.

Despite these limitations, our study provides researchers and managers with clear guidance for achieving strategic differentiation and long-term competitive advantages through mass customization.

7.4 Conclusion and Outlook

“Capability means imagination, the one quality needed to combine specialized knowledge with ideas, in the form of organized plans designed to yield riches”

(Hill 1938, p. 125).

Contrary to Kotler’s (1989) famous prediction, the mass market is not dead yet. Implementing a profitable and scalable mass customization strategy has turned out to be more difficult than originally assumed. Only recently have we seen a larger number of applications in business. This positive trend is driven primarily by increased demand for custom products and improved capability to manage mass customization. On the demand side, the inherent reluctance of customers to adopt custom products is fading, as they are becoming more acclimated to a marketplace where they can get whatever they want, whenever they want it. Companies like Facebook, Twitter, iTunes, and Pandora’s Internet radio increasingly enable customers to tailor the information they see or hear; from there, it is only a small step to tailored physical goods. The Millennial Generation (or Generation Y) in particular, which grew up with e-commerce, social media, and an abundance of choices in many areas of life, strives for more individuality—and it has the necessary disposable income now to purchase custom products online. However, the Millennial Generation has emerged not only as an important customer group, but increasingly also as the founders of mass customization firms—developing innovative business models based on their own unsatisfied needs, their deep domain expertise, and the newest customer-facing technologies. On the capability side, two decades of intense academic research have produced a better understanding of what essential capabilities a mass customization firm should develop to translate customers’ heterogeneous needs into
opportunities to create value. The presented empirical results add to this body of accumulated work by highlighting the importance of complementarities among the capabilities.

Some prominent business failures over the years have prompted claims that mass customization is not scalable. We, however, reject these claims: We believe that companies that can match their product offerings to the true shape of the demand curve—that is, a curve that incorporates both “hits” at the head as well as “niches” in the tail—will be best positioned to grow and prosper in the 21st-century economy. Therefore, combining standard and custom offerings in one business model should result in superior competitiveness and profitability. In fact, a standard product is simply a specific configuration in a firm’s predefined solution space. Already today many traditional mass producers successfully provide customized products to a premium segment of customers, together with standard product lines—while many pure-play mass customizers offer popular standard variants to attract those customers who are unwilling to engage in tedious configuration activities. This shows that the boundaries between mass production and mass customization are beginning to blur. The only limit here is imagination, the one quality needed to capture new markets and customer groups.
8 Appendix

8.1 Appendix to Chapter 3

Appendix 8.1.1: Search terms for literature review (Moser 2007)

<table>
<thead>
<tr>
<th>Search terms</th>
<th>Mass customization</th>
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<th>or</th>
<th>or</th>
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<th>or</th>
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<tr>
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<td>Mass customisation</td>
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<tr>
<td>and</td>
<td>Competence/-ies</td>
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<td></td>
<td>Dominant competence/-ies</td>
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<tr>
<td></td>
<td>Capability/-ies</td>
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<tr>
<td></td>
<td>Core capability/-ies</td>
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<td></td>
<td>Resource(s)</td>
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<td></td>
<td>Factor(s)</td>
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<td></td>
<td>Success Factors</td>
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</tbody>
</table>
## 8.2 Appendix to Chapter 5

### Appendix 8.2.1: Measurement scales for strategic mass customization capabilities and market performance

<table>
<thead>
<tr>
<th>Construct:</th>
<th>Solution Space Development (SSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification:</td>
<td>Reflective</td>
</tr>
<tr>
<td>Source:</td>
<td>Newly developed</td>
</tr>
</tbody>
</table>

**Items:**

Please rate the following statements with regard to your ability to develop the product assortment and customization options.

- **SSD1** We constantly monitor changes in our customers' needs and preferences for variety.
- **SSD2** We are able to determine exactly how much variety is requested by our customers.
- **SSD3** We are able to identify along which product attributes customers' preferences differ the most.
- **SSD4** We continuously adapt the product variety offered to changing customer requirements.
- **SSD5** We have developed routines to determine the optimal amount of product variety we offer.

<table>
<thead>
<tr>
<th>Construct:</th>
<th>Robust Process Design (RPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification:</td>
<td>Reflective</td>
</tr>
<tr>
<td>Source:</td>
<td>Adapted from Zhang et al. (2003)</td>
</tr>
</tbody>
</table>

**Items:**

Please rate the following statements with regard to your ability to quickly adapt your resources and processes to changing customer requirements.

- **RPD1** We can operate efficiently at different levels of output.
- **RPD2** We can operate profitably at different production volumes.
- **RPD3** We can produce different products in the same plant at the same time.
- **RPD4** We can quickly change the quantities of our products produced.
- **RPD5** We can change over quickly from one product to another.
### Construct: Choice Navigation (CN)
**Specification:** Reflective  
**Source:** Newly developed

<table>
<thead>
<tr>
<th>Items:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please rate the following statements with regard to your ability to</td>
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<tr>
<td>interact with customers.</td>
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<tr>
<td>CN1 We are able to effectively navigate our customers through the</td>
</tr>
<tr>
<td>customization process.</td>
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<td>CN2 We provide customers with realistic visualizations of their</td>
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<td>product configurations.</td>
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<td>CN3 We allow customers to conveniently compose products to their</td>
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<tr>
<td>specific needs.</td>
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<tr>
<td>CN4 We enable our customers to find the optimal product configuration</td>
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<tr>
<td>without confusing them.</td>
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<tr>
<td>CN5 We provide guidance and support to our customers throughout the</td>
</tr>
<tr>
<td>entire product configuration process.</td>
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</tbody>
</table>

### Construct: Mass Customization Capability (MCC)
**Specification:** Reflective  
**Source:** Adapted from Tu et al. (2001)

<table>
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<tr>
<th>Items:</th>
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<tbody>
<tr>
<td>Please rate the following statements with regard to your overall</td>
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<tr>
<td>mass customization capability.</td>
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<tr>
<td>MCC1 We can customize products efficiently without sacrificing</td>
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<tr>
<td>quality.</td>
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<tr>
<td>MCC2 We are highly capable of large-scale product customization.</td>
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<td>MCC3 We can effectively respond to customization requirements of</td>
</tr>
<tr>
<td>our customers.</td>
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<td>MCC4 We can customize products efficiently without sacrificing</td>
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<td>volume.</td>
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<tr>
<td>MCC5 We are highly capable of managing product customization</td>
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<td>without increasing cost.</td>
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</tbody>
</table>

### Construct: Market Performance (MP)
**Specification:** Reflective  
**Source:** Adapted from Homburg and Pflesser (2000)

<table>
<thead>
<tr>
<th>Items:</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you rate your market performance relative to your main</td>
</tr>
<tr>
<td>competitors?</td>
</tr>
<tr>
<td>MP1 Attracting new customers</td>
</tr>
<tr>
<td>MP2 Achieving customer satisfaction</td>
</tr>
<tr>
<td>MP3 Keeping current customers</td>
</tr>
<tr>
<td>MP4 Providing value for customers</td>
</tr>
<tr>
<td>MP5 Attaining desired growth of customer base</td>
</tr>
<tr>
<td>MP6 Securing market share</td>
</tr>
<tr>
<td>MP7 Achieving sales growth</td>
</tr>
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</table>
Appendix 8.2.2: Inter-rater reliability (Fleiss 1971)

<table>
<thead>
<tr>
<th>Items</th>
<th>Constructs</th>
<th>SSD</th>
<th>RPD</th>
<th>CN</th>
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<td>1</td>
<td>1</td>
<td>8</td>
<td>0.622</td>
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<tr>
<td>2</td>
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<td>10</td>
<td>0</td>
<td>0</td>
<td>1.000</td>
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<tr>
<td>3</td>
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<td>0</td>
<td>1</td>
<td>1.000</td>
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<tr>
<td>4</td>
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<td>1</td>
<td></td>
<td>0.800</td>
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<tr>
<td>6</td>
<td>0</td>
<td>10</td>
<td>0</td>
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<td>42</td>
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<tr>
<td>P&lt;sub&gt;c&lt;/sub&gt;</td>
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<td>0.280</td>
<td>0.420</td>
<td>0.300</td>
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</tbody>
</table>

**Results**

- P<sub>c</sub> = 0.345  Degree of agreement expected by chance
- P<sub>c</sub> = 0.756  Actual degree of agreement
- κ = 0.627  Fleiss' Kappa

**κ Interpretation (Landis and Koch 1977)**

- < 0  Poor agreement
- 0.01 – 0.20  Slight agreement
- 0.21 – 0.40  Fair agreement
- 0.41 – 0.60  Moderate agreement
- 0.61 – 0.80  Substantial agreement
- 0.81 – 1.00  Almost perfect agreement
Appendix 8.2.3: Measurement scales for antecedents and contingency factors

**Construct:** Product Modularity (PDM)  
**Specification:** Reflective  
**Source:** Adapted from Tu et al. (2004)

**Items:**
To what extent are your products modular?
- **PDM1** Our products use modularized design.
- **PDM2** Our products share common modules.
- **PDM3** Our product features are designed around a standard base unit.
- **PDM4** Product modules can be rearranged by end-users to suit their needs (adaptable products)

**Construct:** Process Modularity (PCM)  
**Specification:** Reflective  
**Source:** Adapted from Tu et al. (2004)

**Items:**
To what extent are your production processes modular?
- **PCM1** Our value chain is designed as re-combinable process modules.
- **PCM2** Our value chain can be adjusted by adding new process modules.
- **PCM3** Our process modules can be adjusted for changing customer needs.
- **PCM4** Our value chain can be broken down into standard sub-processes that produce standard base units and customization sub-processes that further customize the base units.
- **PCM5** Process modules can be rearranged so that customization sub-processes occur last.

**Construct:** Flexible Automation (FA)  
**Specification:** Reflective  
**Source:** Adapted from Koste et al. (2004)

**Items:**
Please indicate to which extent you agree with the following statements.
- **FA1** We rely on highly automated machinery capable of manufacturing a broad variety of products.
- **FA2** We rely on highly automated machinery capable of manufacturing a very diverse variety of products.
- **FA3** We rely on highly automated machinery that have minimal setup costs.
- **FA4** We rely on highly automated machinery that perform consistently—no matter what specific product variant they are manufacturing.
**Construct:** Skills Flexibility (SF)  
**Specification:** Reflective  
**Source:** Adapted from Bhattacharya et al. (2005)  
**Items:**  
How flexible is your workforce with regard to its skills?  
SF1 Our employees can switch to new jobs in our company within a short time.  
SF2 Our firm is capable of meeting demand for new skills by retraining or shifting its existing employees.  
SF3 Many employees in our firm have multiple skills that are used in various jobs.  
SF4 People in our firm can learn new skills within a short period.

**Construct:** Environmental Contingencies  
**Specification:** Reflective  
**Source:** Adapted from Jaworski and Kohli (1993)  
**Items:**  
Please rate to which extent your business is subject to:  
Market turbulence  
MT1 In our kind of business, customers' product preferences change quite a bit over time.  
MT2 Our customers tend to look for new products all the time.  
MT3 We are witnessing demand for our products and services from customers who never bought them before.  
Competitive intensity  
CI1 Competition in our industry is cutthroat.  
CI2 Anything that one competitor can offer, others can match readily.  
CI3 Price competition is a hallmark of our industry.  
Technological turbulence  
TT1 The technology in our industry is changing rapidly.  
TT2 Technological changes provide big opportunities in our industry.  
TT3 A large number of new product ideas have been made possible through technological breakthroughs in our industry.
Appendix 8.2.4: Construct-level factor analysis results for SSD, RPD and CN

<table>
<thead>
<tr>
<th>Items</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>SSD3</td>
<td>.851</td>
</tr>
<tr>
<td>SSD2</td>
<td>.791</td>
</tr>
<tr>
<td>SSD4</td>
<td>.759</td>
</tr>
<tr>
<td>SSD5</td>
<td>.737</td>
</tr>
<tr>
<td>SSD1</td>
<td>.602</td>
</tr>
<tr>
<td>RPD3</td>
<td>.775</td>
</tr>
<tr>
<td>RPD2</td>
<td>.760</td>
</tr>
<tr>
<td>RPD4</td>
<td>.715</td>
</tr>
<tr>
<td>RPD1</td>
<td>.705</td>
</tr>
<tr>
<td>RPD5</td>
<td>.575</td>
</tr>
<tr>
<td>CN3</td>
<td>.724</td>
</tr>
<tr>
<td>CN1</td>
<td>.674</td>
</tr>
<tr>
<td>CN4</td>
<td>.656</td>
</tr>
<tr>
<td>CN2</td>
<td>.775</td>
</tr>
<tr>
<td>CN5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.776</td>
</tr>
</tbody>
</table>

Notes: Main component extraction and varimax rotation with Kaiser normalization; loadings below .4 are not shown.

<sup>a</sup>Item was deleted in further analysis

Appendix 8.2.5: Unidimensionality assessment of direct mass customization capability construct (MCC)

<table>
<thead>
<tr>
<th>Items</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>MCC3</td>
<td>.753</td>
</tr>
<tr>
<td>MCC5</td>
<td>.750</td>
</tr>
<tr>
<td>MCC4</td>
<td>.704</td>
</tr>
<tr>
<td>MCC1</td>
<td>.699</td>
</tr>
<tr>
<td>MCC2</td>
<td>.630</td>
</tr>
</tbody>
</table>

Notes: Main component extraction and varimax rotation with Kaiser normalization; loadings below .4 are not shown.
Appendix 8.2.6: Unidimensionality assessment of market performance construct (MP)

<table>
<thead>
<tr>
<th>Items</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>MP2</td>
<td>.840</td>
</tr>
<tr>
<td>MP3</td>
<td>.754</td>
</tr>
<tr>
<td>MP4</td>
<td>.733</td>
</tr>
<tr>
<td>MP1</td>
<td></td>
</tr>
<tr>
<td>MP5</td>
<td></td>
</tr>
<tr>
<td>MP6</td>
<td></td>
</tr>
<tr>
<td>MP7</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Main component extraction and varimax rotation with Kaiser normalization; loadings below .4 are not shown.

Appendix 8.2.7: Reliability and exploratory factor analysis

**Construct: Solution Space Development (SSD); Cronbach’s α = 0.816; AVE = 0.584**

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD1</td>
<td>We constantly monitor changes in our customers' needs and preferences for variety.</td>
</tr>
<tr>
<td>SSD2</td>
<td>We are able to determine exactly how much variety is requested by our customers.</td>
</tr>
<tr>
<td>SSD3</td>
<td>We are able to identify along which product attributes customers' preferences differ the most.</td>
</tr>
<tr>
<td>SSD4</td>
<td>We continuously adapt the product variety offered to changing customer requirements.</td>
</tr>
<tr>
<td>SSD5</td>
<td>We have developed routines to determine the optimal amount of product variety we offer.</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

**Construct: Robust Process Design (RPD); Cronbach’s α = 0.758; AVE = 0.521**

<table>
<thead>
<tr>
<th>Items</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPD1</td>
<td>We can operate efficiently at different levels of output.</td>
</tr>
<tr>
<td>RPD2</td>
<td>We can operate profitably at different production volumes.</td>
</tr>
<tr>
<td>RPD3</td>
<td>We can produce different products in the same plant at the same time.</td>
</tr>
<tr>
<td>RPD4</td>
<td>We can quickly change the quantities of our products produced.</td>
</tr>
<tr>
<td>RPD5</td>
<td>We can change over quickly from one product to another.</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”
### Construct: Choice Navigation (CN); Cronbach’s $\alpha = 0.702$; AVE = 0.629

<table>
<thead>
<tr>
<th>Items</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN1</td>
<td>We are able to effectively navigate our customers through the customization process. 0.519</td>
</tr>
<tr>
<td>CN2$^{a}$</td>
<td>We provide customers with realistic visualizations of their product configurations. 0.383</td>
</tr>
<tr>
<td>CN3</td>
<td>We allow customers to conveniently compose products to their specific needs. 0.511</td>
</tr>
<tr>
<td>CN4</td>
<td>We enable our customers to find the optimal product configuration without confusing them. 0.524</td>
</tr>
<tr>
<td>CN5$^{a}$</td>
<td>We provide guidance and support to our customers throughout the entire product configuration process. --</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

$^a$ Item was deleted in further analysis.

### Construct: Mass Customization Capability (MCC); Cronbach’s $\alpha = 0.730$, AVE = 0.502

<table>
<thead>
<tr>
<th>Items</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCC1</td>
<td>We can customize products efficiently without sacrificing quality. 0.511</td>
</tr>
<tr>
<td>MCC2</td>
<td>We are highly capable of large-scale product customization. 0.427</td>
</tr>
<tr>
<td>MCC3</td>
<td>We can effectively respond to customization requirements of our customers. 0.546</td>
</tr>
<tr>
<td>MCC4</td>
<td>We can customize products efficiently without sacrificing volume. 0.502</td>
</tr>
<tr>
<td>MCC5</td>
<td>We are highly capable of managing product customization without increasing cost. 0.561</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

### Construct: Customer Success (CS); Cronbach’s $\alpha = 0.667$; AVE = 0.616

<table>
<thead>
<tr>
<th>Items</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS1</td>
<td>Achieving customer satisfaction 0.542</td>
</tr>
<tr>
<td>CS2</td>
<td>Keeping current customers 0.494</td>
</tr>
<tr>
<td>CS3</td>
<td>Providing value for customers 0.462</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “much worse relative to main competitors – much better relative to main competitors”

### Construct: Market Growth (MG); Cronbach’s $\alpha = 0.839$; AVE = 0.685

<table>
<thead>
<tr>
<th>Items</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MG1</td>
<td>Attracting new customers 0.760</td>
</tr>
<tr>
<td>MG2</td>
<td>Attaining desired growth of customer base 0.737</td>
</tr>
<tr>
<td>MG3</td>
<td>Securing market share 0.589</td>
</tr>
<tr>
<td>MG4</td>
<td>Achieving sales growth 0.627</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “much worse relative to main competitors – much better relative to main competitors”
## Construct: Product Modularity (PDM); Cronbach’s α = 0.742; AVE = 0.797

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDM1: Our products use modularized design.</td>
<td>0.512</td>
</tr>
<tr>
<td>PDM2: Our products share common modules.</td>
<td>0.561</td>
</tr>
<tr>
<td>PDM3(^a): Our product features are designed around a standard base unit.</td>
<td>0.395</td>
</tr>
<tr>
<td>PDM4(^a): Product modules can be rearranged by end-users to suit their needs (adaptable products)</td>
<td>0.277</td>
</tr>
</tbody>
</table>

\(^a\)Item was deleted in further analysis

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

## Construct: Process Modularity (PCM); Cronbach’s α = 0.825; AVE = 0.667

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCM1: Our value chain is designed as recombinable process modules.</td>
<td>0.654</td>
</tr>
<tr>
<td>PCM2: Our value chain can be adjusted by adding new process modules.</td>
<td>0.742</td>
</tr>
<tr>
<td>PCM3: Our process modules can be adjusted for changing customer needs.</td>
<td>0.632</td>
</tr>
<tr>
<td>PCM4: Our value chain can be broken down into standard sub-processes that produce standard base units and customization sub-processes that further customize the base units.</td>
<td>0.592</td>
</tr>
<tr>
<td>PCM5(^a): Process modules can be rearranged so that customization sub-processes occur last.</td>
<td>0.479</td>
</tr>
</tbody>
</table>

\(^a\)Item was deleted in further analysis

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

## Construct: Flexible Automation (FA); Cronbach’s α = 0.936; AVE = 0.834

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA1: We rely on highly automated machinery capable of manufacturing a broad variety of products.</td>
<td>0.869</td>
</tr>
<tr>
<td>FA2: We rely on highly automated machinery capable of manufacturing a very diverse variety of products.</td>
<td>0.875</td>
</tr>
<tr>
<td>FA3: We rely on highly automated machinery that have minimal setup costs.</td>
<td>0.826</td>
</tr>
<tr>
<td>FA4: We rely on highly automated machinery that perform consistently—no matter what specific product variant they are manufacturing.</td>
<td>0.831</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”
### Construct: Skills Flexibility (SF); Cronbach’s α = 0.873; AVE = 0.730

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF1</td>
<td>Our employees can switch to new jobs in our company within a short time. 0.722</td>
</tr>
<tr>
<td>SF2</td>
<td>Our firm is capable of meeting demand for new skills by retraining or shifting its existing employees. 0.760</td>
</tr>
<tr>
<td>SF3</td>
<td>Many employees in our firm have multiple skills that are used in various jobs. 0.714</td>
</tr>
<tr>
<td>SF4</td>
<td>People in our firm can learn new skills within a short period. 0.738</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

### Construct: Market Turbulence (MT); Cronbach’s α = 0.660; AVE = 0.747

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT1</td>
<td>In our kind of business, customers' product preferences change quite a bit over time. 0.445</td>
</tr>
<tr>
<td>MT2</td>
<td>Our customers tend to look for new products all the time. 0.562</td>
</tr>
<tr>
<td>MT3</td>
<td>We are witnessing demand for our products and services from customers who never bought them before. 0.369</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

*Item was deleted in further analysis.

### Construct: Technological Turbulence (TT); Cronbach’s α = 0.914; AVE = 0.853

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT1</td>
<td>The technology in our industry is changing rapidly. 0.801</td>
</tr>
<tr>
<td>TT2</td>
<td>Technological changes provide big opportunities in our industry. 0.876</td>
</tr>
<tr>
<td>TT3</td>
<td>A large number of new product ideas have been made possible through technological breakthroughs in our industry. 0.805</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

### Construct: Competitive Intensity (CI); Cronbach’s α = 0.724; AVE = 0.784

<table>
<thead>
<tr>
<th>Items*</th>
<th>Item-to-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI1</td>
<td>The technology in our industry is changing rapidly. 0.550</td>
</tr>
<tr>
<td>CI2</td>
<td>Technological changes provide big opportunities in our industry. 0.419</td>
</tr>
<tr>
<td>CI3</td>
<td>A large number of new product ideas have been made possible through technological breakthroughs in our industry. 0.585</td>
</tr>
</tbody>
</table>

*All items were rated on 5-point Likert scale and anchored “strongly disagree – strongly agree”

*Item was deleted in further analysis.
## Appendix 8.2.8: Construct-level factor analysis for all eleven purified scales

<table>
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<th>Items</th>
<th>Components</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>FA2</td>
<td>.934</td>
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<tr>
<td>FA1</td>
<td>.928</td>
</tr>
<tr>
<td>FA3</td>
<td>.876</td>
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<tr>
<td>FA4</td>
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<td>SF1</td>
<td>.860</td>
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<td>.845</td>
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<td>SF4</td>
<td>.809</td>
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<td>PCM2</td>
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<td>PCM1</td>
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<td>PCM3</td>
<td>.792</td>
</tr>
<tr>
<td>PCM4</td>
<td>.586</td>
</tr>
<tr>
<td>SSD3</td>
<td>.830</td>
</tr>
<tr>
<td>SSD2</td>
<td>.797</td>
</tr>
<tr>
<td>SSD4</td>
<td>.762</td>
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<tr>
<td>SSD5</td>
<td>.674</td>
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<tr>
<td>MT2</td>
<td>.511</td>
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<td>MG1</td>
<td>.862</td>
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<td>MG2</td>
<td>.849</td>
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<tr>
<td>MG4</td>
<td>.749</td>
</tr>
<tr>
<td>MG3</td>
<td>.739</td>
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<tr>
<td>TT2</td>
<td>.929</td>
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<td>TT3</td>
<td>.893</td>
</tr>
<tr>
<td>TT1</td>
<td>.888</td>
</tr>
<tr>
<td>RPD1</td>
<td>.742</td>
</tr>
<tr>
<td>RPD2</td>
<td>.697</td>
</tr>
<tr>
<td>RPD3</td>
<td>.693</td>
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<td>MT1</td>
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</tr>
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<td>.804</td>
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<tr>
<td>CN4</td>
<td>.722</td>
</tr>
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<td>CS1</td>
<td>.848</td>
</tr>
<tr>
<td>CS3</td>
<td>.736</td>
</tr>
<tr>
<td>CS2</td>
<td>.642</td>
</tr>
<tr>
<td>CI1</td>
<td>.821</td>
</tr>
<tr>
<td>CI3</td>
<td>.820</td>
</tr>
<tr>
<td>PDM1</td>
<td></td>
</tr>
<tr>
<td>PDM2</td>
<td>.779</td>
</tr>
</tbody>
</table>

Notes: Main component extraction and varimax rotation with Kaiser normalization; loadings below .4 are not shown.
Appendix 8.2.9: Confirmatory factor analysis for SSD, RPD, CN, MG, CS, and MCC

### Construct: Solution Space Development (SSD)

<table>
<thead>
<tr>
<th>Item</th>
<th>Item reliability</th>
<th>Item loading (stand.)</th>
<th>t-value</th>
<th>Construct reliability</th>
<th>AVE</th>
<th>Fornell-Larcker ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.297</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSD2</td>
<td>0.579</td>
<td>0.755</td>
<td>--</td>
<td>0.82</td>
<td>0.53</td>
<td>0.25</td>
</tr>
<tr>
<td>SSD3</td>
<td>0.736</td>
<td>0.866</td>
<td>8.196***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSD4</td>
<td>0.413</td>
<td>0.634</td>
<td>6.403***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSD5</td>
<td>0.435</td>
<td>0.672</td>
<td>6.798***</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Item was deleted in further analysis.

*** p < .001

### Construct: Robust Process Design (RPD)

<table>
<thead>
<tr>
<th>Item</th>
<th>Item reliability</th>
<th>Item loading (stand.)</th>
<th>t-value</th>
<th>Construct reliability</th>
<th>AVE</th>
<th>Fornell-Larcker ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPD1</td>
<td>0.497</td>
<td>0.773</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPD2</td>
<td>0.549</td>
<td>0.742</td>
<td>5.983***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPD3</td>
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### Construct: Choice Navigation (CN)

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## Appendix 8.2.10: Mean, standard deviations, and correlations of all variables

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