Approaches to mass customization: configurations and empirical validation

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Abstract

Mass customization is a paradox-breaking manufacturing reality that combines the unique products of craft manufacturing with the cost-efficient manufacturing methods of mass production. Although this phenomenon is known to exist in practice, academic research has not adequately investigated this new form of competition. In this research, we develop a configurational model for classifying mass customizers based on customer involvement in design and product modularity. We validate this typology through an empirical analysis and classification of 126 mass customizers. We also explore manufacturing systems and performance implications of the various mass customization configurations. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Mass customization, once considered a paradox to be resolved in the future, has become an everyday reality for many manufacturers. Stanley Davis coined the term “mass customization” in his 1987 book, Future Perfect. Davis suggested that existing technology constrained possibilities for mass-customized products, markets, and organizations, although he said that the phenomenon would prevail in the future. More contemporary researches suggest that the advances in manufacturing, information technology and management methods since the publication of Future Perfect in 1987 have made mass customization a standard business practice (Kotha, 1995; Pine, 1993). The confluence of these advances allows producers to customize at low cost and customers to reap the benefits of customized products with relatively low prices.

The practice of mass customization does not fit the conventional paradigm of manufacturing management. Historically, companies chose processes that supported the production of either customized crafted products or standardized mass-produced products. This traditional practice means that customized products usually are made using low volume production processes that cope well with a great variety of products and with design processes that
can accommodate a high degree of customer involvement in specifying the product. In contrast, a mass production process is chosen for making standardized products in a high volume environment where great attention is paid to efficiency and capturing scale economies. Further, product variety is relatively low in mass production and customer involvement is sought through market research only to capture standard product design attributes that have wide appeal. In contrast to the traditional paradigm, Davis (1987) envisioned a one-of-a-kind product manufactured to customer specification without sacrificing scale economies. In this way, customers are able to purchase a customized product for the cost of a mass-produced item. Similarly, Pine (1993) defines the goals of mass customization as providing enough variety in products and services so that nearly everyone finds exactly what they want at a reasonable price.

Although these definitions provided by Davis and Pine sketch the essence of mass customization, they do not possess the specificity required to identify companies as mass customizers or how a company can achieve a mass customization capability. Accounts of mass customization practices in companies described in the literature label a broad range of production practices mass customization; however, the diversity of the practices and the companies further clouds the meaning of mass customization. In short, extant literature has not established good conceptual boundaries for mass customization, nor has that literature presented a means to distinguish among the vast array of mass customization practices in a way that lends clarity.

This paper addresses three important elements missing from the literature. First, we develop a conceptual model of mass customization to identify and classify mass customizers. This model is based on the key dimensions of mass customization and validated through literature, field studies, and survey testing. Second, we develop a classification scheme to group mass customizing companies according to the way they achieve mass customization. Third, we explore different approaches to mass customization implied by the typology by comparing the manufacturing approach of each type. Our approach yields mass customization configurations that are empirically validated.

We establish the external validity of the model through empirical investigation of companies in six different industries. By using a number of industries in our sample, we address the issue of whether mass customization is a robust concept applicable across a range of industries, or whether it can be applied only to a limited number of special cases. On the other hand, by limiting the study to six industries, we are able to show that mass customization is a competitive choice open to a number of competitors in the same industries. In addition, we are able to control and test for industry effects.

2. Research proposition

Because mass customization is a relatively new idea; scholarly literature related to the topic is scant. In this research, we seek to uncover the important dimensions of mass customization from an operations perspective. We argue that the essence of mass customization lies in resolving the seeming paradox of mass producing custom products by finding efficiencies in two key dimensions. First, mass customizers must find a means for including each customer’s specifications in the product design. Second, mass customizers must utilize modular design to achieve manufacturing efficiencies that approximate those of standard mass produced products. Choices made by mass customizers on how they approach these two dimensions suggest a useful typology of mass customization:

Proposition 1. Mass customizers can be identified and classified based on two characteristics: the point in the production cycle of customer involvement in specifying the product and the type of product modularity employed. Each mass customization configuration exhibits a distinct approach to the manufacture of mass-customized products.

More specifically, we will suggest a classification with four fundamental, mutually exclusive types of mass customizers. We argue that this typology will also serve to identify manufacturers that do not mass customize.
The underlying choices with respect to customer involvement in design and modularity type imply different approaches to manufacturing processes, policies, and technologies, thereby making the classifications useful to manufacturers. In other words, knowing the point at which a mass customizer involves the customer in product design and the approach to modularity taken by the mass customizer suggests the configuration of processes and technologies that will be used in designing and making the mass-customized product. We concede that other characteristics such as flexibility, agility, or service approach also play important roles in mass customization viewed from an operations perspective. We argue, however, that customer involvement and modularity are the key elements in defining mass customization approach. This paper develops and tests this argument in detail in the following manner.

To explore this proposition, we first develop the dimensions of mass customization and discuss the implications of the mass customization configurations from a theoretical perspective. Then, the model is operationalized through an empirical evaluation of 194 manufacturing plants. These data are used to establish the mass customization dimensions in practice, classify actual plants, and explore these mass customization configurations in the context of the manufacturing systems variables employed.

3. Mass customization dimensions

The boundaries of mass customization can be more clearly established by delineating two issues: (1) the basic nature of customization and (2) the means for achieving customization at or near mass production costs. The first issue, the nature of customization, has been addressed by Mintzberg (1988). A customized product is designed specifically to meet the needs of a particular customer. Variety provides choice for customers, but not the ability to specify the product. A great deal of variety in the marketplace may satisfy most customers and, hence, substitute for customization; but customization and variety are distinct. For example, having hundreds of varieties of breakfast foods on the shelf of the supermarket is different from being able to specify one’s exact breakfast food formulation from the cereal supplier. It is important to realize that the availability of hundreds of varieties probably limits the market appeal of customized products for most customers. However, variety is not customization. As Womack (1993) remarks, this distinction between customized products and product variety is overlooked in the examples of companies pursuing mass customization by Pine (1993). This distinction is important because it implies that customers must be involved in specifying the product.

The second issue that we delineate — the method of achieving customization at or near mass production costs — addresses the “mass” in mass customization. How can unique products be developed and manufactured in a mass production fashion? How can high volume, low cost customization be implemented? Pine (1993) argues that modularity is a key to achieving mass customization. Modularity provides a means for the repetitive production of components. Modularity allows part of the product to be made in volume as standard modules with product distinctiveness achieved through combination or modification of the modules. Therefore, modules that will be used in the custom product can be manufactured with mass production techniques. The fact that parts or modules are standardized allows for mass-customized products to achieve the low cost and consistent quality associated with repetitive manufacturing. Thus, modularity can be viewed as the critical aspect for gaining scale or “mass” in mass customization. We further develop the issues of customization and modularity to provide a basis for a more comprehensive definition of mass customization.

3.1. Customization issues

A customized product must be designed to customer specifications. From the literature, it is apparent that identifying the point of initial customer involvement is critical to determining the degree of customization. Mintzberg (1988) and Lampel and Mintzberg (1996) developed the idea that the level of customer involvement in the production cycle can play a critical role in determining the degree of customization. McCutcheon et al. (1994) argued that
the production stage where a product is differentiated is a key variable in process choice decisions. By extension, the point of customer involvement in specifying the product also may be related to choices about the customization process. We argue that the point of customer involvement in the production cycle is a key indicator of the degree or type of customization provided. For purposes of defining mass customization, we take a narrow view of the production cycle. Specifically, we include four points in the production cycle: design, fabrication, assembly, and use. If customers are involved in the early design stages of the production cycle, a product could be highly customized. If customer preferences are included only at the final assembly stages, the degree of customization will be not as great. In this manner, point of customer involvement provides a practical indicator of the relative degree of product customization.

Thus, we argue that products with early customer involvement are relatively more customized than those with later involvement. The typology of Mintzberg (1988) supports this reasoning. Mintzberg views customization as taking one of three forms: pure, tailored, or standardized. Each form differs in the portion of the production cycle involved and the degree of uniqueness of the product. A pure customization strategy furnishes products designed and produced from scratch for each individual customer. Pure customization includes the customers in the entire cycle, from design through fabrication, assembly and delivery and it provides a highly customized product. A tailored customization strategy requires a basic design that is altered to meet the specific needs of a particular customer. In this case, the customer enters the production cycle at the point of fabrication where standard products are modified. In a standardized customization strategy, a final product is assembled from a predetermined set of standard components. Here, the customer penetrates the assembly and delivery processes through the selection of the desired features from a list of standard options. The categorization of Mintzberg (1988) shows that the type of customization chosen by the producer implies different levels of customer involvement in product design and different points at which that involvement begins. These different customization strategies also imply degrees of customization, with

pure customization providing the highest degree of customization with all of the products designed specifically for the customer, and standard customization the lowest degree with only an arrangement of components determining the customized configuration.

3.2. Modularity issues

Mass customization requires that unique products be provided in a cost-effective manner by achieving volume-related economies. A number of observers suggest that modularity is the key to achieving low cost customization. Pine (1993) stated that true mass customization requires modularity in production, although he was not specific about where or how modularity should be used. Baldwin and Clark (1994) discussed modularity in production as a means to partition production to allow economies of scale and scope (Goldhar and Jelinek, 1983) across the product lines. McCutcheon et al. (1994) suggested that modular product design is the best way to provide variety and speed, thereby alleviating the customization responsiveness squeeze, which occurs when customers demand greater variety, and reduced delivery times simultaneously. A modular approach can reduce the variety of components while offering a greater range of end products. Flexible manufacturing systems (FMS) provide for lower cost customization through the use of some form of modularity in their design. In the design of products for FMS manufacture, program modules for different product characteristics are used to achieve fast set-up manufacture. These program modules are used to repeat manufacturing sequences across products and provide for modularity in the design of new products. Therefore, FMS production contains modularity.

Similarly, Ulrich (1992) argued that modularity can help increase product variety, but he also addressed the use of modularity to shorten delivery lead times, and provide economies of scope. Pine et al. (1995) asserted that to be successful, mass customizers must employ a production/delivery strategy that incorporates modularity into components and processes. In essence, the literature suggests that modularity can facilitate increasing the number of product features available while also decreasing costs.
Therefore, it follows that the successful implementation of mass customization requires effective use of modular product designs.

Modularity is multifaceted in concept and is generally described either in relative terms or as a typology. For example, Ulrich and Eppinger (1995) viewed modularity as a relative property with products characterized as more or less modular in design. To better distinguish types of mass customizers, a range of modularity types should be considered. Modularity can take a number of forms. The various types of modularity found in production environ-

These types of modularity can be used separately or in combination to provide a customized end product.

Component-sharing Modularity
Common components used in the design of a product. Products are uniquely designed around a base unit of common components
Example: Elevators

Component-swapping Modularity
Ability to switch options on a standard product. Modules are selected from a list of options to be added to a base product
Example: Personal computers

Cut-to-Fit Modularity
Alters the dimensions of a module before combining it with other modules. Used where products have unique dimensions such as length, width, or height. Example: eyeglasses

Mix Modularity
Also similar to component swapping, but is distinguished by the fact that when combined, the modules lose their unique identity. Example: House paint

Bus Modularity
Ability to add a module to an existing series, when one or more modules are added to an existing base. Example: Track lighting

Sectional Modularity
Similar to component swapping, but focuses on arranging standard modules in a unique pattern. Example: Legos

Fig. 1. Modularity types (Ulrich and Tung, 1991).
ments were discussed in Pine (1993), although he does not explicitly link modularity types with mass customization. More recently, Ulrich and Tung (1991) developed a similar typology of modularity. Fig. 1 depicts these types of modularity.

Modularity can represent many forms of flexible manufacturing. For example, Levi Straus’ custom-fit jeans are made possible through their flexible manufacturing process, which cuts each unique pattern prior to stitching and sewing. In the Ulrich and Tung typology, the Levi’s example can be described as a “cut-to-fit” modularity. The unique patterns are built upon one traditional style of five-pocket jeans that is altered or “cut-to-fit” the specific dimensions of the customer. These “made-for-you” jeans are available for alteration only within a limited size range (0–18). The concept of modularity is a basic building block in the manufacturing situations traditionally considered to be flexible.

To make the concept of modularity operational, Ulrich and Tung’s typology is adopted and integrated into the framework of the production cycle, as seen in Fig. 2. Using the design/fabrication process as a reference point, the different types of modularity can be assigned to the phases of the product cycle.

For example, during the design and fabrication, modules can be altered or components can be fabricated to provide for the unique requirements of the customer. Cut-to-fit and component sharing modularity require that components are newly designed or changed; therefore, these types of modularity must take place during the design and fabrication stages. With cut-to-fit modularity, components are altered to the physical dimensions specified by the customer. This alteration requires the fabrication of a component that is standard except in a specific dimension, e.g., length, that is specified by the customer. This customization necessarily takes place during the design/fabrication stages. In general, component sharing also takes place in the design and fabrication stages. Although a standard base unit is incorporated into the product, additional components are fabricated to provide an end-product that meets customer specification. Modularity incorporated in the standard base simplifies fabrication and reduces the total cost of the customized product.

During the assembly and use stages, modules are arranged or combined according to customer specification, but components cannot be manufactured nor can modules be altered. Component swapping, sec-

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**Fig. 2.** Customer involvement and modularity in the production cycle.

- **Point of Customer Involvement**
  - High degree of customization
  - Low degree of customization

- **Production cycle**
  - Design
  - Fabrication
  - Assembly
  - Use

- **Modularity Types**
  - Component Sharing
    - Cut-to-fit
  - Component Swapping
    - Mix, Bus, Sectional

Components are original designs or alterations to standard designs

Components are standardized and repeatable
tional, mix, and bus modularity use standard modules without alteration; therefore, these types of modules can be combined during the assembly and use stage of the production cycle. In each case, standard modules are combined to form an end-product that is specified by the customer. In their pure form, component swapping, sectional, mix, and bus modularity all provide customization by allowing customers to specify a choice among a number of standard modules without the option of altering any of the modules. In particular, sectional modularity can also be used in the post-production phases where the customer combines components across manufacturers (e.g., stereo components). Sectional modularity may require the adoption of uniform industry standards (Garud and Kumaraswamy, 1993).

When customer involvement in specifying the product and modularity types are combined, mass customization can be fully realized in practice. Customer involvement provides the customization while the modularity restricts the range of choice to decrease the possible variety of components, thus allowing for repetitive manufacturing. When modularity is employed in mass-customized products, product distinctiveness is a result of either the combination of standard modules into a finite number of permutations or the alteration of prescribed modules into a limited range of products. In contrast, purely customized products are infinite in permutations resulting from craft manufacture. Modularity bounds the degree of customization of the product and distinguishes mass customization from pure customized products. The fact that these parts or modules are standardized allows for mass-customized products to achieve the low cost and consistent quality associated with repetitive manufacturing.

4. Mass customization configurations

In Section 3, we argue that the model of mass customization that emerges from the literature uses two critical identifiers: customer involvement in the production cycle and modularity type. Bringing these concepts together, mass customization can be defined as building products to customer specifications using modular components to achieve economies of scale. Distinctions can be made among mass customizers based on the point at which the customer becomes involved in the design process and the type of modularity employed by the producer. These two attributes are interrelated and when taken together suggest mass customization archetypes. Fig. 3 shows the dimensions juxtaposed, with point of customer involvement in design and type of modularity forming the archetypes.

4.1. Classification matrix

As shown in Fig. 3, mass customizers can be identified and classified based on customer involvement and modularity type. Mintzberg’s definitions of customization provide a good beginning for describing the degree of customer involvement and can be seen down the left-hand column. When customers are involved at the design stage, products can be altered to fit customers’ expectations with infinite variety. In the fabrication stage, customer involvement means specifying relatively incremental changes to a standard design. In the assembly stage, customer requirements must be met from a finite set of components. These two stages represent a time in the production cycle when customer preferences require physically altering existing components or constructing unique components. Building further on Mintzberg’s ideas, customer involvement in the post-production or use stage should also be considered. A product that can be adjusted or manipulated by the consumer to provide customization at the point of delivery can also be considered mass-customized. Both Davis (1987) and Pine (1993) discuss this type of post-production customization which we refer to as “point of sale customization”.

Modularity provides the basis for repetitiveness in production or the “mass” in mass customization. Baldwin and Clark (1994) use phases in a product’s development to circumscribe the type of modularity employed. They argue that the type of modularity differs at different points in the production cycle. The typology of Ulrich and Tung (1991) identifies types of modularity that can be employed that, by definition, fit the stages of the production processes of design and manufacturing. The model, depicted in Fig. 3, overlays Baldwin and Clark’s production
Modularity is addressed across the top row of the model. When modules are designed to provide the ability to modify components, modularity will be utilized in the design and fabrication stages of the production cycle. In the later stages of the production cycle, assembly and use, modules are added or interchanged, but not altered.

4.2. Archetypes

The juxtaposition of customer involvement and modularity create four groups or mass customization types. Group 1 includes both the customer involvement and modularity occurring during the design and fabrication stages. Since in this instance both the customer involvement and modularity require fabricating a customized component, we name this group the Fabricators. Fabricators involve the customers early in the process when unique designs can be realized or major revisions can be made in the products. Fabricators closely resemble a pure customization strategy, but employs modularity to gain commonality of components. An example of a Fabricators is Bally Engineered Structures, a manufacturer of walk-in coolers, refrigerated rooms, and clean rooms described by Pine et al. (1993). Product modules are cut-to-fit specific dimensions of the customer, providing unique rooms manufactured from modular components. Modular components are altered in fabrication to “fit” the specific building. In addition, unique components may be designed for
specific application. Customers are involved in the design and fabrication stage of the production cycle, and component sharing and cut-to-fit modularity are used to provide the mass-customized product.

Group 2 incorporates customer involvement in product design during the design and fabrication stages but uses modularity during the assembly and delivery stages. Because customer involvement precedes the use of modularity, we refer to this group as Involvers. With Involvers, customers are involved early in the process although no new modules are fabricated for this customer. Customization is achieved by combining standard models to meet the specification of the customer. Perhaps, the early involvement of the customer imbues the customer with a greater sense of customization or ownership of the product design, although no customized components are fabricated. Because they do not fabricate customized components to customer specification, Involvers capture greater economies of scale than Fabricators while maintaining a high level of customer involvement. An example of this type of mass customizer is Andersen Windows. Andersen uses a design tool that helps customers develop the specific design of their windows. However, products are produced from 50,000 possible window components (Pine et al., 1995). Components are not designed or fabricated for the specific application. However, customers specifications are “designed” and then, the components are selected by the manufacturer to fit this design. The sheer number of components prohibits the customer from simply choosing from a prescribed list, as with component swapping modularity. The customer is involved in the specification during the design and fabrication stages, but the product is assembled from modular components in the assembly and use stages of the production cycle.

Group 3 involves the customer during assembly and delivery but incorporates modularity in the design and fabrication stages. Group 3, which we call Modularizers, develops a modular approach in the design and fabrication stages, although customers do not specify their unique requirements until the assembly and use stage. Modularizers use modularity earlier in the manufacturing process than when customization occurs. This modularity may be considered component commonality. In this type, Modularizers may not gain maximum customization advantages from modularity. For example, a mass customizing upholstered furniture manufacturer uses modularity in the design of a sofa frame which is used in many product lines (component sharing). This modularity provides for component commonality, but is not used for customization. In the assembly stage, a customer chooses a fabric or wood finish from a prescribed list (component swapping), providing some degree of customization. Modularizers incorporate both customizable modularity in the later stages of the production cycle and non-customizable modularity in the design and fabrication stages of the production cycle.

Group 4 brings both customer involvement and modularity to bear in the assembly and use stages. We call this group Assemblers. Assemblers provide mass customization by using modular components to present a wide range of choices to the customer. Assemble-to-order manufactures can be considered mass customizers if customers specify products from a pre-determined set of features. Assemblers more closely resemble the operations of mass production than the other configurations of mass customers. Assemblers differ from mass producers in that the products have been designed so that the customer can be involved in specifying the product. Because the range of choices made available by Assemblers is large relative to mass producers, customers perceive the product to be customized. Motorola pagers, a recognized leader in mass customization, can be considered a “mass standard” customizer. Pagers can be designed to a customer’s specification from a wide range of options that are added at the production phase (Pine, 1993; Donlon, 1993).

In short, mass customizers can be typed on the basis of two key dimensions: modularity and customer involvement. These same dimensions can be used to identify companies that do not possess mass customization capabilities. Manufacturers that do not involve the customer in the design process or do not employ modularity should not be considered mass customizers. Without some degree of customer involvement in the design process, a product cannot be considered as customized. Companies that do involve the customer in the design process, but do not exhibit modularity in manufacturing, are also excluded. These manufacturers should be considered the traditional customizers, a producer of one-off
It is interesting to note that applying this typology allows us to conclude that some widely cited examples of mass customization do not fit the bill. For example, Davis (1987) used Cabbage Patch dolls as an example of gaining a competitive edge through mass customization. While it is true that each doll is a unique end-item which customers select at a retail outlet, the customer does not participate in the design of the doll. To be mass-customized, the producer would have to offer customers a means of having a doll made to their specifications, such as eye or hair color. Similarly, Pine (1993) used Swatch watches as an example of mass customization. Swatch offers customers an extraordinarily wide selection of products. Although this provides great variety, customers do not have the ability to specify the design in any way; therefore, this example misses the mark. These examples illustrate that the two-dimensional operational definition of mass customization lends clarity to the more casual definitions found in the literature.

5. Empirical validation

The conceptual typology presented above has been validated using both secondary and primary data and both case studies and surveys. In using multiple methods, we follow the advice of Harrigan (1983) who argued for using multiple research methodologies (or granularities) for testing business strategy models. Case studies provide the ability to capture nuances of a company’s strategy, while surveys of larger samples allow more confidence in general conclusions.

The typology validation process itself provides for three levels of granularity (Harrigan, 1983). Initially, the model was validated using case examples from practitioner journals which discuss mass customization examples. Fifteen companies were identified that appear, based on the information provided in the literature, to exhibit mass customization characteristics. The next level of validation included interviews with managers from companies randomly selected from an APICS directory to determine the extent of product customization. Based on the information obtained in the interview, more than half of the companies selected at random could be considered mass customizers. These interviews suggested that mass customization might be practiced in some form by a fairly large portion of companies drawn at random. A more intensive study of mass customization, including plant visits and phone interviews, was then conducted in the furniture industry. The furniture industry was selected for plant visits since this industry has traditionally provided customization of end-products. This more in-depth study of furniture manufacturers was used to better illustrate mass customization characteristics prior to the survey, as well as validate the survey instrument. The third level of validation included a survey of 639 companies in industries anticipated to include mass customizers based on evidence from the literature. This three-level validation process provides both coarse- and fine-grained looks at mass customization configurations to substantiate the conceptual model. In this paper, we concentrate on the model validation through the survey and use the data collected from the 194 respondents to validate the model.

5.1. Survey methods

The sample was drawn from the Society of Manufacturing Engineers (SME) membership data. Respondents were selected based on title (Vice President of Manufacturing, Manufacturing Manager, Plant Manager) to assure that respondents represented a high level of responsibility. Executives in the sample were selected randomly but their companies were limited by size (more than 50 employees), industry (furniture and fixtures, fabricated metal products, machinery except electrical, electric and electronic equipment, transportation equipment, and instruments and related products) and geography (Indiana, Massachusetts, Michigan, North Carolina, Ohio, and Pennsylvania). Size and geographic limitations were imposed in the interest of homogeneity and efficiency. Because we seek to understand mass customization practice rather describe its proliferation, industries were selected on the basis of external evidence suggesting that mass customization was fairly common in these industries. Using the methods suggested by Dillman (1978) and Salant and Dillman (1994), the questionnaire was sent to 639 plants with 194 responding (30.4%).
To determine if the respondents differed significantly from those that did not respond, the job classification of the respondents and total sample were compared. The portion of respondents in each category was compared to the expected number of respondents based on the percentage of each category represented in the total sample. A Chi-squared test of the expected and actual number of respondent was not significant at the level of $\alpha = 0.05$. This finding supports the assertion that there was no systematic difference between those companies responding to the survey and those that did not.

In addition, a similar test was performed using industry classification. The portion of respondents in each category was compared to the expected number of respondents based on the percentage of each category represented in the total sample. A Chi-squared test of the expected and actual number of respondent was significant at the level of $\alpha = 0.05$, indicating that respondents may differ from non-respondents in industry representation. This result is not surprising as the questionnaire was directed at plants producing customized products and standard product manufacturers may have been reluctant to respond. The level of customization of products will most likely differ between the industries represented. Since customizers are more likely to respond, this may explain the respondent bias based on industry codes.

Multiple respondents from the same plant are compared to assess the degree of agreement and thereby appraise the reliability of responses from the primary informants. James et al. (1984) developed a method to assess the degree of agreement among raters. Data for two respondents were collected for 47 plants in the present study. Threshold values have been established to determine “good” reliability, where values closer to 1.0 represent better agreement. All values reported for the scales used exceed 0.70 and, therefore, are judged to have “good” agreement.

To focus respondents on the customized portion of their product lines that may be produced at a plant, the following definition of customization was included in the survey: Customized products are those products that are designed, altered, or changed to fit the specifications of an end-user. Please answer the following questions regarding only your “customized” products. Component or intermediate products are only considered to be customized if the user of the finished product dictates or influences the specifications of the component.

5.2. Instrument development

To the extent possible, established scales were used to enhance validity, reliability and generalizability of measures. Established scales were used extensively for the contextual variables and will be described in Section 5.2.2. When proven established scales were not available, survey questions were developed based on existing literature. The classification variables, customer involvement and modularity were developed from literature and are discussed in detail in Section 5.2.1.

5.2.1. Classification variables

Because of the paucity of empirical research published on mass customization, two key scales were constructed: customer involvement in the design process and product modularity. Exploratory factor analysis using Principle Components and a Varimax rotation was used for the two scales representing customer involvement and modularity, respectively, as the initial determinant of factor composition following the criteria recommended by Hair et al. (1992). These authors suggested that for a simple structure factor solution, only one loading on any factor for each variable should be significant, and that the lowest factor loading to be considered significant would, in most instances, be 0.30. These criteria were upheld for both the customer involvement and modularity scales. All items had significant factor loadings on at least one factor as described by Hair et al. (1992).

Following the logic recommended by Carmines and Zeller (1979), the number of factors was determined using an external validation technique. Gerbing and Anderson (1988) and Anderson et al. (1987) suggested a similar technique using the correlation of factors with external variables to test for unidimensionality of factors. External validation techniques and inter-item analysis were used to determine the number and composition of the factors and to validate the unidimensionality of these factors. These methods are supported by Flynn et al. (1990), Ander-
son and Gerbing (1982), and Carmines and Zeller (1979). Further factor simplification and reliability assessments were made using Cronbach’s reliability coefficients. The resulting factors were developed using the factor analysis to produce individual standardized factor scores.

5.2.1.1. Customer involvement. To determine the point of customization in the production cycle, this survey addressed the stages where an end-user customer participates in specifying the product. Using the definition of Mintzberg (1988) as a guideline, items were included that address the various ways products can be specified from customers. These questions were designed to measure the point of customer involvement in the design process as one of the following: design, fabrication, assembly, or use. Respondents were asked to indicate the level of agreement, from strongly disagree to strongly agree, with each customer-involvement-related statement using a seven-point Likert scale.

The initial exploratory factor solution was simplified using inter-item analysis and validated following the logic of construct validation, as described above. One item was dropped from each of the scales. In factor one, “customers can assemble a product from components” was omitted to increase the Cronbach’s alpha coefficient from 0.7422 to 0.7657. In factor two, “customer specifications are used to alter standard components for each order” was dropped to improve the Cronbach’s alpha coefficient from 0.6255 to 0.6404. Both these factors’ Cronbach’s coefficient alpha exceed the 0.60 threshold often cited for exploratory work (Nunnally, 1978) to assess inter-item reliability. The resulting two factors represent customer involvement in the design and fabrication stages. Customers can change the actual design of the product or introduce new features rather than selecting features from a listing as specified in the factor, CI_ASMUSE. This involvement requires the design or fabrication of a unique component for such customers.

In the second factor (CI_ASMUSE), all items relate to the involvement of the customer through the selection of standard components or products from a prescribed listing of features. This involvement does not allow for new designs or features to be produced; therefore, the customer is not involved in design and fabrication, but instead in the assembly or use stage of the production cycle.

In combination, these two factors, CI_DESFAB and CI_ASMUSE, accurately depict the role of the customer in the design process as seen in Fig. 3. CI_DESFAB represents the involvement of the customer at the beginning stages of the production cycle, when product are designed and components are fabricated. CI_ASMUSE represents involvement of the customer in the assembly and use stages of the production cycle. Positive values for these scales show that the respondent agrees that a particular mode of customer involvement is used in their customized product line. Negative values show that the respondents disagree that customers are involved at a particular point in the production cycle.

5.2.1.2. Customer involvement in the design and fabrication stages (CI_DESFAB).

- Customer’s requests are uniquely designed into the finished product;
- Each customer order requires a unique design;
- Customers can specify new product features;
- Each customer order requires the fabrication of unique components prior to assembly; and
- Customers can specify size of products.

5.2.1.3. Customer involvement assembly and use (CI_ASMUSE).

- Each customer order is assembled from components in stock;
- Customers can select features from listings;
- Customer orders are filled from stock; and
- Customers can assemble a product from components.

The first factor (CI_DESFAB) represents customer involvement in the design and fabrication stages. Customers can change the actual design of the product or introduce new features rather than selecting features from a listing as specified in the factor, CI_ASMUSE. This involvement requires the design or fabrication of a unique component for such customers.

In the second factor (CI_ASMUSE), all items relate to the involvement of the customer through the selection of standard components or products from a prescribed listing of features. This involvement does not allow for new designs or features to be produced; therefore, the customer is not involved in design and fabrication, but instead in the assembly or use stage of the production cycle.

In combination, these two factors, CI_DESFAB and CI_ASMUSE, accurately depict the role of the customer in the design process as seen in Fig. 3. CI_DESFAB represents the involvement of the customer at the beginning stages of the production cycle, when product are designed and components are fabricated. CI_ASMUSE represents involvement of the customer in the assembly and use stages of the production cycle. Positive values for these scales show that the respondent agrees that a particular mode of customer involvement is used in their customized product line. Negative values show that the respondents disagree that customers are involved at a particular point in the production cycle.
5.2.1.4. Modularity. The type of modularity employed is suggested to be a critical issue in understanding a manufacturer’s approach to mass customization. Items addressing the modularity of customized product lines are based on the definition of modularity types of Ulrich and Tung (1991) (Fig. 2).

The initial exploratory factor solution was simplified using inter-item analysis and validated following the logic of construct validation of Carmines and Zeller (1979). The resulting two-factor solution is presented below.

The first factor (MOD_FAB) includes four items that reflect modularity issues involving design or changes to the components for a specific customer. MOD_FAB can be considered a measure of modularity in the design or fabrication of a product. The second factor (MOD_STD) contains five items that address modularity in the form of options to standard products or interchangeability of components. This type of modularity most likely will be utilized in the assembly stages of a manufacturing process. These two factors represent two distinct approaches to modularity. The components of these factors are listed below.

5.2.1.5. Modularity through fabrication (MOD_FAB).

- Components are designed to end-user specifications;
- Components are sized for each application;
- Components are altered to end-user specifications; and
- Component dimensions are changed for each end-user.

5.2.1.6. Modularity through standardization (MOD_STD).

- Products have interchangeable features and options;
- Options can be added to a standard product;
- Components are shared across products;
- New product features are designed around a standard base unit; and
- Products are designed around common core technology.

Reliability assessments were made using Cronbach’s reliability coefficients. MOD_FAB achieved a Cronbach’s alpha of 0.7887 and MOD_STD yielded a coefficient of 0.6901. These alpha values both exceed the suggestion of 0.60 for exploratory research by Nunnally (1978).

When taken together, these two factors provide a measure of the types of modularity in use. MOD_FAB, when positive, indicates that the respondent agrees that some components are fabricated or sized to provide customization in their products. MOD_STD, when positive, indicates that the respondent agrees that features and options are added to standardized components or base technologies to achieve customization of end-products.

5.2.2. Contextual variables

The typology is explored using manufacturing decision variables that reflect the paradoxical nature of mass customization. Mass customizers can choose to develop manufacturing systems that are based on the traditional manufacturing practices of “custom” craft or standard “mass” produced products. Three categories of structure and infrastructure manufacturing decision variables (Hayes and Wheelwright, 1984) were used to represent the manufacturing system variables that are implicit in the tactical operation’s concepts of “mass” and “custom”. To explore the nature of “mass” in a manufacturing system, the structural variables of process choice and technology were used. Inherent in the process choice decision is an implication of product volumes as seen in the Product–Process matrix variables (Hayes and Wheelwright, 1984). If high volumes are anticipated, as in standard product production, line processes are selected over job shop processes that are reserved for craft production. Therefore, the selection of line processes may imply that mass customizers are utilizing a large volume of modules or standard components. Process choice was represented by the respondent assessing the usage rates of the traditional process forms: job shop, batch, line, continuous. To capture the usage of purchased components, “purchased from suppliers” was added. Respondents were asked to identify, on a seven-point Likert scale, the appropriate level of usage expressed as a percentage of the products from “No Products — 0%”,

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through “Some Products — 50%”, to “All Products — 100%”.

To update the traditional process choice alternative, technology usage also was selected as an indicator of “mass” manufacturing techniques. Newer manufacturing technologies may provide similar indications of higher volume production of standard parts or modules. Technology variables were developed based on a set of items in the Boston University Manufacturing Futures Project (Miller and Vollman, 1985; Ward et al., 1988). These items have been used effectively and have been deemed reliable (De Meyer and Ferdows, 1985; Boyer et al., 1996). These scales develop three technology variables: design, manufacturing and administrative. Administrative technologies are used to represent process control methods. Variables were included to represent design and manufacturing technologies to better examine the nature of the manufacturing approach of each type. Design technologies include: Computer-Aided Design (CAD), Computer-Aided Engineering (CAE), and Computer-Aided Process Planning (CAPP). The manufacturing technologies include: Computer Numerical Control (CNC), Computer-Aided Manufacturing (CAM), Robotics, Real-time process control system, Group Technology (GT), FMS, and bar coding/automatic identification. The respondent was asked to “Please indicate the extent to which the following are used for your ‘customized’ products”. The seven-point Likert scale was anchored at 1 with “not used — 0%”, at 4 with “used for some orders — 50%”, and at 7 with “used for all orders — 100%”.

Customization of products can also be assessed by the usage of variables representing production planning and material control methods as described by Hayes and Wheelwright (1984). Administrative technologies can be used to assess these methods. In addition, Vickery et al. (1999) used a firm’s made-to-order (MTO) capability to capture the extent to which a company customizes. The use of production planning methods to facilitate MTO manufacturing was used as a tactical representation of customization in manufacturing systems. Variables were included to explore administrative technology and production control methods. Administrative technologies were developed from the scales described above (De Meyer and Ferdows, 1985; Boyer et al., 1996). Administrative technologies include: Electronic Data Interchange (EDI), Material Requirement Planning (MRP), Decision Support Systems (DSS), and Knowledge-Based Systems. These technologies can be used to facilitate the production planning and material control functions.

Production planning techniques also were measured by assessing the usage of different methods: MTO, made-to-stock (MTS), assemble-to-order (ATO) and JIT. The respondent was asked to “Please indicate the degree to which the following production planning techniques are used for my ‘customized’ product line”. The seven-point Likert scale was anchored with “strongly disagree” and “strongly agree”.

5.3. Financial performance

Business performance is a crucial indicator for all strategic configurational works (Ketchen et al., 1993). To obtain a relative measure of performance while preserving privacy, this study used perception of performance in relation to competitors. Return on investment, return on sales (profit margin), and market share were used to measure performance relative to competitors. In addition, growth in these measures, as well as sales growth, was used to capture trend in performance. These measures have been used most recently as a group in Boyer et al. (1997) and Vickery et al. (1994). This performance factor achieved a Cronbach’s alpha of 0.914, which exceeds suggestions for exploratory research by Nunnally (1978).

6. Operationalized model

Customer involvement in the production process determines the degree of uniqueness of the product, and is represented by two variables, CI_DESFAB and CI_ASMUSE. CI_DESFAB represents involvement in the design and fabrication stage while CI_ASMUSE represents involvement during the assembly or use phases. Modularity follows a similar pattern. Modularity in the design and fabrication of a product is represented as MOD_FAB, and MOD_STD represents the use of standardized components in the assembly or use phases of a production.
6.1. Classification criteria

To classify any company, the specific combination of customer involvement and modularity variables must be examined. In practice, it is reasonable to assume that once a customer is involved in the process, or modularity is employed, that involvement or modularity would carry throughout the production cycle. For example, if a customer’s initial point of involvement is in the design stage of the production cycle, the customer’s preference would be incorporated throughout the remaining stages of fabrication, assembly, and use. With regard to modularity, a similar situation exists. If a product were manufactured from modular components in the design process, these modular components would be included in the product throughout the production cycle. Since only one measure is required of each company for each construct, either customer or modularity, will be used to represent the respective variable for that company. For each case, a set of two values, one that corresponds to the customer involvement axis and one that represents the modularity axis, is needed.

To operationalize this concept, the factor scores corresponding to the earliest point of involvement, design and fabrication, of the product will be considered first. If a respondent company scores positively in the design and fabrication variable, this variable will be used to represent the construct on the axis. If a company’s response yields a negative score, the design and fabrication variable is excluded and the assembly and use variable is examined. A positive value on assembly and use is used to represent the construct, while negative values are excluded. If negative values occur for both the design and fabrication variable and the assembly and use variable, no value is assigned. Table 1 shows the mass customization groups and the corresponding variable values.

Once each company has been assigned one value for each of the variables, customer involvement and modularity, the classification process is simplified. Each respondent is assigned to a specific cell of the matrix based on the values used to create the variable. If a company has customer involvement and modularity variables assigned from the design and fabrication stages, these variables would be assigned to Group 1, Fabricators. If the variables assigned for both customer involvement and modularity were from the assembly and design stages, the case would be assigned to Group 4, Assemblers. The classification of 194 companies resulted in 126 mass customizers: 77 Fabricators, 15 Involvers, 17 Modularizers and 17 Assemblers.

6.2. Industry effects

The groups were tested to determine the effects of industry on group membership. Using SIC codes, plants were grouped into similar SIC classifications. SIC data were available for 116 of the 126 mass customizers. A Chi-square test of group membership and SIC category was not significant ($p = 0.56$). Therefore, group membership is not related to industry classification.

7. Manufacturing context of typology

After the mass customization types were explicitly identified, the groups were examined to fulfill the third purpose of the study — to explore the different manufacturing approaches to mass customization implied by the typology. The conceptual model allows for different implementations of a mass customization strategy. As described in previous sections, three categories of variables were selected to represent the “mass” and “custom” components of a manufacturing system: process choice, planning techniques and technology. For descriptive purposes, an ANOVA with post-hoc Scheffé’s test was used to determine the differences of the variables between
groups. Table 2 shows the group means and ANOVA significance levels of these variables. Significant differences exist between the groups for at least one variable in each of the categories of process choice, technology, production planning, and performance at the 0.05 alpha level. This implies that there are differences in the manufacturing implementation of mass customization between the groups.

### 7.1. Process choice

The mass customization types use different processes to achieve their mass customization capability. Significant differences exist between the groups for percent of components manufactured using line processes and the percent of components that are purchased, but not for job shop and batch processes.

#### Table 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>p-value, one-way ANOVA</th>
<th>Group 1, n = 77</th>
<th>Group 2, n = 15</th>
<th>Group 3, n = 17</th>
<th>Group 4, n = 17</th>
<th>n = 126</th>
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<td>Job</td>
<td>0.119</td>
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<td>4.27</td>
<td>3.5</td>
<td>2.59</td>
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<td>Batch</td>
<td>0.881</td>
<td>3.57</td>
<td>3.67</td>
<td>3.31</td>
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<td>Line</td>
<td>0.000</td>
<td>2.72 (3∗, 4∗)</td>
<td>2.86</td>
<td>4.44 (1∗)</td>
<td>4.56 (1∗)</td>
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<td>Purchased</td>
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<td>2.93</td>
<td>3.50 (3∗)</td>
<td>1.75 (2∗)</td>
<td>2.59</td>
<td>123</td>
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<tr>
<td>MTS</td>
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<td>2.70 (4∗)</td>
<td>3.73</td>
<td>2.23 (4†)</td>
<td>4.00 (1†, 3†)</td>
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<td>ATO</td>
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<td>6.41 (4∗)</td>
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<td>6.36</td>
<td>5.13 (1∗)</td>
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<td>JIT</td>
<td>0.503</td>
<td>4.17</td>
<td>4.47</td>
<td>3.33</td>
<td>4.20</td>
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<td>Design</td>
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<td>CAPP</td>
<td>0.011</td>
<td>2.96</td>
<td>4.13 (3∗)</td>
<td>1.67 (2∗)</td>
<td>2.47</td>
<td>123</td>
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<tr>
<td>CAD</td>
<td>0.000</td>
<td>5.93 (3∗, 3∗)</td>
<td>6.00 (3∗)</td>
<td>4.05 (1†, 2∗)</td>
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<td>CAE</td>
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<td>3.00</td>
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<td>Robotics</td>
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<td>1.67</td>
<td>2.43</td>
<td>1.25 (3)</td>
<td>2.59 (4)</td>
<td>122</td>
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<td>Group Technology</td>
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<td>2.36</td>
<td>3.47</td>
<td>2.20</td>
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<td>Real-time controls</td>
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<td>3.27</td>
<td>1.56</td>
<td>2.88</td>
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<td>FMS</td>
<td>0.011</td>
<td>3.09 (2∗)</td>
<td>4.47 (1†, 3∗)</td>
<td>2.13 (2∗)</td>
<td>3.29</td>
<td>121</td>
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<tr>
<td>Bar coding</td>
<td>0.173</td>
<td>3.09</td>
<td>3.33</td>
<td>1.88</td>
<td>3.31</td>
<td>122</td>
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<tr>
<td>EDI</td>
<td>0.046</td>
<td>3.20</td>
<td>4.07 (4†)</td>
<td>2.56</td>
<td>2.19 (2†)</td>
<td>122</td>
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<tr>
<td>MRP</td>
<td>0.042</td>
<td>4.97 (2∗)</td>
<td>6.53 (1∗)</td>
<td>4.75</td>
<td>5.29</td>
<td>124</td>
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<td>DSS</td>
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<td>2.53</td>
<td>117</td>
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<td><strong>Performance</strong></td>
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<td>−0.162 (4∗)</td>
<td>0.557</td>
<td>−0.002 (4†)</td>
<td>0.813 (1∗, 3†)</td>
<td>126</td>
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</tbody>
</table>

∗ Significant differences between groups at α = 0.05.

∗∗ Significant differences between groups at α = 0.01.

∗∗∗ Significant differences between groups at α = 0.10.
Fabricators exhibit a significantly lower level usage of line processes in the manufacturer of components than Modularizers and Assemblers. Fabricators are the mass customization type that most closely mirrors pure customization. Therefore, this limited use of line processes for component manufacturer in the Fabricators is not surprising. Fabricators, by definition, provide customization through fabrication of distinct components. This custom fabrication would increase the need for more flexible manufacturing methods than the traditional line manufacture of components.

Assemblers have been described as the mass customizer that most closely resembles mass producers. Assemblers have the highest usage of line processes, which is consistent with their similarity to mass producers. Therefore, the use of line manufacture by Assemblers is not surprising. Assemblers, by definition, provide customization through fabrication of distinct components. This custom fabrication would increase the need for more flexible manufacturing methods than the traditional line manufacture of components.

Modularizers also incorporate line manufacturer into their manufacturing systems. Modularizers and Assemblers share customer involvement in the late stages of the production cycle, but Modularizers utilize modularity in the early stages of the production cycle. Modularizers may use modules to provide component commonality without providing customization until the customer is involved in the later stages.

Involvers have the highest usage of purchased components and show significant difference with Modularizers. These two groups do not share customer involvement or modularity dimensions, but neither group has matched involvement of customer and modularity dimensions in the production cycle. Involvers have customer involvement early in the process and modularity later in the production cycle while Modularizers exhibit the opposite characteristics. Perhaps for Involvers, the early customer involvement allows time for the purchase of components for specific customer.

### 7.2. Production control

The use of process control techniques mirrors the anticipated usage by mass customization type. Assemblers, the mass customizer that most closely resembles mass producers, have the highest usage of make-to-stock (MTS) planning systems. Assemblers differ significantly in their usage levels of MTS from Fabricators and Modularizers, both of which utilize modularity early in the production process. In addition, Fabricators, the mass customizers that most closely resemble pure customizers, have the highest usage in MTO planning systems, which differs significantly from the Assemblers. The use of process control techniques follows the anticipated usage for Assemblers and Fabricators. It should be noted, however, that if the raw scores are examined, all mass customizers utilize high levels of MTO and ATO planning technique and moderate levels of JIT in their manufacturing system. This high usage level of MTO/ATO control techniques is expected. By definition, all mass customers should have customer involvement specifying the product’s attributes at some point in the production cycle. This customer involvement would require the use of production to order and not to stock.

### 7.3. Technology

Mass customizers differ in their usage of technology. At least one variable differs significantly across the groups for design, manufacturers and administrative technologies. For design technologies, the group Modularizers is significantly different from Fabricators and Involvers. Modularizers have significantly lower usage of CAD technologies than Fabricators and Involvers. The conceptual model suggests that Fabricators and Involvers have customer involvement in the design and fabrication stages of the production cycle while Modularizers have customer involvement in the assembly and use stages. It appears that mass customizers employ CAD technology when customers are involved in the early stages of production. The use of design technologies, such as CAD, to manage the customer specifications in these stages should be expected. When customers are involved early in the process, more resources may be required to manage the design function.

However, use of CAPP differs between Involvers and Modularizers with Involvers exhibiting the highest usage of CAPP technology. Once again, this finding is expected since Involvers have early customer involvement that must be planned and managed through the assembly stages of production. This arrangement would require the use of CAPP technologies. Unexpectedly, the third design technology variable (CAE) did not reflect any differences among
the groups. The raw scores for these variables reflect low levels of usage of CAE. Groups using modularity in the early production stages require modules to be altered and, therefore, may rely on CAD for design purposes. Perhaps, the emphasis on CAD technologies supplants the use of CAE technologies for these mass customizers.

For manufacturing technologies, the most significant differences between the groups can be seen in the usage of flexible manufacturing technologies (FMS). The highest users of FMS technology are Involver — the mass customizer with customer involvement early in the production stage and modularity employed at later stages. The Involver have significant difference in FMS usage than both Fabricators and Modularizers, both which have modularity early in the process. This indicates that if customers are involved prior to the usage of modularity, mass customizers are adopting a higher level of FMS usage. This result is not unexpected. FMS usage may replace the more traditional forms of modularity in the early stages of production. FMS modularity is gained through modularity of programs and replication of design aspects between products. The flexibility of this technology to quickly change part types allows customer to specify more aspects of a product than may not be captured with the concepts of modularity presented in this study.

Robotics usage also differed across the mass customizing groups. Assemblers have the highest usage while Modularizers have the lowest usage. However, the raw scores for both groups are less than three, which would indicate Robotics usage on less than of 32% of products. (Note: The questions anchored the raw scale score responses to percentages of usage. The seven-point Likert scale was anchored at 1 with “not used — 0%”, at 4 with “used for some orders — 50%”, and at 7 with “used for all orders — 100%”. A score of 3 is approximately 32%). This does indicate a greater usage of Robotics in Modularizers than Assemblers, although no significant conclusions should be drawn from this fact. The other manufacturing technology variable, CAM, CNC, Group Technology and Bar coding, do not show significant differences between the groups. However, these variables can give us a richer picture of the mass customizers. The low level of usage of these technologies by all the mass customizers in the study may signify their lack of importance to the implementation of mass customization.

Administrative technology usage also differs among mass customizers. Assemblers have significantly lower usage levels of EDI than Involver. Both these groups have modularity in the later stages of the production process, but differ on the customer involvement. The higher usage level of EDI by Involver may correspond to an earlier involvement of customers. This finding would not be surprising if the electronic communication medium is used for customer interaction. However, this study cannot confirm the usage of EDI with customer as opposed to suppliers.

The usage of MRP system also differ among the groups with Involver exhibiting the highest usage while Modularizers and Fabricators exhibit lower levels of usage. Involver have the highest usage level, and although not significant, Assemblers have the second highest usage levels. Involver and Assemblers share modularity in the later stages of production. It is not surprising that these mass customizers would use MRP technologies to plan for the use of the modules in the assembly and use stages of the production cycle.

7.4. Financial performance

Business performance varies both within and across mass customizer configurations. Both high and low performers are practicing mass customization in each of the groups. Significant differences in the financial performance factor exist between the groups, with Assemblers displaying a significantly higher group mean for performance than Modularizers and Fabricators. Involver also exhibits high performance when measured as a group mean. Both Assemblers and Involver have modularity in the later stages of production, but differ on point of customer involvement in specifying the product. Although no significant difference is seen between the performance means of Modularizers and Involver, differences do exist between Modularizers and Assemblers. The use of modularity in the later stages of production may point to increased performance for mass customizers.

The findings with respect to business performance of companies adhering to each of the mass cus-
tomization types provide valuable insights for companies pursuing mass customization. There appears to be a performance difference among companies pursuing mass customization based on the type of modularity employed. Companies using modularity in the assembly and use stages exhibit higher performance than those using modularity in the design and fabrication stages. This suggests that those mass customizers that are closest to mass producers in manufacturing approach are most likely to reap the benefits of mass customization. Perhaps, these mass customizers that best able to achieve scale economies while delivering a customized product will exhibit better financial performance than those that do not. However, this alone may not guarantee high performance. Companies should be aware that high-performing companies are found across the spectrum of all types of mass customization.

8. Summary and conclusions

This study develops a conceptual typology of mass customization that provides an explicit means for identifying and categorizing mass customizers from the perspective of operations. We suggest that two variables are key in classifying mass customizers: the point in the production cycle where the customer is involved in specifying the product and the type of modularity used in the product. We validate the conceptual types empirically using data from a sample of mass customizers.

We also suggest and demonstrate broader configurations of mass customization. Specifically, the different approaches to mass customization implied by the typology were examined to provide a richer picture of the manufacturing systems employed. Process choice, planning techniques, and technology variables were examined as well as business performance. We demonstrate that mass customizers do differ on each of these dimensions based on their mass customization type. Most particularly in this typology, those mass customizers that theoretically resemble mass producers, Assemblers, choose manufacturing systems that use line processes, incorporate the highest levels of MTS planning methods and utilize MRP. Fabricators, those mass customizers that most closely resemble craft producers, have the highest levels of MTO planning systems and high usage levels of CAD. The commonality of the manufacturing systems among mass customizers is also noteworthy. All mass customizers use some form of a MTO or assemble-to-order planning system, incorporate some form of batch processing and a majority of the products are made using CAD technology. This finding is not surprising. The use of CAD technology may be required to manage the “custom” portion of the order in an efficient cost-effective manner. Batch processing may provide the “mass” production of common modules. Then, the overall production process is managed using MTO and assemble-to-order planning systems. The differences and commonalities among these mass customization groups provide a rich description of mass customization manufacturing systems.

Although both high and low performers are found among all mass customization types, we do discern better business performance among the types that use standard modules and employ modularity in the later stages of the production cycle.

8.1. Limitations and future research

This study has only begun to explore mass customization as a manufacturing phenomenon. This study takes a step forward in mass customization research by providing a conceptual model of mass customization and substantiating this model through an empirical investigation. However, this empirical exploration provides a one-time snapshot of company practices. A natural extension of this research, and most empirical work in manufacturing strategy, is a longitudinal examination of companies. Manufacturing systems are ever changing and a time lag may exist between making a decision on manufacturing priorities and realizing the related manufacturing capability. A longitudinal look at mass customizers would clarify the issues relating to the implementation of this strategy in practice.

This study neglects to include the use of service as a mass customization technique. In addition to customizing product attributes, products may be mass-customized through the availability of customizable services. Manufacturers are increasingly looking to expand their product offerings through the addition of service to the product package (Wise and
Baumgaretener, 1999). Services may also be modularized and may provide another avenue for mass customization. Future research may wish to include services as part of the mass customization model.

In addition, this study only investigates the customized portion of company’s product lines. The integration of customized and standardized products is not examined. Mass customization may enable overall firm performance, including the design and production of standard products, through information gained regarding customer preferences. The relationship of mass customization to the entire organization may play a critical role in the success of a mass customization strategy. Therefore, the scope of mass customization research should be broadened to include both mass-customized and standard products.

This paper has broadened the conceptual model of mass customization and its manufacturing implications, but has neglected to make any specific value judgments to the inherent worth of mass-customized products. Future studies may wish to explore the market implications of mass customization, the accompanying customer benefits, the effects of choice on customer satisfaction, and the costs associated with the implication of mass customization practices.

References