

MASS CUSTOMIZATION

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WHAT IS MASS CUSTOMIZATION?

Mass customization can be defined as producing goods and services to meet individual customer's needs with near mass production efficiency [1]. This term was coined to parallel mass production that relied on producing large volumes of identical products like the Ford Model T line. The fundamental difference between mass production and mass customization is in the amount of product variety that is enabled by the process. Pine popularized this concept in the 1990s [2]. Over the years, it has been popular to claim that a firm provides high degree of variety in offerings, therefore the term *mass customization* has been overused.

Customization is everywhere—it is the degree of customization and the way it is offered that may be different. Automotive firms allow limited customization of individual cars through bundled options like air conditioning and leather are offered typically with an automatic transmission; Burger King offers “Have it your way” burgers that enable customers to selectively customize ingredients in their burgers; Dell computers and other electronics manufacturers successfully adapted customization to enable customers to pick and choose the key modules (such as memory, disk drive, chipset) that are associated with the computer; Sun Microsystems Java applets as well as the more popular Apple iPod and iPhones take this customization to the next level wherein the hardware is identical, but the software components (applets or iTunes files) are chosen by the customer according to their choice; the Build-A-Bear experience wherein the customer

cocreates the bear and clothing of choice is another example of customers actively involved in the customization process. There are three types of mass customization.

- *Cosmetic*. A popular approach is to customize aesthetic design of the product such as color, label, packaging, and so on. For example, M&M's (www.mymms.com) can be customized to have a personalized message, picture, and packaging. Cosmetic customization is especially popular in apparel and footwear. One example is Nike's custom-colored sneakers, which also allows the customer to imprint a name on the shoe. Nike's customization initiative is called NikeID. Customized sales accounted for 20% of the sneakers purchased from Nike.com in 2002 [3]. Another example is Zazzle offering shirts, shoes, hats, ties, and so on, with custom colors, embroidery, as well as imprinted images [4].
- *Physical Fit*. Customized physical fit can be achieved by individually customizing measurements of the product for each customer. Examples include mi adidas, Land's End, and Andersen Windows. In the mi adidas example, width, length, and insole of the shoe are customized based on the the 3D scan of the customer's foot [5]. Interestingly, an analysis of the order data shows that more than 40% of the orders are placed with different sizes for the right and left shoe [6]. Land's End, which sells custom shirts and pants, does not use 3D scanners; it asks customers to take their own measurements along with other questions about their body shape and then it relies on an algorithm fitting software developed by Archetype Solutions that finds the closest match in the extensive database of typical sizes [7]. Likewise, Andersen Windows can build a window to fit any size. Offering customized physical fit becomes more challenging

when it involves more spatial dimensions [8]. Note that customized physical fit in apparel and footwear usually requires customization along three dimensions. A number of companies either gave up their customization initiatives or went bankrupt. Examples include Levi's original spin initiative and Customatix [9], which went bankrupt selling customized sneakers.

- *Features.* Firms can also customize functional features of the product. These firms take advantage of the modular product architecture and allow customer to choose from many options for each module enabling vast number of choices for the end product. For example, Dell builds custom laptops where the customer gets to choose features like memory, hard drive capacity, CPU speed, and multimedia options. Similarly, carmakers let customer choose from various features, which can be added to the car on the basis of the customer's preferences.

Note that these three types of customization are not mutually exclusive.¹ A firm can customize its product in more than one way. For example, in addition to customized features Dell provides cosmetic customization by allowing personalized laptop covers with many different color and pattern options. Similarly, mi adidas also offers cosmetic customization allowing personalized colors and imprints on its sneakers in addition to customized physical fit. While many of the examples above are from the business to consumer segment, a large number of examples are available from the business to business segment as well. For example, Xilinx's field programmable gate arrays (FPGA) allowed customers to burn and change the circuit on the chip much later in the process. Similarly, Dell created customization in their sales process for individual business customers through customized web pages as well as staff (more examples in Ref. 13).

¹Also note that other taxonomies for mass customization are possible; for example, see Refs 10–12.

BENEFITS OF MASS CUSTOMIZATION

A firm's ability to offer mass customized products leads to a number of marketing and operational benefits.

Pricing Advantage

Mass customization creates value for customers by providing products that better match their individual preferences. This allows charging a price premium for custom products. For example, Nike is able to add 10–20% price premium for its customized sneakers that allows for custom colors and personalized imprint [3]. Adidas offers a higher degree of customization, it allows customized fit in addition to customized colors and imprinted names, and this in turn enables charging a higher 30–50% price premium [6]. In general, products that require matching physical dimensions often allow a higher price premium than products that customize just on design patterns. A customer survey on customized footwear shows that more than 50% of customers are willing to accept a price premium of 20–30% on average for custom shoes [14]. Furthermore, because mass customization allows a vast number of product versions, it enables implementing a finer price discrimination. For example, Time 121 (www.121time.com) produces custom-made Swiss watches with many modular customization options. It uses a modular pricing approach, pricing each component differently, which allows creating a product that matches more closely each customer's willingness to pay.

Mass customization also helps a firm avoid competing solely on the basis of price. Offering individually customized products enables a firm differentiate itself from its competition. A firm can offer unique attributes that cannot be directly compared to standard product alternatives (see Ref. 15 for a discussion of competition between firms following mass customization and mass production). In particular, mass customization can be a successful strategy against low-cost overseas manufacturers, as they have limited customization capabilities due to the distance from the market. Indeed, mass customization is recognized as a strategy followed by a

variety of domestic industries to fight the outsourcing of production to low-cost overseas manufacturers [16–18]. The US furniture industry is one example: US manufacturers are more successful against imports in market sectors where they offer more customization [19]. Other examples include the EU apparel industry [16] and footwear manufacturing in Finland [20].

Customer Loyalty

Customization is information intense in that a customer needs to communicate her preferences to the service provider. The firm gets into a learning relationship [21] with its customers, which increases the revenue from each customer through repeat purchases and related sales. Mass customization helps establish stronger relations with customers and gain customer loyalty. For example, when ordering a custom shirt from Lands' End [22], a customer needs to specify many physical measurements in addition to the preferred style choices. Similarly, in the case of mi adidas, the customer's feet need to get scanned to achieve customized fit. This is in addition to customers describing their style choices. In both examples, the customers can reorder with ease from the same company. Even when a customer prefers a shirt of different style, Lands' End can easily pull up the measurements from the previous order. In contrast, if the customer wants to order from a different company, she again needs to go through the process of supplying information for product customization. With mass customization, the customer invests effort to understand the firm's customization offerings and communicate her preferences, which serve as sunk costs that increase the customer's *switching costs* [23]. Furthermore, the stronger relationship established and higher levels of information acquired provide more opportunity for related sales. Thus mass customization helps build customer loyalty. The most recent example of Apple iPhone is a good one. While the sleek looks and the touch screen got the initial attention of the customer base, most of the iPhone customers rave about the application features that does small tasks such as fetching

weather, rating restaurants, finding bank information, and teaching small sentences in new languages. More importantly, no two iPhones are likely to have the same application set—demonstrating the fact that each customer's need is unique and the platform provides an opportunity for completely customization. The net result is that iPhone customers are more likely to be loyal customers.

The customer becomes coproducer of the product with mass customization. This experience itself can create additional value on top of the value of a custom product. For example, the Build-A-Bear workshop lets its customers create their custom teddy bears and other stuffed toy animals. First, the customer selects her unstuffed bear and then brings it to the stuffing machine where she gets to watch her chosen stuffing material put into the bear. This includes the memorable heart ceremony where the customer gets to choose a heart, make a special wish and place it inside her stuffed bear. The customer also gets to choose from various outfits and accessories to personalize the stuffed bear to her liking. Another example is create your own food style restaurants such as Fire and Ice (www.fire-ice.com) where the customer gets to choose the ingredients and sauces and a chef cooks the food to customer's liking. In both of these examples, the customers attain value from the customization process in addition to the end product. Note that because the customer is the coproducer of the product, he/she will have a higher tolerance and is more likely to like the product.

Better Market Understanding

In the early nineties, when Dell's computer business showed strong growth, one of the main reasons that was cited for the growth was the loyalty shown by their business customers whose needs were met more closely by Dell in comparison with its competitors. Dell accomplished this by creating individually customized web pages for each of their clients. Such an effort enabled Dell to get a better understanding of customer needs and preferences. Letting each customer design the product to her liking allows the

firm observe a more accurate reflection of customer preferences. By aggregating these observations the firm can generate better market research information without incurring any traditional market research cost. This is especially valuable for firms that also sell standard products. Indeed, most firms that offer custom products also sell standard products and they need to decide the design of products in their standard product line. In these examples, mass customization can make it possible to improve the design of standard products to better match the needs of customers. One firm that took advantage of these synergies between mass production and customization is P&G. Through its subsidiary Reflect, P&G offered customized cosmetics where customers created their own cosmetic line, mixing and matching various options like colors, scents, and skin-care preferences.² Reflect had sold nearly 10 million customized items since its launch [24]. Matching the customized order specifications with sociodemographic profile of customers and their feedback or change of specifications after the sale provided invaluable market information, which can then be used to improve the standard product offerings [23].

Better market understanding resulting from mass customization can also be very helpful for identifying trends in the marketplace and responding to them sooner. For example, when many of Dell's customers choose large-capacity hard disks in their customized configurations, Dell understands that the demand for large-capacity hard disks will go up and it can strike deals with its suppliers before the competitors notice this trend.

Reduced Inventories

An important operational benefit of mass customization is that it allows operating make-to-order as opposed make-to-stock. Because customers receive individually customized products, they are willing to

²P&G decided to close Reflect in June 2005 and continue its mass customization initiative under its own brands such as Cover Girl [24].

wait to some extent for their custom orders. A classic example in this regard is the European Delivery Program of BMW, where the long wait for delivery is offset by the fact that the car is built according to specifications and the customer gets a chance to pick it up from Europe.³ Industry analysts estimate that if the US car makers were to operate on a build-to-order basis that would translate to cost savings of \$3600 for each car and \$65–80 billion per year for the entire industry [26]. Avoiding carrying inventory helps avoid costs associated with inventories. For example, Dell [27] operates with less than 4h of work in process inventory and practically no finished-goods inventory. This leads to significant savings in inventory-holding costs; furthermore, this also eliminates the forecasting risks, which are especially important for technology and fashion products. Retailers sell more than one-third of their inventory at discounted prices mainly either because of having too many items or because of stocking unpopular items [28]. Furthermore, inventory of technology products are prone to devaluation and obsolescence. The make-to-order model also has a cash flow advantage as goods are sold and at least partially paid for before they are produced. Moreover, the fact that the customers tolerate waiting for a customized product allows a firm to sell the product without even touching it as in Lands' End; in this case, the product is produced and distributed by third parties [22].

As discussed above, there are some important benefits of mass customization. However, mass customization is not for everyone. Zipkin points out that mass customization imposes special requirements for information elicitation, process flexibility,

³However, one needs to be careful with customization delays. A survey of manufacturing firms [25] that adopted or were considering mass customization found that delay was viewed as an important shortcoming of mass customization. For some products, customers may not have too much tolerance for delay, indeed this is one of the main reasons that few US consumers (7% in 2000) order custom cars [26].

and logistics, and many product markets are not attractive for mass customization [8]. Companies like Mattel and Levi Strauss have experimented with mass customization and abandoned these initiatives, and a number of companies went bankrupt selling customized products. Pine [2] identifies conditions under which mass customization is attractive vis-a-vis mass production. Mendelson and Parlakturk [15,29] characterize some operational and market characteristics that make mass customization attractive.

ENABLERS OF MASS CUSTOMIZATION

One of the key issues related to mass customization is that in most situations it leads to greater variance in operations and difficulties in predictability [30]. This inability to predict well leads to worse performance and hence leads to additional cost. While many firms tend to increase the price for a customized product or service, sometimes operating costs outweigh any benefits that a firm may have gained in pricing a highly customized product or service. This is one of the main reasons that mass customization in its extreme form is not widely prevalent in industry [30]. It is important to address this challenge in order to successfully implement mass customization.

Standardization Techniques

In mass customization, variability could be introduced in different ways. The most common types of variability that are associated include variability in demand both in terms of quantity and timing of orders, variability in terms of processing times since each order is different, and variability in customer knowledge and ability to participate in the cocreation of products and services. These variabilities make it difficult to operate efficiently. One way to address this is through standardization techniques. Swaminathan [30] describes four common standardization techniques, namely, process standardization, product standardization, part standardization, and procurement standardization.

Process Standardization. Process standardization (also called *postponement* or *vanilla box approach*) refers to standardizing the initial steps in the process delivery and stocking inventory at that point. Such inventory is utilized to customize individual orders that come in. The key trade-off in postponement is the ability to respond quickly and effectively to individual customization needs while optimizing the amount of additional investments in the form of semifinished inventory; Refs 31–33 provide an extensive survey of research and results on postponement while Venkatesh and Swaminathan [13] provide a rich set of real success stories and managerial implications of adopting postponement.

Product Standardization. Product standardization refers to reducing the amount of products that are actually available for the customer to buy even though on paper it might appear that everything can be customized. This way the firm is able to reduce the amount of internal variability that is created. In such situations, the firm should either price their unique products higher or quote a longer than normal lead time for delivery. This is also called *reduction* by Frei [34] in that the menu of offerings is reduced.

Part Standardization. Part standardization refers to standardizing components in the product platform; therefore, while providing high degree of variety and customization, the firm could still benefit from economies of scale on these basic components. Clearly, adopting part standardization has its negative implications as well. It is important that a customer does not perceive that level of commonality between its premium and low-quality product. However, if done right, the economies of scale and the associated innovation on parts could significantly improve the overall product and lead to higher sustained quality in such products [35]. Many successful firms such as Honda and Sony utilize part and platform standardization as an integral part of their operations strategy.

Procurement Standardization. Procurement standardization refers to creating

synergies across various components and services a firm might be buying. This is often overlooked in large organizations that grow into very independent smaller organizations that have separate procurement arms. For example, GM, in the early nineties, went through a significant change in its procurement strategy by making it more centralized and by standardizing parts and procurement across many of its product lines. This enabled the firm to cater to multiple segments in the market while obtaining synergies in procurement.

Technology Solutions

Firms can also take advantage of various technology solutions to overcome the challenges of mass customization. An important enabler is flexible manufacturing systems, which reduces the trade-off between variety and productivity. Mass customization requires the production to switch between different product versions rapidly and frequently; flexible manufacturing systems make this possible without significantly increasing the costs. Firms offering custom-fit footwear and apparel such as mi adidas and Brooks Brothers use 3D scanner technology to elicit customers' measurements, while Land's End relies on software technology running a series of algorithms that can identify a person's body size by taking just a few of his or her measurements along with questions about his or her body shape and then running them against a huge database of typical sizes. This helps create a custom fit for each customer. Companies like Amazon are able to make personalized offers taking advantage of data-mining capabilities. Amazon's recommendation engines process vast amount of information collected not only from the targeted customer but also from other customers with similar profiles. Another strategy is to provide customization through customized software while keeping the hardware identical, as in the examples of iPod and iPhones. Here, the product is decoupled into hardware and software and customization is achieved by customizing the software, which is relatively easier. In these examples, customers can add software components and content to customize the

functionality of the product on the basis of their preferences.

Involving Customers

Finally, another way to manage mass customization is to cocreate the product or service along with the customer [36]. This provides an opportunity to utilize customer labor, which can result in lower costs for the firm. For example, in the case of Fire and Ice restaurants, the customer fills a bowl with her selected vegetables, meats, and sauces, which is then cooked to the customer's liking. Here, the customer prepares the meal herself by adding the ingredients and bringing it to the centralized grill and after it is cooked, the customer carries food to her table. All these enable the restaurant avoid much of the needed labor. From the perspective of the customer, she is getting a highly customized product, while from the perspective of the restaurant, it is operating highly standardized processes, that is, replenishing ingredient bins and cooking the food brought by customers. This is possible because the customer is an integral part of the customization. Zazzle also takes advantage of greater customer involvement. Zazzle provides a platform that allows its customers to design their custom line of merchandise including T-shirts, ties, hats, mugs, shoes, and so on. The customer decides what to include in her shop (called a *gallery*) and she can customize the products by adding custom images and texts. The customer then gets a commission when another customer orders a product from her gallery. Zazzle does the order fulfillment. In this case, tasks with higher variability are done by customers whereas tasks performed by Zazzle.com have less variability. The customers design the products to be included in their stores, for other customers to buy. The products differ only in the images imprinted on them, so the production can be standardized to a great extent. Similar examples include Cafepress and Threadless.

OR/MS MODELS OF MASS CUSTOMIZATION

Mass customization is attracting increasing interest in the OR/MS literature

[15,29,37–40]. In the following, we review some of the analytical models used in these studies. Mass customization aims to eliminate each customer’s sacrifice from her ideal choice by providing individually customized products. This is captured through the classical Hotelling model [41] where differences in customers’ tastes are represented by their locations on the unit interval. Each product type also maps to a point on the unit interval. When a type- θ customer buys product type ζ at price p , her utility is equal to

$$U(\theta, \zeta, p) = w - p - r|\theta - \zeta|, \quad \theta, \zeta \in [0, 1], \quad (1)$$

where the reservation price $w > 0$ is the customer’s willingness to pay for her ideal product and $r > 0$ is the intensity of customer preference. Mass customization enables a firm eliminate the customer’s disutility by adjusting its product type to match the customer type. This framework allows studying the competition between standard and custom products [15,39,40]: firms selling standard products choose fixed locations on the unit interval (i.e., their product configurations), whereas firms selling a custom product can match any point on the interval.

There are important differences between the operations of traditional and customizing firms. A traditional firm usually carries inventory and fulfills customer demand from stock. In contrast, a customizing firm does not carry finished-goods inventory because it makes to order. Mendelson and Parlakturk [15], Xia and Rajagopalan [40], and Alptekinoglu and Corbett [42] add a delay cost to Equation (1), which is proportional to the delay customer experiences before getting her customized product. Mendelson and Parlakturk [15], Alptekinoglu and Corbett [42] model make-to-order production as an $M/M/1$ queue with higher congestion resulting in longer delays for the customers. Mendelson and Parlakturk [15], Jiang and Lee [38], and Alptekinoglu and Corbett [42] also include holding costs for standard products, which reflect the inventory cost advantage of customized products.

While the above models of mass customization are very important for developing

insights on the problem and developing strategies around product offering, yet another of the set of OR/MS models can be useful for practical operations for mass customization. These are two-stage stochastic models where, in the first stage, the firm may decide on the variants of the products to be offered and the inventory of semifinished products or parts to be stocked, while in the second stage, the firm decides how to allocate the inventory and capacity to meet the demand for customized products. While Swaminathan and Tayur [32] and Lee and Tang [43] provide details on specific models where inventory is stored as semifinished products, a much broader set of such stochastic models of this kind that are related to mass customization are discussed in Refs 33 and 44.

CONCLUSIONS

In summary, there is a growing demand for products that better match customers’ individual preferences. With mass customization, the firms aim to provide each customer with his/her ideal product rather than proliferating the marketplace with product versions and hoping that customers find products that are close enough to their ideal choices. Firms mainly offer three types of customization: (i) Firms can customize appearance of the product involving colors, labeling, and so on; (ii) they can customize physical fit of the product such as customizing width, length, and insole of a sneaker; or (iii) finally, firms can customize functional features of the product adding on options that the customer chooses. There are a number of benefits that makes mass customization attractive. This includes ability to charge price premiums, establishment of stronger relations with customers, better market understanding as a result of directly observing customers’ preferences, and cost savings due to operating without finished-goods inventories. While mass customization results in many benefits, it leads to some challenges due to the variability it induces to a firm’s operations. To overcome these challenges, a firm can use standardization techniques such as product, part,

and procurement standardization. It can use technology enablers like flexible manufacturing systems, 3D scanners, and software technologies and finally, it can take advantage of greater customer involvement, which gives the opportunity to pass some of the task complexity on to customers.

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