Enabling Customization Using Standardized Operations

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There is a high degree of product customization across almost all industry segments today. Toyota is gearing itself to deliver a custom built car within five days of receiving the order. Dell promises delivery of a customized PC within a few days of receiving the order. Motorola delivers their made-to-order cellular phones the next day to customers anywhere in the United States. Proctor and Gamble once offered 13 different product designs in their Pamper Phases line to reflect the change in infants as they grow from newborns to toddlers. Greater adoption of the Internet by customers and businesses alike will likely lead to an even higher degree of customization in the coming years. A recent article on the effect of the internet on customization, for example, describes a Hong Kong based internet site, idtown.com, where one can obtain any variety of customized watches at the same cost as a standard watch sold in retail stores.

While being an ideal situation from the customer standpoint, such an environment puts immense pressure on supply chain operations of the firm. Research shows that different firms follow quite different strategies while trying to cope with increased product variety. Pine, for example, describes four types of customization strategies a firm might undertake: point of delivery customization, customizable product or service design, quick response (reducing lead times through the supply chain), and modular product design. Gilmore and Pine present a framework for mass customization that identifies alternative ways of providing mass customization and classifies them based on actual changes in the

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product variants as well as their representation. Their framework addresses the issue of connecting the customer into the production and distribution process. While these frameworks are helpful in addressing how the customer will interact with the product and distribution processes in a mass customization environment, they do not address crucial operational issues that arise in such environments. The focus of this article is on identifying dominant operational strategies employed by firms engaging in mass customization to meet the needs of their businesses.

Over the last six years, we have performed detailed analytical and empirical analysis of operational strategies for managing mass customization with several firms, including IBM, 3Com, Sun Microsystems, Agilent Technologies, US Filter, Visteon, Chrysler, and Perkin-Elmer. Further, other researchers have also analyzed operational strategies related to product variety management. (See Lee and Swaminathan for detailed review of analytical research in this area.) Based on the above, we have identified a handful of key strategies for mass customization and have gained an understanding of the circumstances under which each of those strategies works best. This article describes the issues companies contemplating mass customization face and presents a framework for thinking through the alternative strategies they must assess.

Customization and Predictability

Mass customization can be a win-win proposition for customers and manufacturers when manufacturers find efficient and effective means of delivering high levels of product variety. Doing so requires manufacturers to manage potentially significant changes in the predictability of both demand and supply in their operations.

Predictability of Demand

The increased product variety associated with mass customization makes predicting demand extremely difficult. First, forecast errors are much greater when forecasts are made at the individual product level than if aggregate forecasts are made for a family or group of products. It is easier, for example, to predict aggregate demand for Toyota Camrys than it is to forecast the demand for a Camry LE model with an anti-lock braking system option. The more different types of products there are, the fewer aggregate forecasts can be usefully made. Second, as product variety increases, the likelihood of correlation among product forecasts increases. Suppose, for example, that a firm offers only one product, A. Then it has only to forecast the demand for product A alone. Suppose, however, that the firm augments its product line with a new product, B. Then the firm has to predict both the total demand for products A and B, but also generate individual forecasts for the two products. A combined forecast of 100, for example, could be split as (50,50) or (99,1) or (1,99) or (20, 80) and so on. Worse, it could be that the demand of product A depends upon what happens.
with product B—high demand for product A might create low demand for product B. Such correlation makes forecasting demand even more difficult.

Therefore, the choice to engage in mass customization by definition leads to higher product variety. This in turn creates greater demand uncertainty due to the difficulties in forecasting for an increased number of products. Greater demand uncertainty in turn requires higher levels of inventory to provide equivalent levels of service.

**Predictability of Operations**

On the supply side of the equation, increased product variety complicates planning and execution in a number of ways.

- Deciding how much inventory to carry to guarantee required service levels is more difficult. Managers have to decide, for example, which product to build to order, which to build to stock, and which products may be substituted for one another if need be.
- Predicting equipment capacity requirements is more difficult. Depending on the product mix, some equipment will be used sparingly, while other equipment will be a bottleneck.
- Forecasting component requirements is more difficult as well. A large PC manufacturer, for example, needed to forecast requirements for processors, memory, hard disks, monitors, and other peripherals across a very broad range of products. They found forecasts can be difficult to compute and are inaccurate when component requirements are correlated.9
- The number of different components or subassemblies used may increase and in turn cause the number of different supplier to increase as well. Not
only are more parts and suppliers more costly to manage, but making changes to products is made more complex as well.

- Mass customization environments typically entail shorter product life cycles as well, which requires additional attention to product introduction issues such as supplier ramp up, inventory phasing, marketing, and pricing.

In short, increased variability makes inventory, equipment capacity, component, supplier, and product changeover management more difficult. The challenge for firms implementing mass customization, then, is to minimize the extent to which engagement in customization increases variability in the operating environment. There are alternative standardization strategies that dampen the negative effects of mass customization on predictability.

**Modularity in Product and Process**

Modularity in product and process plays an important role in determining the effectiveness of standardization. A modular product is one that can be made by appropriately combining the different components or subassemblies (modules) that are used in the product and where customers are interested in alternative options for the different modules. Mass customization entails providing customers a number of options for each module. For example, a personal computer is defined in terms of memory size, processor speed, hard disk size, and peripherals. The manufacturer can provide variety in these key modules and achieve a huge amount of variety at the customer level. Swatch watches provide variety by combining different design and colors for the dial, needle, and strap. Examples of non-modular products might include shirts, trousers, and coats, which are evaluated by customers in their entirety. Even in such products, there is some degree of modularity. For example, in ski parkas, button and zipper types are dimensions of variety that interest customers.

A modular process is one where each product undergoes a discrete set of operations making it possible to store inventory in semi-finished form and where products differ from each other in terms of the subset of operations that are performed on them. Any discrete assembly process would classify as modular. Semiconductor wafer fabrication (particularly application-specific integrated circuits) is modular, since the type of chip produced depends on the unique subset of operations performed on it. Oil refining, on the other hand, is a non-modular process as it is continuous and inventory storage in semi-finished forms is difficult once the refining process starts.

Modular products do not necessarily always get made in modular processes. The biotech and pharmaceutical industries make modular products, but use non-modular process. Many products in these industries can be derived by varying the mix of a small number of ingredients, which makes them modular. They are made, however, in continuous flow processes and thus inventory cannot be stored in semi-finished forms.
of demand uncertainty came from the choice of colors that customers wanted. So in order to exploit that Benetton resequenced the process by first knitting the sweaters and then dyeing them after perfect demand information was obtained. Lee and Tang analyze the above model in detail.12 Swaminathan and Tayur describe a model, methodology, and insights obtained from process sequencing optimization for postponement based on experiences at US Filter.18 They evaluated alternative assembly line configurations that enabled postponement and parallel operations for the reverse osmosis pump line while taking into account design costs and operational benefits.

The automobile industry employs a modification of process standardization which involves designing platforms that allow multiple car models to be produced on the same production line without major changes to the line configuration. A few years ago, for example, Honda redesigned their cars to allow for production of sedans, wagons, and sports car models all on the same line.

Process standardization also enables the firm to pool the demand risk across different products and manage demand correlation more efficiently, thereby reducing inventory requirements.19 The degree of process standardization to pursue depends on factors such as type of product and where in the process customization occurs. Lampel and Mintzberg describe five types of standardization—pure standardization, segmented standardization, customized standardization, tailored standardization, and pure customization—that involve customization at different levels (design, fabrication, assembly, distribution) of the delivery process.20

**Product Standardization**

In product standardization, a firm offers a large variety of end products, but, using the 80/20 rule, stocks only a few of them in inventory.21 The advertised availability of products is thus far greater than actual availability on average. When a customer asks for a version of the product that is not normally stocked, the manufacturer either makes the product after receiving the order or, in a process called downward substitution, provides the customer one of the available models that has a superset of features required by the customer. Downward substitution is quite common in the semiconductor industry where a higher speed/functionality chip (under appropriate circumstances) is marked as a lower speed/functionality chip when the lower-end chip is not available in inventory. Another example of this is the rental car business, where customers are provided a higher-end car or upgraded when the car requested is not available on the lot.

This approach reduces the negative impact of customization related to product proliferation both in terms of reduced costs for managing existing products as well as reducing the number of product design changes over the life cycle. Rao et al. demonstrate that this approach could be beneficial in terms of inventory reductions as well.21 The downside of the product standardization approach is that customers ordering items that are not stocked may either have
A Framework of Standardization Strategies for Enabling Customization

There are four standardization approaches used by firms to implement mass customization while mitigating the negative effects of increased product variety and variability. They include part standardization, process standardization, product standardization, and procurement standardization.

Part Standardization

The simplest and most well known standardization approach uses commonality in either the components or subsystems of the product line. By using common components across members of a product line, the firm reduces costs (due to economies of scale), reduces inventories (due to risk pooling), reduces parts proliferation, and improves the predictability of requirements for components. While beneficial to operations, however, too much part commonality can reduce product differentiation in the eyes of the customer leading to a cannibalization effect. Robertson and Ulrich differentiate external and internal commonality sets and emphasize that increasing internal commonality does not necessarily lead to cannibalization of demand. For example, if commonality is introduced in the wire harness of high-end and low-end model cars of a manufacturer, it is not readily noticed by customers (since these wires are hidden under the upholstery) and thus cannibalization effects are minimal. On the other hand, if the dashboards of those two models are standardized, this could potentially lead to some degree of cannibalization.

Process Standardization

The second approach delays differentiation or postpones the customization until as late in the process as possible, making the front end of the process standard. Process standardization requires that the process be modular and enables the firm to store inventory in semi-finished form (before full information about demand is realized) and later customize the product according to requirements. Hewlett-Packard delayed the differentiation of their DeskJet printers bound for Europe by adding customizing material such as manuals and power supplies in local distribution centers in Europe. This led to several million dollars of reduction in inventory for HP. Lee and Tang present an analytical model to study the costs and benefits associated with process standardization. Swaminathan and Tayur studied the final assembly of IBM RS6000 machines and provide instances where storing inventory in semi-finished forms (called "vanilla boxes") reduces the inventory requirements while improving response times and providing high levels of customization.

Process standardization provides immense benefits when based on clear market requirements, such as it was in Benetton’s case. The sweater-making process primarily consists of two stages: knitting and dyeing. The original process was to dye first and then knit based on requirements. However, the main source
to wait a long time for the products to be built or may receive an item that is not exactly what they want. In either case, customer satisfaction may suffer.

**Procurement Standardization**

*Procurement standardization* leverages commonality in part and equipment purchasing. When a wide variety of products offered by a firm are made on similar equipment and/or use a shared set of components, then demand can be pooled across the variety of end products, and equipment and parts can be purchased accordingly.

For example, consider a large semiconductor manufacturer’s wafer fabrication facility that produces application specific integrated circuits (ASICs). These products are highly customized and have unpredictable demand due to technology changes. Further, the processing equipment that manufactures these wafers is very expensive (sometimes in hundreds of thousands of dollars), has a long lead time, and needs to be made to order. Investment made in this equipment affects the financial and operational performance of the firm in a significant manner. Although there is a high degree of variety at the final product level, each wafer has to undergo a common set of operations over the same set of processing equipment. The firm reduces the risk of investing in the wrong equipment by pooling the demand across its variety of products thus allowing them to plan and procure the equipment efficiently. Swaminathan presents a model, methodology, and empirical insights on utilizing such an approach.²³

Another instance where procurement standardization has been used quite effectively is the PC industry. PC systems share a large number of common components and firms have reduced the risk in the procurement of these components by aggregating the demand based on the requirements from all the products and then purchasing the required components.

The main benefit of procurement standardization, then, is better utilization of production resources and reduced raw material or component inventories due to risk pooling across the variety of end products.

**Considerations in Choosing Standardization Strategies**

The choice of standardization strategy undertaken by a firm depends in part on the extent to which it is possible for the firm to modularize its products and processes. Figure 2 shows the four possibilities and which processes are most appropriate under which conditions.

- If both the product and the process are modular, the firm maximizes its performance by adopting process standardization. Modular electronics and computer products such as printers and personal computers have these characteristics.
If the product structure is modular but the manufacturing process is not, then part standardization that leverages part commonality is the most effective approach.

When the process is modular but the product is not, as in the semiconductor wafer production example, the firm gains most from adopting procurement standardization.

Finally, when neither the product nor the process is modular, a firm could effectively manage product variety by product standardization.

Clearly, there are many cases in which a combination of strategies is most effective. Swaminathan and Kukukyavuz studied an example from the biotechnology industry where the firm utilized both process and product standardization. In this case, process standardization was used by postponing packaging until the final stages and product standardization was adopted for the end products that were substituted between customers. Further, one type of standardization may require that other standardization approaches be adopted first. For example, part standardization enables both procurement and postponement strategies.

In addition to the product process characteristics (which to a great extent determine the feasibility of adopting a strategy), a firm also needs to consider other important issues:

- Implications for Product Design—Engaging in part standardization implies changes in the ways in which the firm designs its products. If it is
Notes

10. Note that the above definition of a modular product is different from earlier definition given by Ulrich where modularity in products was mainly defined in terms of independence of the sub-assembly in terms of functionality whereas here we have defined modularity in terms of customer preferences. K.T. Ulrich, "The Role of Product Architecture in the Manufacturing Firm," *Research Policy*, 24 (1995): 419-440.
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redesigning existing products, there may be a one-time cost of doing so. If it is designing a new family of products based on a part standardization strategy, it will have to think through a new means of managing product design.

- **Ability to Meet Customer Requirements**—If customer responsiveness is important, then process standardization could be quite efficient (as long as the lead time for customization from the generic product is small enough). If the customer is very particular about certain features in the product line, then adopting a substitution strategy (product standardization) on those features could lead to customer dissatisfaction. Similarly, introducing too much part standardization (which is easily perceived by the customer) could lead to cannibalization effects within the product line.

- **Process Changes**—Adopting any of the four standardization strategies could lead to changes in the processes related to design, procurement, production, and distribution. The costs associated with such changes should be carefully taken into account while choosing one strategy over the other. Sometimes, the changes may not be physical but may involve changes in operational decision-making. For example, when firms adopt procurement standardization, then aggregation becomes important and decisions may have to be made in a centralized manner. Similarly, employing process standardization requires retraining human resources, which could be a very high and difficult cost to assess.

- **Degree of Outsourcing**—It is not only important to choose the right degree of outsourcing for a firm’s product and supply chain environment, but it is also important to choose the appropriate standardization strategy for the degree of outsourcing used. Dell, for example, focuses its internal operations on final assembly and passes all its component-related variety back to its suppliers by requiring just-in-time delivery of major components. Although this reduces internal operational complexity, it may pose more challenges during new product or platform development.

## Conclusions

Product variety is increasingly important in many businesses. Along with product variety comes increased uncertainty and a number of operational challenges. These challenges can be met by using various types of standardization—product, part, procurement, and process. The ability for a firm to use these standardization approaches depends in part on the degree to which it can modularize its products and processes, in part on what it is trying to achieve for its customers and in part on the costs associated with standardization. The framework presented here can assist in choosing among these options.