Chapter 2
Process Typology of Mass Customizers

Rebecca Duray[1]

Rebecca Duray
University of Colorado at Colorado Springs
College of Business and Administration
1420 Austin Bluffs Parkway
Colorado Springs, Colorado 80918, USA
rduray@uccs.edu

Abstract Traditional manufacturing practices required a choice between providing low cost products with mass production or custom products with craft manufacturing methods. Mass customization resolved this trade-off by providing both low cost and customization. Today, mass customization is no longer a new phenomenon but a realistic strategic choice for many manufacturers. As mass customization becomes more commonplace in practice, academia needs to update the traditional models to incorporate this new competitive form. This chapter takes a look at the traditional process tradeoff models and develops a new process model to incorporate the practice of mass customization.

2.1 Introduction

Mass customization had been in practice for many years before academics tried to decipher its components. To some degree, mass customization evolved from traditional manufacturing practices as manufacturers addressed changing customer requirements. Mass customization is emerged in both custom and standard product manufacturers (Duray 2002). For purely custom products, competitive pressure, worldwide markets, and changing consumer behavior pushed manufacturers to reduce costs. The value equation for traditional custom products, such as tailored suits and custom designed furniture, no longer favored providing infinite variety. Custom product producers began to lower their cost structures by either providing less variety or adding commonality among their end items, thereby reducing inventory requirements, cost and/or lead times. For example, some custom shirt tailors

[1] Rebecca Duray is a professor at the University of Colorado at Colorado Springs and Chair of the Department of Management. Her research interests are in the strategic use of operations, the processes required for mass customized products and services, and lean applications in information systems operations and healthcare.

began to offer limited or more static designs in a few select popular styles with limited fabric choices at lower price points. Cost savings were found with economies of scale in purchasing fabrics and increased volume of certain styles and lead times were shortened with only selected materials readily available to customers. These custom tailors may have lamented the good old days of true customization, but they probably did not label their changes as "mass customization." Rather, these changes were the methods employed to stay competitive with savvy customers requiring reduced prices and quicker delivery. As a counter point, standard product manufacturers were hit with similar competitive pressures of lower cost substitutes. In this type of marketplace, companies often look to differentiate their products. Some standard product manufacturers may have offered mass customization as a means to satisfy customer demand and/or gain customer loyalty. In the early 1990s, Levi Strauss was an early entrant into mass customization in the United States, offering custom jeans at Levi's stores. Levi offered jeans to women only because research showed that women had a more difficult time finding jeans that fit. This is an early example of a standard product manufacturer developing a much publicized mass customization capability. Mass customization is no longer a new phenomenon but a realistic strategic choice for many manufacturers.

Academics have been interested in mass customization since Stan Davis coined the term in his 1987 book *Future Perfect.* Academics in both business and engineering have explored the design, marketing, manufacturing, technology, and information systems requirements of mass customization. Abundant research exists on the practice of mass customization, yet academics have not incorporated mass customization into some of the basic process models used in operations education. The traditional process models are based on Hayes and Wheelwright's (1979) product process matrix. This groundbreaking typology showed the interaction of marketing and operations and highlighted the need for coordination between these two functions. Mass customization is a good example of the marketing manufacturing interface, but it does not fit in this process typology. If mass customization is becoming more commonplace in practice, then academia needs new models to incorporate new competitive forms. This chapter takes a look at the traditional process tradeoff models and develops a new volume-variety-variation process model to incorporate the practice of mass customization.

2.2 Mass Customization and the Product Process Matrix

2.2.1 Defining the Product Process Matrix

In 1979, Hayes and Wheelwright introduced the product process matrix; a framework for mapping product structure with process structure (see Figure 2.1). This revolutionary model defined the concept of a process lifecycle where "the process evolution typically begins with a 'fluid' process–one that is highly flexible, but not very cost efficient–and proceeds towards increasing standardization, mechanization and automation". This process life cycle represents the growth and development of a product, a company, or an entire industry through four stages: jumbled flow (job shop), disconnected line flow (batch), connected line flow (assembly line), and continuous flow. The inherent process trade-off between flexibility (which provides variety) and low cost (achieved by economies of scale with high volume) are explicitly stated.

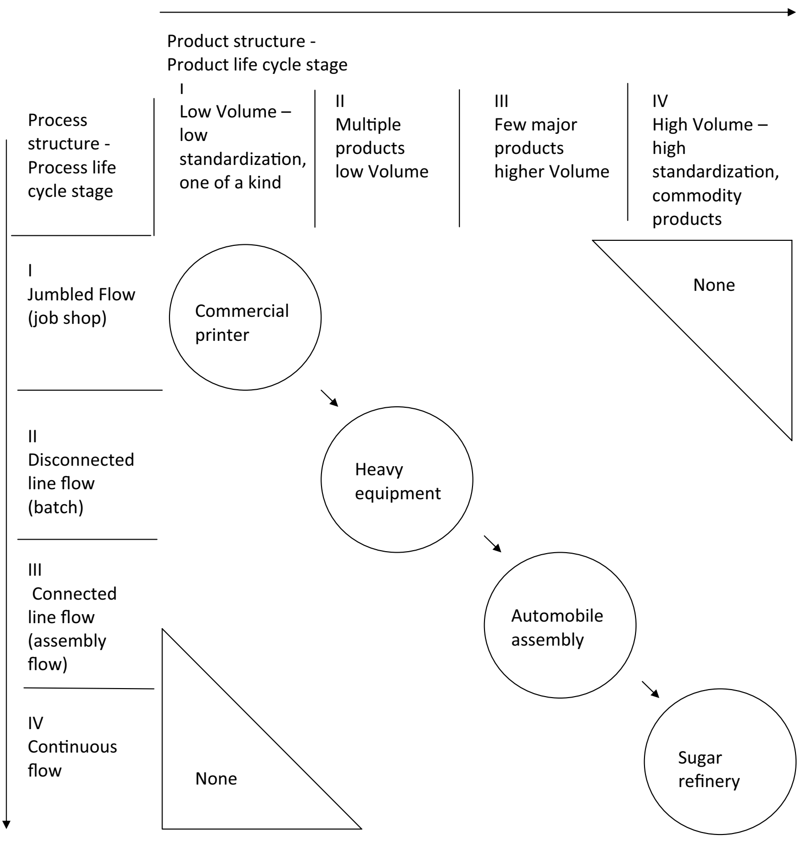

Figure 2.1 Product process matrix (Hayes and Wheelright 1979). Reprinted by permission of Harvard Business Review

The matrix is constructed by mapping the rows to represent the major stages of process evolution from fluid to systematic, while the columns represent product life cycles from large product variety of startups to standardized commodity products. Examples are used to define the intersection of each of these stages on the diagonal; examples show commercial printers, heavy equipment manufacturers, automobile assembly, and sugar refineries. Hayes and Wheelwright further developed this concept in their 1984 book, *Restoring Our Competitive Edge: Competing Through Manufacturing.*

The product process matrix became the cornerstone of process definition. Numerous introductory operations management textbooks include this model (Jacob *et al.*, 2009; Krajewski *et al.* 2007; Schroeder, 2007; Stevenson, 2009). The product process matrix defines the parameters of manufacturing processes in all of these texts. In addition, this matrix provides the foundation for most discussions of operations strategy.

Although the matrix is widely accepted, many textbooks alter the model to better define the process types. The model suffers from two weaknesses. First, the example companies are from different industries. This implies that positions are characterized by specific traditional processes types, when in reality companies in the same industry can compete from different positions on the matrix. For example, cookies can be mass produced on assembly lines and sold through supermarket chains or they can be made by the local bakery in a small batch operation. Using one product across process types better illustrates that that process type is a strategic choice. Hayes and Wheelwright (1979) use the product and process life cycle intersection on the diagonal to show the strategic alignment of operations and marketing strategies.

Secondly, the product life cycle incorporates both volume and variety dimensions that define the exact position of the major process archetypes. Stevenson (2009, p. 231) renames the axes volume and variety with little alteration on the specific definitions. The *X* axis incorporates the concept of volume while the *Y* axis represents variety through the specific product types of job shop, batch, repetitive and continuous. Although this model strips down the axes to volume and variety, their definitions are still incomplete. Variety is represented by process type not by a defined product line breadth and therefore, process type is a poor representation of variety. Although it is true that processes are distinguished by the flexibility in producing product, process types are also defined by the volume that they can accommodate. Stevenson (2009) uses industries, although different industries, for the diagonal examples of processes. This adaptation of the product process matrix does not appear to increase the clarity of the descriptions.

Jacobs *et al.* (2009, p. 207) alter the matrix using standardization and product volume as the axes. Their spectrum of standardization flows from "low – one of a kind" to "high – standardized commodity", which is the definition of the product life cycle. Therefore, Jacobs *et al.* (2009) follow the traditional definition of the *X* and *Y* axes. However, their model adds "work center" to replace the traditional "job shop" and "manufacturing cells" as the central "batch." Both the Stevenson (2009) and Jacobs *et al.* (2009) examples show that many authors have tried to expand upon the original concept for clarity in presentation and to accept more forms of manufacturing used in practice.

Krajewski *et al.* (2007 p. 129) use an adaptation of the product process matrix that places process types on the diagonal and uses product design as the *X* axis and process characteristics as the *Y* axis. The process types replace the industry examples, but basically this matrix duplicates the *Y* axis on the diagonal. The list of process characteristics is the same as the definitions of the processes types used on the diagonal. However, when teaching the concepts of process choice, the accompanying video of King Sooper relies on the volume-variety tradeoff to define the process types, *i.e.*, process choice decisions are based on volume and variety. High volume bread is produced on a dedicated line, numerous pastries, rolls, and coffee cakes are produced in a linear flow, batch process, while custom decorated cakes are produced in a job shop. All processes types are located in the same facility. This concept of volume and variety better illustrate the inherent trade-off in processes, but rarely appears in the operations management textbooks. For example, not all automobiles are produced on a traditional assembly line. Automobiles can be produced as project, job shop, batch, or line depending on the volume and variety. While major auto manufacturers use line processes, Tesla electric sports cars prototypes are produced as projects (http://www.teslamotors.com/media/press_room.php?id=1380) and Morgan Motors (http://www.morgan-motor.co.uk/production/index.html) produces its Roadsters in a batch process. Process choice is not industry dependent, but it should be based on the volume and variety of the products.

A summary of the variations on Hayes and Wheelwright's (1979) product process matrix presented in this section is given in Table 2.1.

Table 2.1 Summary of variations of the product process matrix

Source	Hayes and Wheelwright (1979)	Stevenson (2009)	Jacobs *et al.* (2009)	Krajewski *et al.* (2007)
X axis		Volume	Standardization	Product design
Y axis	Process structure	Variety	Product volume	Process characteristics
Diagonal	Industry types	Industry types	Process type	Process type

2.2.2 *Strategy of the Diagonal*

Hayes and Wheelwright (1979) only considered as appropriate the process configurations located on the matrix diagonal. In the original diagram, the corners of the matrix are void. The authors state that the lower left-hand corner represents a one-of-kind product that is made by continuous or very specific processes. They state that such processes are simply too inflexible for unique product requirements. Using the traditional definition of process types of line and continuous, this premise holds true. Highly mechanized, high volume line processes are designed for specific repetitive tasks and are not designed for flexibility. The upper right-hand corner is characterized by a job shop that provides commodity products. Hayes and Wheelwright state that no companies or industries are in this void. But in practice, mass customizers operate in both of the voids. By definition, mass customization provides one-of-a-kind products at low cost. Hayes and Wheelwright propose that "void" positions are not economically feasible. Producing commodities in a job shop will not be competitive with the low cost and consistent quality of commodities produced in automated line processes. But mass customization could be characterized as "unique products" (job shop) and "large quantity" (commodity). However, mass customized products fall in the other "void" area; one-of-a-kind products made by dedicated processes. With mass customization, most products exhibit some degree of modularity. There is often a portion of the product that is mass produced and used in all products, although each end item is custom designed to a customer's specifications.

Hayes and Wheelwright do allow for "off diagonal" strategies although they caution companies not to drift off the diagonal position. They acknowledge that successful companies make a deliberate decision to move off the diagonal. They advise that changes in product volume or mix can both have a negative impact on profitability. Off-diagonal positions should be specifically intended strategies such as Rolls-Royce Ltd. producing a limited product line in a job shop. Hayes and Wheelwright do not offer any examples of the opposite void where mass customized production would most likely occur, perhaps implying that mass customization is not possible.

2.2.3 Defining Made-to-order

Most operations management textbooks show the traditional product process matrix and discuss the volume, variety, and flow tradeoffs inherent in process choice. In addition, most textbooks divide manufactured goods into categories such as made-to-stock, assembled-to-order, and made-to-order Historically, these two classification systems were in sync; made-to-order products were best manufactured as projects and job shop processes, while batch and line processes produced made-to-stock items. But in more recent years, these classifications no longer map directly to specific processes. Made-to-order products are available on all process types (Schroeder, 2007, p. 61, Table 4.3) negating some of the distinction found in the product process matrix. In the matrix, only job shop processes produce made-to-order products.

These classifications were further obscured when one considered "custom" orders of significant volume that could be built in repetition perhaps even on dedicated lines. The printing industry is often cited as a made-to-order product since the typeset changes for each job. However, each job could be very high in volume. Therefore, it is not the traditional made-to-order product produced in a job shop, nor a traditional production line product.

In addition, these models and classifications do not adequately reflect the practice of mass customization. Although the made-to-order, engineered-to-order, assembled-to-order classification defines "custom" products made by various process types, these definitions do not incorporate the "mass" component of mass customization. An engineered-to-order product could be developed from the ground up or it could be a variant of another product. Neither of these examples implies mass customization. These distinctions encompass the "customized" part of mass customization, but do not delineate the concept of "mass."

The made-to-order, engineered-to-order, assembled-to-order descriptions capture the customer involvement portion of mass customization. However, the current matrix or product descriptions do not capture the "mass" or modularity component of mass customization capabilities. Duray *et al.* (2000) look at both customer involvement and modularity of product design to define mass customization types. Each type of mass customizers uses a different manufacturing system or process type. With the spectrum of made-to-order and the different process types for mass customizers, we surmise that in practice, some form of customization is available on all process types. If "one of a kind" is available on all process types then the product process matrix cannot adequately capture this type of customization.

2.2.4 The Paradox of Mass Customization

Mass customization presents a paradox of providing customized goods at low cost. In concept, the basis for mass customization is the ability to provide meaningful customer specifications or variety, and low cost through high volume-related economies simultaneously. The apparent process choice paradox presented by mass customization stems from the conflicting capabilities required. The process choice continuum from one-of-a-kind project based processes through mass produced and continuous processes presented by Hayes and Wheelwright (1979) is no longer adequate to explain the new manufacturing initiatives implied by mass customization. Traditionally, the manufacturing capabilities of low cost could only be achieved with standard products represented by line or continuous processes. Traditional customization is supported through a project or jobbing process where general purpose machines are used to support small lots of unique product. A flexible manufacturing capability to produce custom products could only be achieved at higher fixed cost than standard production using project or job shop methods. Batch systems provided some flexibility over the more standardized processes and lower cost than the more flexible process types. However, traditional definitions of batch systems did not contemplate the ability to provide end user customized products. Mass customization attempts to provide customization using low-cost mass production methods. Therefore, mass customizers are resolving the capability trade-off of cost *versus* customization.

2.3 Defining Mass Customization

Mass customizers resolve the apparent process choice paradox implied by mass customization by constraining the type and degree of customization and the point at which the customer participates in the design process. The earlier the customer enters the design process, the more customized the product will be (Mintzberg 1988). This concept holds true for all customized products. For mass customization, some part of the end product must be produced in large quantities. In essence, a modular design is used to narrow and rationalize the range of choices offered to the customer, thus allowing large batch or mass production processes to be used for part (modules) of the product. The type of modularity determines how standard modules are combined or altered to provide a product made to the customers (constrained) specification. Duray *et al.* (2000) defined mass customization to have these two dimensions of customer involvement and modularity.

Customization implies that the product is altered in some manner to suit the specific needs of a particular customer. For a product to be customized it must be uniquely produced for the customer and the customer must be involved in the design process. Duray *et al.* (2000) used a modified version of Mintzberg's (1988) typology to define customization as taking three forms: pure, tailored, and standardized. Each form differs in the portion of the value chain involved and the degree of uniqueness of the product. Mintzberg's (1988) definitions show that the form of customization represents different levels of customer involvement in the design and production process. These levels of customer involvement in the value chain can be seen to represent different levels of product uniqueness or degrees of customization. The earlier the customer is involved in the design process the more unique the end item. For example, a customer can build a custom home by purchasing land and asking an architect to design a site specific house. This will provide a high level of customization as the customer is involved in the green field design. Alternatively a customer can go to a housing development and choose from an array of home plans making minor modifications on the specified design. In this case, the customer is involved after the base plans are finalized and only minor changes of fit and finish are incorporated. Therefore, this customer has less choice and a less customized product. This view of customization is consistent with the made-to-order, engineered-to-order, assembled-to-order spectrum used in traditional operations management courses.

To gain economies of scale in production, mass customized products must have some common designs or components. For this reason, mass customization is highly dependent on modularity. Modularity provides for the higher volumes required for mass production of low cost components. Pine (1993) developed the concept of how to achieve modularity using the methodologies of Ulrich and Tung (1991). Duray *et al.* (2000) operationalized these modularity types providing specific definitions to be used to identify different types of mass customizers based on modularity type and point of customer involvement. Using a modular product design limits the options available to customers. For example adiamondisforever.com allows the user to determine the exact size of diamond in a ring using a sliding scale. The diamond is a module that can be "swapped' in the design of the ring. This gives the customer a wide range of options on the diamond. However, only two different designs are available to the consumer: a solitaire or three diamond design. The ring design is constrained from that of a "job shop" jeweler where the options are limited only by your imagination, the properties of the metals and jewels, and the skill of the jeweler.

Mass customization works because it restricts the choices of consumers to prescribed options derived through modularity. When modularity and form of customization are combined, a distinct picture of mass customization emerges. Modularity is used throughout the production process to provide different levels of customization through a mix of standard and custom components. A mass customized product is defined as providing end-user specified customization achieved through the use of modularity of components. The end-user specified customization takes the form of customer involvement on the production process which provides the aspect of customization. The "mass" component of the definition provides the economy of scale through modularity of components.

Duray *et al.* (2000) introduced the concept that all mass customizers do not use the same manufacturing processes. The point of customer involvement and the type of modularity in the product design determine the manufacturing process to be used. The traditional product process may consider the level of customization in both the product structure and process design. However, the concept of modularity is not part of the model.

2.4 Developing the New Model – Volume, Variety, and Variation

The new model builds on the traditional product process matrix but better differentiates the concepts of volume and variety while adding a new dimension of process variation, which estimates the amount of changes required of the process. First, the product life cycle is dissected into two pieces: the volume and the variety of the items. Second, the process lifecycle is represented on the diagonal of the matrix. The model is defined using volume to describe the product lifecycle axis, while variety represents the process lifecycle axis. Finally, the third dimension of variation is introduced. Variation captures the concept of standardization in the process, which manifests itself in terms of modularity.

In the product process matrix, the two axes of product lifecycle and process lifecycle are fairly stagnant. Examples are laced on the diagonal to describe the archetypes, but the process types are predefined on the *Y* axis. Therefore the matrix does not allow for newer process configurations such as manufacturing cells or automated technologies. A model using volume and variety on the axes allows for a broader interpretation of process types. The volume-variety matrix shows process types on the diagonal and not on the *Y* axis and therefore it does not preclude other positions in the matrix.

2.4.1 Volume and Variety

The new model disaggregates the product life cycle into two components: volume and variety, and adds a third dimension of process variation. In the new model, volume is thought of as volume for the entire process; *i.e.*, "how many products are produced on the process?" The product life cycle is explicit in differentiating the life stages based on volume of the product (Figure 2.1). Stages I and II are defined as low volume while phases III and IV are higher and of high volume. The translation from the product life cycle to volume is straightforward. For example, a high speed line with a cycle time of one minute would produce up to 480 items *per* 8-hour shift regardless of the configuration of the end items.

The product life cycle also describes the variety of the products in detail. Stage I has "one of a kind products" or high variety, Stage II has "multiple products", Stage III has "few major products" or medium variety, and Stage IV contains "commodity" or few products. In the new model, variety is on the *Y* axis and is defined as the number of different products produced on the process. A different product is defined as any deviation from the standard output. This would include even minor changes such as color or personalization.

Using "volume" and "variety" on the axes, the traditional process types are defined on the diagonal. Each process type can be distinguished by its volume and variety of products. Projects produce an infinite amount of truly unique products with each individual project completing one or a small number of products. Job shops produce a high variety of products in small volume. Batch processes produce small to medium sized lots of a more limited or preset number of items. Some batch processes have jumbled flows while others have linear flow patterns. Batch processes that have jumbled flows will generally have higher variety than those with linear flows. Line processes produce standardized products with high volumes while continuous processes produce a homogenous flow of non-discrete products. These are the traditional parameters of manufacturing process and they fit the volume-variety matrix.

The volume and variety matrix allows for the possibility of off-diagonal processes. Any combination of variety and volume can be captured on the matrix. The biggest problem is that the current product process matrix and volume-variety approaches do not capture the differences in processes at each predefined step. Using production lines as an example, there are assembly lines that produce products with no variety making the exact same product in massive quantities. This "line" process can be captured on the diagonal. However, the Toyota Production System can incorporate numerous design variants on an assembly line, resulting in a high variety of end items. Toyota's assembly line would occupy the top right corner of the matrix. With this placement, Toyota appears to have an entirely different process type than the traditional auto assembly line. However, the Toyota production process is extremely standardized with one automobile completed approximately every minute. In many practical process terms, the layout of the Toyota assembly line is no different from other automobile producers; it is a linear, automated process with a paced line speed. This radical difference in placement in the volume-variety model does not capture the original spirit of a "process life cycle." The volume-variety model opens up the possibility of producing high variety on automated processes such as a line. However, the placement of the mixed model assembly approach (such as Toyota's assembly line) on the volume and variety matrix does not capture the similarity to the traditional line and overemphasizes the differences. The differences are more than negligible but not as extreme as the placement on the volume-variety matrix.

The mixed model assembly line requires different operational tasks than a traditional commodity line. First, the mixed model product design process is more complex as multiple models must share the assembly line sequence, timing, and tasks. Second, with multiple models, the correct materials and assemblies must be matched to the correct vehicle at the precise time it arrives at each work station. This requires a refined materials management system. Third, each order must be tracked separately from order receipt until final delivery and each order is assigned to a specific end item. In commodities, there is only one design. All components and end items are identical, thereby simplifying the management tasks and reducing the costs.

Some forms of mass customization appear similar to the mixed model assembly line. The main difference is that mass customization requires that each order be tied directly to an end user customer. Often, mixed model assembly line products are made-to-stock or pulled from distribution, but not by customers, as evidenced by the large finished goods inventory of car manufacturers in the recent economic downturn. The volume-variety model still does not adequately capture mixed model assembly nor most forms of mass customization.

2.4.2 The Third Dimension – Variation

The third dimension process variation is defined as the amount of change required of the process to produce each of the orders (Figure 2.2). This dimension is of particular concern to mass customizers as it reflects the amount of modularity inherent in the product structure. Variation can be represented by the mix of end products that is achieved without stopping the process. For mass customization, this could be restated as the amount of modularity that is in a product design. A more modular product will be able to achieve variation with little interruption.

Following Duray *et al.* (2000), modularity can be employed at different points in the manufacturing cycle: design, fabrication, assembly, and/or use. The point of the manufacturing cycle where modularity is employed will determine the amount of variation in the process. For example, a mixed models assembly line is not stopped to retool for each item but rather flows without interruption. Modularity is designed into the assembly stages of the manufacturing process, and the process is fairly standardized. For mass customized clothing, fabric is cut to specific dimensions in the fabrication stages of the cycle. This requires specific patterns for each customer. However, computer control cutting equipment can retool for this process without delay once the specific dimensions are programmed. For modularity in the design phase, products will require more flexible processes to adapt to the unique requirements. In general, modularity in the earlier stages of the manufacturing cycle will require flexible processes while modularity in the later stages will be less disruptive to the process flow.

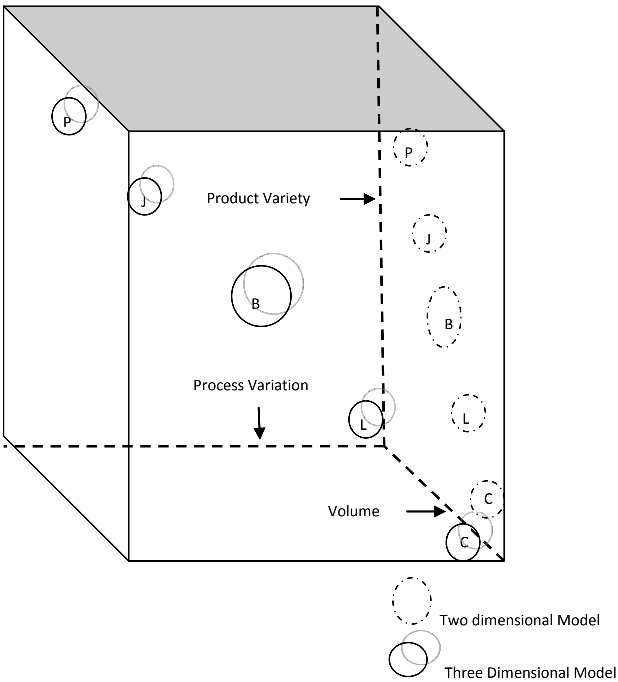

Figure 2.2 Process type placement on the proposed model (project, jobbing, batch, line, continuous)

The classic example of assembled-to-order may have high end item variety but little or no process variation. The Toyota example is easily incorporated into the new model. Toyota has very standardized processes but can produce different variants of their cars through choices of options. Simple color choice or personalization is a very visible differentiator for the customer, while it may have little effect on the processes.

For engineered-to-order products, there may be a much greater distinction in the variation of the process depending on whether modularity is used. In engineered-to-order products without modularity, there will be a great deal of variation in the process as each item is specifically design in its entirety. For engineered-to-order products with modular components, the design and manufacturing lead-times will be much shorter. Some modules will be shared across all products thereby decreasing manufacturing time and cost. The new three dimensional matrix is capable of incorporating both regular and mass customized products.

By looking at each process type, you can easily see how variability occurs in the traditionally defined process types. Each type can incorporate variation. It is through process variation that a distinction can be made within each process type. The three dimensional matrix supports the traditional process types on the diagonal in the cube. Each process type is elongated on the third dimension of variation to show the differences in process variation. For each process, the example archetype now incorporates process variation. Traditional projects have high variety and low volume, but the new model can incorporate either truly unique projects or those projects that have some degree of repeatability. For example, software development projects may present revolutionary new codes and methods and be truly unique endeavors. In opposition, software development projects may as well have a repeatable sequence of steps that are used, and perhaps documented and required to be used, for each new project. With repeatable steps, the process has less variation than if it were a one-time only project. Both of these software development projects can be shown in the new model in the elongated description of the process type.

Job shop processes can have multiple levels of variation. In a traditional job shop, such as a commercial printer, each job would be truly unique. However, if component sharing modularity exists, the core technology or modules of the product are not uniquely designed for each order, resulting in reduced variation in the process. Sharing core technology can be seen in elevator or conveyor systems. The basic technology to create movement is the same in each product. However each unique product is designed to adapt to its specific installation.

Batch processes can contain the highest degree of variation through modularity. Since batch processes operate close to job shops on one side of the continuum and to line processes on the other, they are defined broadly. Batch processes can incorporate many forms of modularity. The type of batch process will be most dependent on the earliest point in the manufacturing cycle where the modularity is employed. If modularity occurs in the design or fabrication stages, the process will most likely have a more jumbled flow. If modularity is designed in the product at the fabrication or assembly stage, the process will have a more linear flow. The placement in the batch category may also be highly dependent on the volume and product variety.

Line processes have been discussed in previous sections. The examples of mixed model assembly lines and traditional standard product lines both occupy a similar space in this model reflecting their similarity in process, regardless of end item variety.

Using the new three dimensional model, one can go back to the original intent of the product process matrix and the ability to see industry, company or process evolution. Individual products can be mapped in the cube (Figure 2.3). Dell is the best known example of mass customization using an assembled-to-order process. The assembly line of Dell is tailored to produce high volume product with variation limited by the module design, with little variation in the process between items. For an engineered-to-order example, escalators are produced for indoor or outdoor use in varying lengths and gradations. However, the basic design of an escalator does not vary between sites. The production process will have some variation but the process steps will be similar for each product. Escalators have higher end item variety as each implementation is different. The product will have lower volumes and the process will have more variation than the Dell example. Modular office furniture is often an example of mass customization which incorporates modularity late in the manufacturing process. For made-to-stock, modular office furniture has great variety as customers can configure their product after

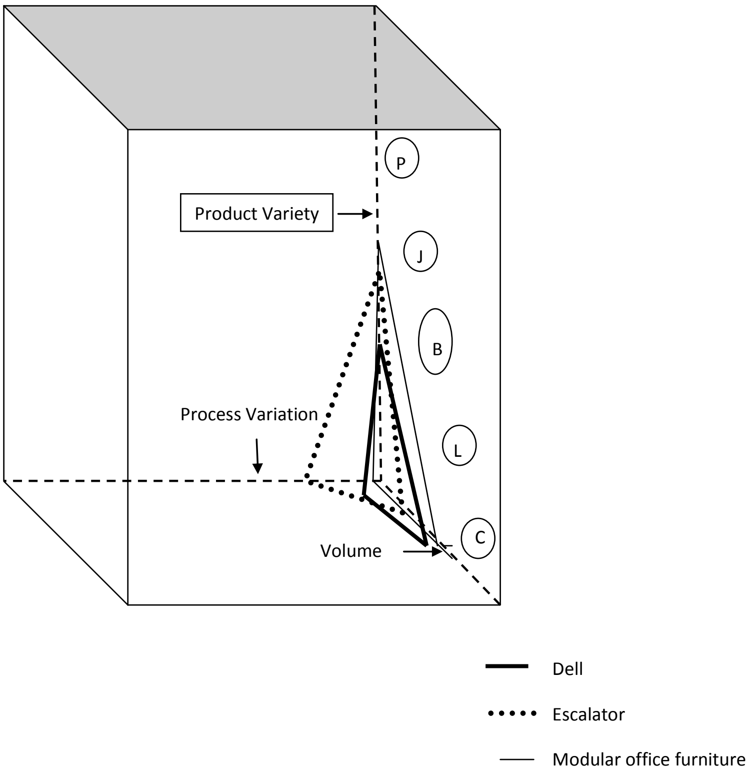

Figure 2.3 Placement of mass customizers on the proposed model

purchase. Since this is a consumer product, volume may be high. The modularity occurs so late in the process, perhaps even in use post sale, that there is little variation in the process. These examples give a small insight into how the new model may be used to map processes.

2.5 Future Directions

One question that immediately arises out of the new volume-variety-variation model is: "Where is the most profitable position on the cube?" For mass customizers, one would assume that the ultimate position on the cube would be high variety, high volume, and low variation. This positioning would portray the ultimate in mass customization capability. However, this position may not necessarily be financially profitable. A market must exist for the product and the functional strategies (marketing, operations, engineering, human resources, information systems, financial aspects, *etc.*) and must be aligned to take advantage of the mass customization capability. The concept of equifinality applies to this model; all positions on the matrix are capable of producing positive performance.

However, the new model can be tested using multiple companies to determine the appropriate environment for each process type. There may be environments where one process type would be more appropriate than another, and which therefore provide a higher financial performance. By examining high and low performers in each section of the cube, key success factors may be determined for each process type. The model could be populated with a large number of example processes to determine all the currently feasible positions. Differences between and within groupings would give a richer look into the components of the operating systems supporting these process types. Industries could be modeled by placing competitors on the cube and determining the relative strategic position of the companies. The new model lends itself to both case study and survey research.

2.6 Conclusion

The volume-variety-variation model provides a fresh perspective on process types in manufacturing. The new model easily incorporates both standard process types and the new competitive capabilities of mass customization. The model deconstructs the product process matrix resulting in a framework that is more adaptable to new process types. The discussion in this chapter introduces these new concepts to be used to better understand the placement of mass customization in the operations management lexicon.

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