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ASSESSING PRODUCT CONFIGURATOR CAPABILITIES FOR SUCCESSFUL MASS CUSTOMIZATION

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ABSTRACT OF THESIS

ASSESSING PRODUCT CONFIGURATOR CAPABILITIES FOR SUCCESSFUL MASS CUSTOMIZATION

Mass customization is becoming a competitive strategy for companies offering individualized products. Product configurators provide a platform for companies to do interactive product configuration which is essential for mass customization. Companies need to realize the degree of customization appreciated by the customers and the extent of customization that can be offered competitively. This research is an effort to develop an approach to ascertain the product configurator requirements to achieve mass customization. The frameworks developed for this research are validated with a case study.

KEYWORDS: Mass customization, Product configurators, Framework, Individualized products, Configurator capabilities.

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2007

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THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Masters of Science in Mechanical Engineering
in the College of Engineering at the University of Kentucky

By

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2007

Dedicated To My Parents and Husband

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1 INTRODUCTION

Mass production has been a trend to manufacture standardized goods in the early 20th century. The first industrialist to develop and make full use of this system was Henry Ford. Mass production is described as a high volume, low variety production which enabled achieving low cost per unit. For Ford, initially it took 14 hours to assemble a Model T car, by the concept of mass production it was reduced to 1 hour 33 minutes. Through further improvement methods, the selling price of the Model T fell from $1000 to $360. Following Ford's success, other companies began implementing mass production methods in their facilities to manufacture cheaper goods [Ford, 1926].

Customer demands today vary widely and cannot be satisfied by standardized products. It may be as small as a change in product color or it could be a change in the functionality of the product. It is a challenge to the industry to maintain a profitable business and still satisfy the customer. There is a need to produce customized good at mass production economies. In this scenario mass customization has evolved as a competitive strategy [Krishnapillai and Zeid, 2006]. It is considered a way to combine the advantages of both customization and mass production [Kotha, 1995; Pine, 1993; Selladurai, 2003].

The use of competitive strategies in manufacturing and information technology enables manufacturers to meet individual needs of a customer. Management and technology tools help in offering wide product variety and allow customization through flexibility and responsiveness [Comstock, et al., 2004; Pine, 1993].

1.1 Mass customization

The latest definition of mass customization as given by Pine is ‘low cost, high volume, efficient production of individual offerings’ (which incidentally may be goods, services, experiences, or transformation) in the current business scenario [Piller, 2007] Customers in the present era demand customized products of better quality at low cost and fast delivery times [Badurdeen, et al., 2007]. Mass customization is a process of delivering customized products and services for individual customers at near mass production efficiency [Pine, 1993]. Conventionally, companies have chosen to follow either mass production or craftsmanship. Thus mass customization presents a paradox, calling for combining customization and mass production offering unique products in mass produced, low cost, high volume production environment [Duray, 2002]. Figure 1-1 gives an idea of degree of customization and volume of production.

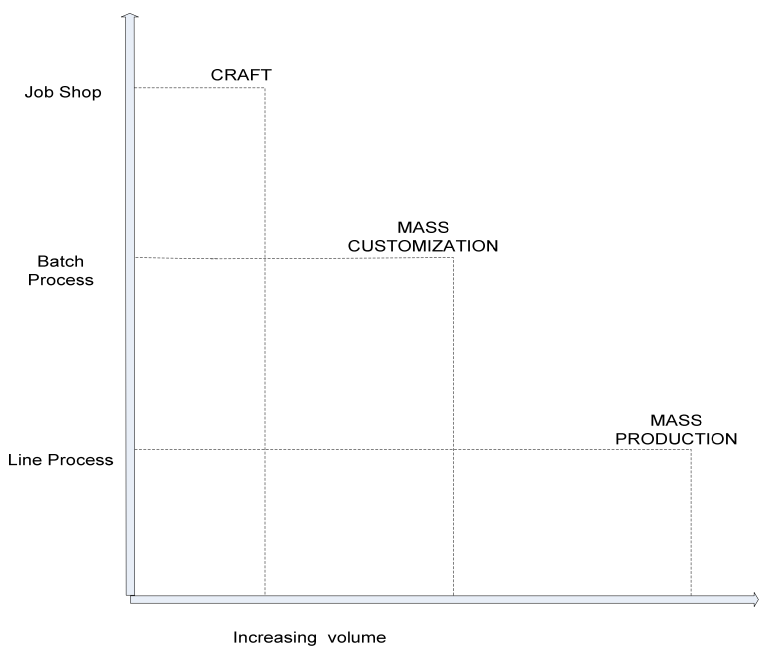


Figure 1-1 Three production forms positioned regarding customization and production volume [Kaj, 2001]

The concept of mass customization has received considerable attention in research literature since its identification by Davis [1987] and followed by Pine's [1993] book. Mass customization provides customers an opportunity to have a product any time they want it, any where they want it, any way they want it, in a similar way that zero defects is an ideal in respect of quality [Hart, 1995].

Mass customization is identified as an emerging strategy by a number of companies to gain an edge in the market. We learn that, making a product customer-specific is the secret of successful business. Companies like Dell computers, Motorola, IBM, 3Com, Procter and Gamble, Toyota, GM, HP and others have effectively used mass customization in their production. Dell has benefited tremendously by implementing mass customization. Dignan [2002] discusses some key measures of Dell's success. Inventory at dell is measured in hours than in days and each factory receives new components in every two hours, 90% of the purchases takes place online and Dell's expense ratio is 9 percent which is the lowest in the industry. The company also has a highly integrated distribution and supplier network that has facilitated Dell's success.

The goal of manufacturing in today's competitive era should be strategic flexibility [Hayes and Pisano, 1994] Companies are implementing flexible processes and information technology to deliver a wide range of products and services that meet specific customer needs. Pine [1993] observes that methods like CAD, CAM, FMS and newer paradigms like JIT, setup reduction and change over times could help in implementing mass customization [Kotha, 1995]. Agile manufacturing is also considered a method as it involves responding quickly to market demands.

Though many companies have fared well by following mass customization, few companies did report some disadvantages. It could be because of increased material cost, increased manufacturing cost, lower on-time deliveries, supplier delivery performance, increase in order response time and reduction in quality. Another cost issue could be the premium cost associated with mass customization [Selladurai, 2000].

1.2 Product Configurators and Their Role

One of the major factors that contributed to the growth of mass customization includes information technology and the internet. The growth of the Internet has given companies a platform to bridge the gap between customer and the manufacturer [Selladurai, 2000]. The Internet has given a means of taking orders and configuring products online. This has displaced the use of highly skilled sales representative in many cases there by reducing some costs. In order to exactly meet the customer needs and build a lasting customer–purchaser relationship it is important to concentrate on how information is collected and saved and translated. Order processing in mass customization can be efficient if the flow of customer information is accurate. Being customer oriented is truly possible if the organization is information intensive [Blatterberg and Glazer, 1994].

Cost effective individualization is possible with increasing information richness of products and processes and this can occur with the potentials of current information technology [Wigand et al, 1998]. One such information technology system that gained significant importance in the context of mass customization is the product configurator. Web-based configurators allow saving time and cost consuming configuration process to the customer [Piller and Moser, 2006]. A configurator is an information system that supports the creation and management, especially in the long term of configuration knowledge [Tiihonen and Soininen, 1997]. With artificial intelligence capabilities, it supports the customer specific adaptation making it less tedious, difficult and error prone [Sabin and Weigel, 1998]. Configurators act as an interface between the customer and supplier over the internet and provide an opportunity of co- creation to the customer.

The question of how to integrate the customer into design and development of a product is answered by configurator. For this the customer need to be aware of the properties and functionalities of a product that can be directly changed by him/her. An example of configurator is shown in Figure 1-2. Large automakers have made it possible for its customers to virtually assemble a car of their needs and preferences [Leckner and Lacher, 2003]. The primary task of a configurator is to facilitate selecting and arranging combinations of parts that satisfy a specification. How ever no new models or component types can be crested during this process.

Figure 1-2 Sample of Nike's product configurator [Nike, 2007]

There are several tools in the market that provide the configurator capability. Some of them are CAS, COSMOS, ET-EPOS, SALES PLUS, SCE, SEON, SELLOR SC-CONFIG [Gunter and Kuhn, 1999].

Configurators are relatively a new concept and needs to be explored. Customers face problems such as complexity, uncertainty and lack of knowledge during the configuration process leading to frustration and mass confusion. Ideally the configurator should be designed to enable a customer to easily understand the degrees of freedom during configuration.

1.3 Motivation for Research

To avoid the pitfalls in mass customization, many companies are utilizing the information technology and flexible manufacturing systems to customize good for customers in high volumes and relatively low cost. But managers need to realize that mass customization can increase the cost and add to the complexity of the system. Before embracing this new concept, it is important to thoroughly understand what kind of customization a customer would appreciate [Gilmore and Pine 1997].

Mass customization framework would help in understanding the degrees of customization and to classify the levels of individualization that can be offered to the customer [Da Silveira, et al., 2001]. A number of schemes have been proposed by various authors to discuss the classification of mass customization. However, existing literature on classifying mass customization has limitations in their ability to understanding the different levels of customization. Most of the frameworks are limited to specific cases of customization and thus cannot accommodate all companies. The variables incorporated being too simple or too complex could be one of the reasons.

Also, in most existing literature, mass customization and product configurators are dealt independently. In recent years, researchers are focusing on the impact of applying product configurators in mass customization business [Skjevdal and Idsoe, 2007]. Most of the research has been into the technical and theoretical aspects of product configurator. There are a large number of software solutions available for companies to meet the product configurator requirements. The capabilities required by a product configurator for its application in mass customization have not been addressed. Thus, it is challenge for a company to weigh the capabilities before it chooses a certain configurator [Skjevdal and Idsoe, 2007]. A framework for configurators classifying them in terms of their capability can help in selecting from the alternatives based on the dimensions. In this context, there is a need for more empirical work to develop a framework for mass customization and product configurators and mapping companies placed on the classification framework to identify product configurator capabilities needed for successful mass customization.

1.4 Research Objective

First, a comprehensive framework to classify companies engaged in mass customization will be developed based on empirical examples and a review of previous models. This approach is an attempt to understand the levels of customization and classify companies accordingly. Secondly, the product configurator framework will be developed to classify product configurators based on various features available. These models are then applied to a case study to evaluate its current mass customization strategy, assess the product configurator capabilities and validate the models. The models present a roadmap for companies to identify and improve product configurator capabilities for successful mass customization.

1.5 Thesis Organization

The literature survey about the recent developments in mass customization and the methodology implemented in developing the mass customization framework is presented in chapter 2. The literature review and methodology for developing product configurator framework is described in chapter 3. Chapter 4 focuses on mapping the mass customization and product configurator frameworks. Analysis of a case company with respect to the frameworks is discussed in chapter 5. Chapter 6 focuses on conclusions and future work.

2 MASS CUSTOMIZATION CLASSIFICATION: LITERATURE SURVEY AND METHODOLOGY

This chapter presents a review on previous models and empirical examples of mass customization classification systems. It also discusses the methodology to develop a comprehensive framework to locate companies following the mass customization strategy.

2.1 Lampel and Mintzberg's Model

They have proposed a continuum of strategies that show that some industries follow customization and some promote standardization, few others mix the above two strategies in their products, processes and customer transactions. Managers need to realize a compromise on a strategy between customization and standardization [Lampel and Mintzberg, 1996].

The concept of aggregation and individualization cannot be treated as mutually exclusive. The continuum of strategies tries to combine these concepts to come up with five strategies between pure standardization and pure customization. The continuum is based on the fact that the trend in industries is not towards pure customization. The difference between standardization and customization is that standardization is an upstream activity and customization is downstream i.e. activities start close to distribution and spread upstream towards design. The continuum is developed with four stages in the value chain: design, fabrication, assembly and distribution. Thus we have pure standardization, segmented standardization, customized standardization, tailored customization, pure customization [Lampel and Mintzberg, 1996].

In pure standardization customer has no direct influence on any stages of value chain and it is more to do with a push system. Typical example is Ford's choice of car color. As discussed above it begins upstream. Segmented standardization targets small group of customers. It has better choices to offer than pure standardization; however customer does not have direct control over design or production. Example is the availability of limitless variety of designer lamps but not with the involvement of the customer. Figure 2-1 presents the continuum of strategies proposed by Lampel and Mintzberg [1996].

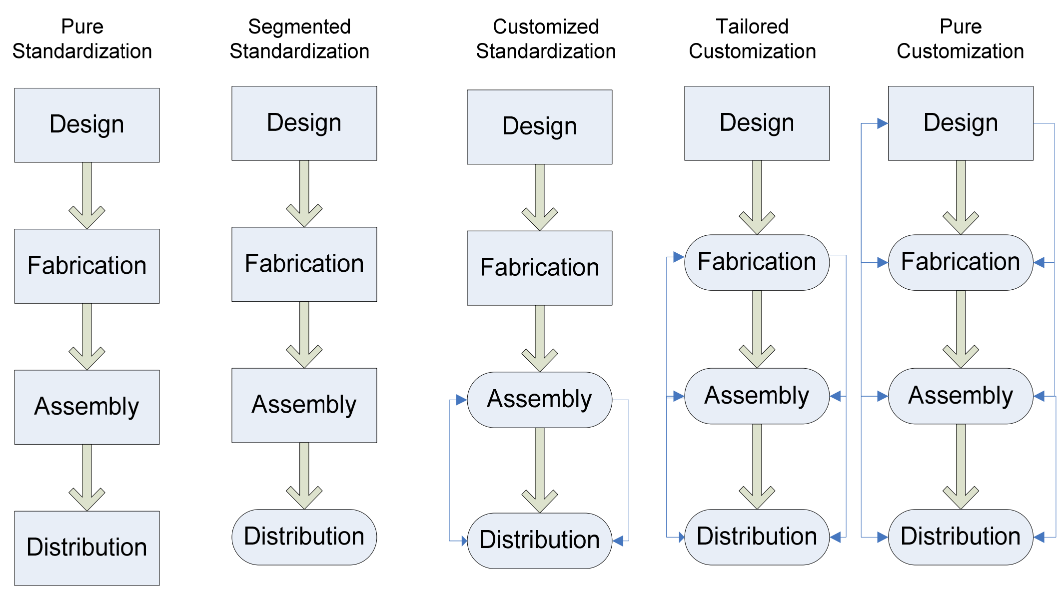


Figure 2-1 Continuum of strategies [Lampel and Mintzberg, 1996]

Customized standardization involves the assembly of standard components i.e. customer involves in the assembly stage of value chain and thus configuration is customized. The concept of modularity is well applicable in this case. Preparation of hamburgers is one of the examples discussed in the model. Tailored customization starts with customer involvement in fabrication stage. A good example is the apparel industry. Another example is construction of home but it can fall some times in the category of pure customization. On the other hand, pure customization is core customization starting from design. The degree of customization is higher of all the previously discussed models. Jewelry making is one of the most common examples discussed in the model [Lampel and Mintzberg, 1996].

This classification is more generic and is a basis to many other frameworks that consider the value chain aspect. Adding one or more dimensions to this model can help in classifying companies according to the mass customization strategy followed. Another thing is that degree of customer involvement and degree of product customization are not mutually exclusive.

2.2 Gilmore & Pine’s Model

Gilmore and Pine [1997] suggest four approaches to customization namely collaborative, adaptive, cosmetic and transparent. Collaborative being highly customized and transparent being the least [Gilmore and Pine, 1997].

Collaborative customization involves a dialogue with the customer in order to identify and fulfill their needs. For example Paris Miki eye glasses. The Mikissimes design system captures the face of a customer and analyses various attributes and customers choice of design and looks. The system then recommends different sizes and shapes of lens and the customer can collaborate with the optician in order to decide the desired lens [Gilmore and Pine, 1997].

Typically, collaborative customization involves service customization by enabling a conversation with the sales person; this could be managed with a product configurator as well. Looking at the customization of the product it self, it can be considered as standardized customization, in the context of Lampel and Mintzberg [1996] model, as the customer chooses from a standard set of components but assembles them according to his will. Thus collaborative customization cannot be considered as pure customization. There are not many companies that do this type of customization. It would be appropriate to say that collaborative customization is a subset of standard customization. However all the examples that fall under standard customization cannot be classified as collaborative. Gilmore and Pine's [1997] model is presented in the Figure 2-2.

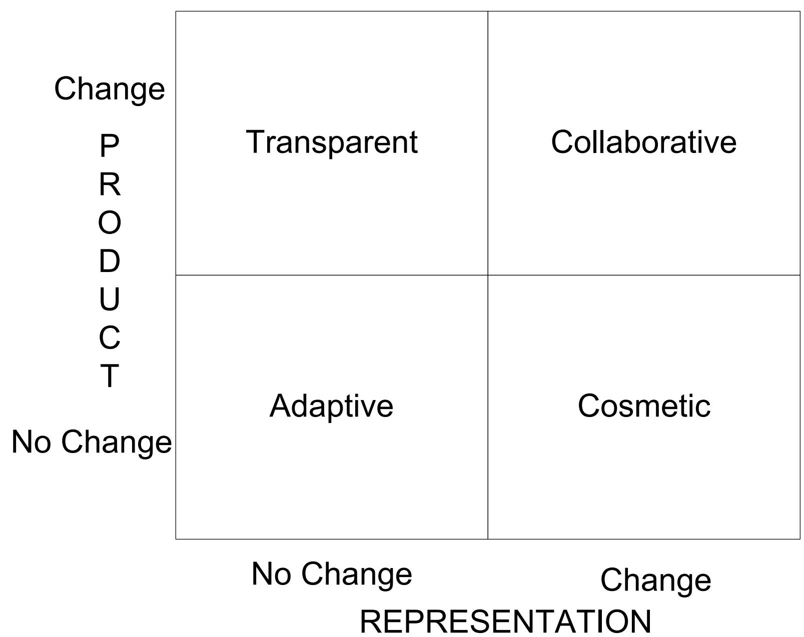


Figure 2-2 Four approaches to mass customization [Gilmore and Pine, 1997]

Adaptive customizers present standard products that can be altered by the user according to their needs. Lutron Grafik [Gilmore and Pine, 1997] lighting system is an example which allows user to have different light effects by merely changing the programmed settings. Cosmetic customization provides standard products differently to different customers. Typically, customization is provided in the distribution and use stages. It's again similar to segmented customization that targets clusters of customers. Most common examples are T-shirts with special prints.

Transparent customization fulfills the needs of customers in a way that the customer may not even know that the product has been customized. It is implemented by closely observing the customer requirements. Since the same product is offered to all the customers it can be considered as pure standardization.

Gilmore and Pine's [1997] classification is based on observations and few case studies and is limited in application. It is not easy to classify a given company under this framework. There are examples that don't fit into any of these discussed types. Let us consider the example of Lego™, this cannot go into any of these categories.

Collaborative customization focuses more on service customization than product customization. Collaborative is considered under providing maximum customization but it does not give a clear idea about the stage at which customer gets involved in value chain. This classification considers product and its representation as different elements but they are not independent elements.

The apparel industry is discussed under collaborative customization, but it would be appropriate to say that it falls in tailored customization [Lampel and Mintzberg, 1996] with assistance of a sales person. Transparent customization does not exist at all as it equivalent to mass production. The problem with both the models discussed so far is that product customization and degree of customer involvement are not mutually exclusive.

2.3 Amaro's Model

Amaro, et al. [1999] discusses a framework for classifying non make-to-stock companies and the role of customization as a competitive advantage. The non make-to-stock companies are classified into Assemble-to-order (ATO), Make-to-Order (MTO) and Engineer-to-order categories (ETO).

In ATO, a number of standardized parts are assembled in different variants according to the choice of the customer. It is similar to standardized customization suggested by Lampel and Mintzberg [1996]. In MTO, an order is manufactured only after the receipt of a customer order. In some cases material is purchased after the receipt of the order. The degree of customization is considered greater than ATO. In ETO, each customer order is a unique set of bill of materials and part numbers. The degree of customization is higher than MTO.

This being a broad classification, Hill [1993] redefined the existing categories and added a few new ones to the above making a total of six different types. Design-to-order (DTO), Make-to-Print (MTP), Engineer-to-Order (ETO), Make-to-Order (MTO), Assemble-to-Order (ATO) and Make-to-Stock (MTS).

DTO companies design and manufacture a product to meet requirements of a customer. In MTP, Products are produced in line with a given drawing. Lead time include only raw materials purchase, supply, manufacturing but not design. In ETO, changes to standard products are offered to customers and only made to order. Lead times include relevant elements of engineering design and all manufacturing. MTO manufactures a standard product only on receipt of a customer order. In ATO, components and sub assemblies are standard with the receipt of an order; the required parts are assembled to order. MTS is based on the sales forecast goods are manufactured and is equivalent to mass production.

The disadvantage of Hill's framework is that there is ambiguity in using the terms ETO and MTO. Also, there would be a better understanding if these are explained with examples.

Amaro, et al. [1999] proposed a new taxonomy for non make to stock companies on basis of three major dimensions. The first one being product customization which covers pure customization, tailored customization, standard customization and non customization. Non customization is more or less a standard part but is not made-to-stock, according to him for expensive goods.

The second dimension is the company responsibility, the third being activities after receipt of order. The company responsibility is discussed in terms of design, specification, purchasing and the activities after receipt of order consist of delivery, assemble, processing, purchasing, routing, specification, design.

These three dimensions are used to develop 11 types of non make to stock companies comprising of 4 types of ETO companies, 5 types of MTO and 2 types of ATO. This taxonomy is empirically validated taking 22 companies into consideration. Table 2-1 gives the framework for non-make-to stock companies.

Table 2-1 Framework for non make-to-stock companies [Amaro, et al., 1999]

Classification categories	ETO	ETO	ETO	ETO	MTO	MTO	MTO	MTO	MTO	ATO	ATO
	1	2	3	4	1	2	3	4	5	1	2
Degree of Customization											
Pure	✓	✓	✓	✓							
Tailored					✓						
Standardized						✓	✓			✓	
None								✓	✓		✓
Company responsibility for											
Design	✓				✓	✓	✓	✓	✓	✓	✓
Specification	✓	✓			✓	✓	✓	✓	✓	✓	✓
Purchasing	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Activities after receipt of order											
Delivery	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Assembly	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Processing	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Purchasing	✓	✓	✓		✓	✓		✓			
Routing	✓	✓	✓	✓	✓						
Specification	✓	✓			✓						
Design	✓										

The eleven categories in the new taxonomy appear excessive and lead to confusion. To the existing taxonomy he adds 4 additional attributes namely the number of customers, nature of the relationship with the customer, the number and type of usage materials, the nature of buying process. Though these have been proposed, they have not been incorporated in the topology.

The combinations of attributes seem to be imprecise. On one hand product customization is discussed and on the other the process part of it is added. It would be appropriate to include business-to-business (B2B) and business-to-customer (B2C) instead of trying to define the number of customers.

2.4 Duray's Model

Duray, et al. [2000] model classifies mass customizers based on customer involvement and product modularity. This topology is validated with an empirical analysis and classification of 126 mass customizers. One of the dimensions is customer involvement in value chain, the new one being modularity. This classification argues that "mass" in mass customization cannot be achieved without modularity. [Duray, et al., 2000]

Pine [1993] stated that achieving true mass customization needs modularity in production. Bladwin and Clark [1994] argued that modularity allows achieving economies of scale and scope across product lines. McCutchen [1994] suggested that modular product design would provide variety and speed up the process by reducing delivery times. Ulrich and Tung [1991] have discussed the various types of modularity that can be applied to mass customization.

Cut-to-fit and component sharing modularity require designing components newly or changing them and therefore this can occur in the design and fabrication stage only. Also in cut to fit modularity a standard product might require change in dimension and this can happen only in fabrication stage. Coming to the sharing modularity, although a standard base unit is incorporated into the product, additional components need to be fabricated according to the needs of the customer.

In the assembly and use stages, no new components are fabricated or designed for the customer, modules are just arranged or combined according to the specification of the customer. Typically, component swapping, sectional and bus modularity use standard modules without any alteration. Figure 2-3 shows the customer involvement and modularity in value chain.

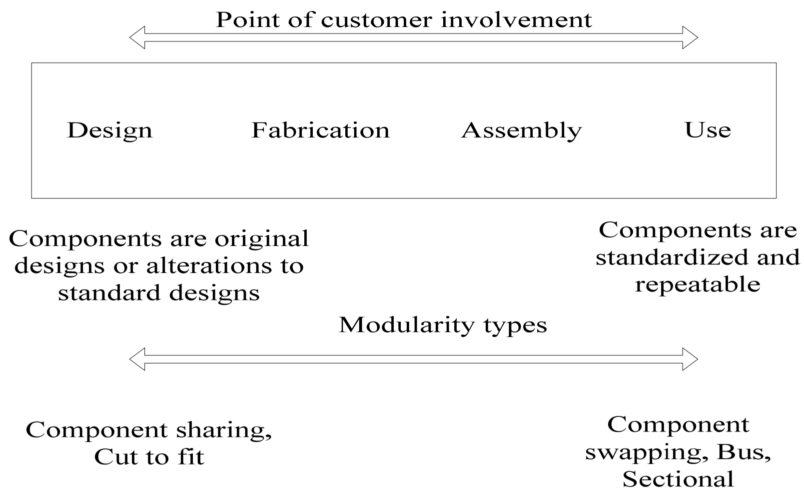


Figure 2-3 Customer involvement and modularity in value chain [Duray, et al., 2000]

Duray, et al. [2000] framework presents 4 types of mass customizers namely fabricators, involvers, modularizers and assemblers. The first group is called the fabricators, involve customers and modularity in the design and fabrication stages. This group resembles pure customization. The type of modularity involved is often cut to fit or component sharing.

Group 2 has customer involvement in design and fabrication stages but uses modularity in assembly and delivery stages. They are called the involvers. Modularity in assembly and delivery stages means that no new modules are fabricated for the customers. Involvers get hold of greater economies of scale than fabricators but maintain high customer involvement. Group 3 involves the customers in assembly and delivery stages but apply modularity in design and fabrication stages. They are called the modularizers, most often component sharing occurs here.

Duray [2002] discusses that the types of manufacturing systems applied for mass customization would vary between traditional manufacturing and custom product manufacturing systems. Emphasis is given on the point that a standard manufacturer and custom manufacturer can expand his product line with mass customization. However approaches to mass customization are different. Figure 2-4 represent the four types of mass customizers.

<table>
<tr><th></th><th colspan="4">Types of Modularity</th></tr>
<tr><th>Point of customer involvement</th><th>Design</th><th>Fabrication</th><th>Assembly</th><th>Use</th></tr>
<tr><td>Design</td><td colspan="2" rowspan="2">1
FABRICATORS</td><td colspan="2" rowspan="2">2
INVOLVERS</td></tr>
<tr><td>Fabrication</td></tr>
<tr><td>Assembly</td><td colspan="2" rowspan="2">3
MODULARIZERS</td><td colspan="2" rowspan="2">4
ASSEMBLERS</td></tr>
<tr><td>Use</td></tr>
</table>

Figure 2-4 Four types of mass customizers [Duray, 2002]

Group 4 are called assemblers, they bring customer involvement and modularity in assembly and delivery stages. Assemblers closely operate as mass producers. But they provide more choice than mass producers which customers perceive as customization.

The author argues that manufactures that do not involve customer in design process or do not implement modularity should not be considered as mass customizers. The above is validated with case studies and surveys.

This model is different from Gilmore and Pine’s [1997] classification in a way that it has modularity as one of the dimensions and has not included service as a mass customization technique. It has not discussed the combination of customized and standard products. But more importantly the issue of modularity has come into picture.

2.5 Da Silveira’s Model

Da Silveira, et al. [2001] proposed a framework for mass customization by understanding the previous literature. His classification contains different levels of mass customization and also the concepts required for practice of mass customization are discussed at length. This framework is derived from the following literature:

Firstly, Gilmore and Pine’s [1997] four levels customization based on empirical examples namely collaborative, adaptive, cosmetic and transparent types. Next discussed model is Lampel and Mintzberg’s [1996] continuum of five strategies comprising of standardization, segmented customization, customized standardization, tailored customization and pure customization. Pine’s five stages of modular production covering customized services, embedded customization, point of delivery customization, providing quick response and modular production. Finally, Spira’s [1996] framework has four types of customization including customized packing, customized services, additional custom work and modular assembly. Table 2-2 represents the eight generic levels of mass customization proposed by Da Silvera, et al. [2001].

Table 2-2 Eight generic level of mass customization [Da Silveira, et al., 2001]

MC generic level	MC approaches	MC strategies	Stages of MC	Types of MC
Design	Collaborative, Transparent	Pure customization		
Fabrication		Tailored customization		
Assembly		Customized standardization	Modular production	Assembling standard components into unique configurations
Additional custom work			Point of delivery customization	
Additional services			Customized services, Providing quick response	Providing additional services
Package and distribution	Cosmetic	Segmented standardization		Customizing packaging
Usage	Adaptive		Embedded customization	
Standardization		Pure standardization		

Analyzing the above frameworks, Da Silveira proposed eight generic levels of mass customization from pure customization to pure standardization [Da Silveira, et al., 2001]. However this model is not empirically validated. The framework doesn't discuss any significant development in mass customization. It gives a jist of all the above discussed frameworks.

Collaborative and pure customizations have common generic level "design". How ever practically speaking they cannot be placed at the same level. Collaborative could be a subset of pure customization but the vice versa doesn't hold well. We need to keep in view that Gilmore and Pine's [1997] approach to mass customization is based on customer's interaction with the sales person.

Additional custom work and additional services are not well defined. Additional services could be same as collaborative customization if it meant interaction with the customer. In that case this generic level can be omitted. Packing, distribution and use are all post manufacture stages and hence they can be categorized in the same level than giving different generic levels. This paper has focused more on the factors that enable mass customization. These factors include manufacturing processes and methodologies, information technology and information transfer.

2.6 MacCarthy's Model

MacCarthy, et al. [2003] derives five modes of mass customization based on three attributes and six processes that are fundamental to mass customization. The classification scheme is applied to five case studies. He discusses the scenarios at NBIC, Motorola, Commercial vehicle, European bicycle, computer manufacturing and classify them under the frameworks proposed by Lampel and Mintzberg [1996], Ross [1996], Alford, et al. [2000], Duray [2002], Gilmore and Pine [1997] and Da Silveira, et al. [2001]. Table 2-3 gives the comparison of the above models with respect to the examples.

Table 2-3 Classification comparison [Mac Carthy, et al., 2003]

	NIBC	Motorola	European bicycle	Computer	Commercial vehicle
Lampel & Mintzberg (1996)	Tailored customization + Customized standardization	Customized standardization	Tailored customization + Customized standardization	Customized standardization	Tailored customization + Pure customization
Ross(1996)	Core customization	Core customization	Core customization	Core customization	Core customization + Post product customization
Alford et al. (2000)	Optional	Optional	Optional	Optional	Core
Duray et al.(2000)	Involver	Assembler	Assembler	Assembler	Fabricator
Da Silveria et. al. (2001)	Fabrication+ Assembly	Assembly	Assembly + Fabrication	Assembly	Design
Pine & Gilmore (1997)	Collaborative	Collaborative	Collaborative	Collaborative	Collaborative

Since Gilmore and Pine's [1997] approach to mass customization is based only on customer interaction with the sales person, all the five company cases fall under collaborative customization only. Schemes of Ross [1996] and Alford, et al., [2000] classify the case studies mostly into core customization and optional customization. Da Silveira, et al. [2001] scheme has some ambiguity in defining additional custom work category and design category.

According to MacCarthy, et al. [2003] observations the weakness of value chain classification is that sufficient prominence is not given to two factors. Firstly, weather the technological resources used in order fulfillment is fixed or modifiable and secondly temporal relationships between activities. The six processes that are fundamental to mass customization are identified as order taking and coordination, product development and design, product validation and manufacturing engineering, order fulfillment management, order fulfillment realization, post order process. The modes of mass customization are obtained by linking three factors and six processes; however all the permutations are not meaningful [Mac Carthy, et al., 2003].

Mode A: Catalogue mass customization: Customers select from a pre engineered catalogue of variants and products are manufactured by order fulfillment activities.

Mode B: Fixed resource design per order: The order fulfillment process is standard, but the customer order is engineered to a customer specific product. Thus it is necessary that the product development process is aware of the process capabilities.

Mode C: Flexible resource design per order: The order fulfillment process is flexible and engineering of customer specific product is possible. In both the above two cases repetition of order is not expected.

Mode D: Fixed resource call off mass customization: It is same as mode B except that repetition of orders is anticipated.

Mode E: Flexible resource call-off mass customization: Same as mode D except that order fulfillment is flexible.

However none of the case studies fall in mode B and mode C categories. No examples are listed in the above modes. Also mode A has four cases listed which is catalogue pre engineered category. It means that no new designs are created for the customer. In all the rest of the four modes design is changed for the customer i.e. the framework can be classified into change in design and no change in design categories and the change in design sub classified into four categories again. Order fulfillment realization speaks about manufacturing process which includes all the internal activities of a manufacturing process i.e. assembly, fabrication etc. In that case classifying companies on basis of value chain is more meaningful. Though five modes are proposed most of the companies fall in one or two modes only all the rest would remain as definitions with no companies to classify under them. Table 2-4 describes the mode summary.

Table 2-4 Mode summary [Mac Carthy, et al., 2003]

	A Catalogue	B Fixed resource design-per-order MC	C Flexible resource design-per-order MC	D Fixed resource call-off MC	E Flexible resource call-off MC
Temporal relationship Product design Product Validation/manu. Eng.	Per-family Per- family	Per-order Per-order	Per-order Per-order	Per-product Per product	Per-product Per product
Once-off/call-off	----	Once- off	Once- off	Call- off	Call- off
Fixed/modifiable order fulfillment resources	Fixed	Fixed	Modifiable	Fixed	Modifiable
Classification of case studies	NIBC, Motorola, Computer, Commercial vehicle			European Bicycle	Commercial vehicle

2.7 Argument

On examining the case studies and frameworks proposed for mass customization by various authors, it still appears that there is a need for some more work in classifying business organizations based on the type of mass customization strategy followed. Motivated by this short coming of the present literature, this work aims to come up with a framework which is based on extent of customization by an organization. This framework would enable a company to know the type of customization they are employing and help in reaching the type of customization they want to achieve. Most of the theories fail as the attributes considered may be too simple for classification. Majority of the frameworks are compiled from limited case examples which narrow down their applicability.

Various studies are reviewed to understand the different approaches by other authors. The analysis of these reviews contributes to the development of framework for this work. The attributes listed in the framework are would help in locating companies following mass customization.

Considering the customer involvement in value chain is important because only this approach can distinguish between the degrees of customization. Gilmore and Pine's [1997] theory is made from observations. Their approach is based on customer interaction with the sales person and collaborative customization is considered as pure customization. There is no clear point to say when and where the customer is involved in value chain and thus this theory fails to accommodate this aspect in mass customization. Undoubtedly, presence of a sales person adds value to the customization process, instead a configurator can replace a sales person. However product configurator capabilities needed to achieve different mass customization strategies is to be identified. In this way all the customizations would become value added. If the customization process is too complex then a sales person can be included. Few authors have taken a different path to explain the degrees of mass customization other than value chain concept. But their discussion still ends up speaking about design, fabrication, assembly and use.

Though all the frameworks talk about mass customization, not many have insisted on how to achieve “mass” in mass customization. Duray, et al. [2000] concept of modularity in value chain has brought a new direction in this regard to mass customization.

So far many papers have examined various mass customizers and discussed a range of frameworks in terms of customer order decoupling point and degree of product customization. But the type of business strategy followed by a firm has never been addressed. Duray [2004] discusses the concepts of production planning and inventory control that are to be implemented differently for various mass customization strategies. To identify the manufacturing system capabilities required for different mass customizers it is necessary to categorize them according to type of business. A framework for mass customization would be meaningful if the companies are classified according to their industry type.

2.8 Methodology

Most of the literature presented on mass customization so far has focused on the product, manufacturing or customer. In order to have a better classification scheme for mass customization, the product as well as customer has to be given priority. In short the dimension used to build mass customization framework should be comprehensive enough to capture the diversity of firms engaged in mass customization and classify them accordingly. Most of the classifications discussed differ by the attributes considered, some are empirically validated and some are not. As argued by Moser [2007], the early classification studies had product and manufacturing focus, applying the degree of product customization as the only attribute for classification. The next generations of classification models have introduced the degree of customer involvement in value chain.

This type includes Lampel and Mintzberg [1996] Gilmore and Pine [1997], Amaro, et al. [1999], Da Silveira, et al., [2001], etc. But these are not easy to apply as the attributes are not explicitly differentiated. The degree of customer involvement and product customization are combined into the same attribute. Duray [2002] and a set of other authors have used these attributes with new ones added. Duray, et al., [2000] model used modularity and customer involvement in value chain as the two attributes which are independent and mutually exclusive.

Based on these analyses, it can be concluded that criteria for selecting the attributes should be as follows:

- Attributes should not be too simple or too complex.
- The number of attributes should be limited.
- The attributes chosen should be able to capture all mass customization companies.
- Attributes should be easy to apply.
- Attributes should be mutually exclusive.
- They should give a new direction for further research and study.

Thus “An *ideal classification of mass customization must include a product and customer focus but should obviously differentiate between the two dimensions by applying two separate attribute*” (Broekhuizen and Alsem) [2002].

Researchers have not developed models for mass customization exclusively but to facilitate the examination of other research objectives. Duray, et al., [2000] developed a classification scheme to study the financial and operational performance of mass customizers and Potter to examine the application of vendor managed inventory for achieving mass customization and Amaro, et al., [1999] to study the competitive advantage and customization issues in non make to stock companies.

Most of the classifications are validated with examples of different consumer or industrial products. In reality the strategic complexities and other factors vary for consumer and industrial products. Many papers have examined various mass customizers and discussed a range of frameworks in terms of customer order decoupling point and degree of product customization. But the type of business strategy followed by a firm has never been addressed. A company could be engaged in business-to-business (B2B) or Business-to-customer (B2C) mass customization. It is totally a different route for B2B and B2C companies to implement mass customization. B2B marketing is generally considered more complex than B2C marketing, as there is often more than one decision maker involved in a B2B sale on the buyer's side. This makes it important to identify mass customizers on basis of type of business.

When it comes to volume of mass customization, many companies adopt a mix of different mass customization strategies. They may even produce standardized products in the same facility as mass customization [Duray, 2002]. Thus the volume of mass customization sales by the company is another important factor for consideration.

This research presents a framework to evaluate various mass customization strategies based on marketing approach (i.e. B2B, B2C), customer involvement and modularity in value chain and whether or not a company pursues a profitable mass customization business strategy. The model proposed has attributes that are mutually exclusive and that can be applicable to all case studies.

2.8.1 Terms and Definitions

This section discusses the different terms considered for developing this framework.

Business strategy

B2B strategy: Business to business is a strategy which involves the transaction of goods or services between businesses [Fleisher and Bensoussan, 2002].

Examples: Deutsche telekom, Marelli Motori, Boeing etc.

B2C strategy: Business to consumer strategy describes activities of commercial organizations serving the end consumer with products and/or services [Fleisher and Bensoussan, 2002].

Examples: Adidas, Nike, Time 121, Dell etc.

Modularity

Modularity is a necessary attribute to validate the term "MASS" in mass customization. To achieve economies of scale, number observers suggest modularity as a key concept. Pine [1993] stated that true mass customization requires modularity in production, although he is not specific about where and how modularity should be used. Bladwin and Clark [1994] discussed modularity in production as a means to partition production to allow economies of scale and scope [Glodhar 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. Similarly, Ulrich and Tung [1991] argued that modularity can help product variety, but he also addressed the use of modularity to shorten delivery lead times and provide economies of scope. Pine, et al. [1993] asserted that to be successful, mass customization must employ a production/delivery strategy that incorporates modularity into components and processes. In, essence, the literature suggests that modularity can facilitate increasing 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 [Duray, et al., 2000].

Modularity can take a number of forms. To better distinguish types of mass customizers, a range of modularity types should be considered [Ulrich and Tung 1991]. The various types of modularity found in production environments were discussed in Pine [1993], although he does not explicitly link modularity types with mass customization. Ulrich and Tung [1991] developed a similar topology of modularity [Duray, et al., 2000]. The different types of modularity are discussed below.

- Component swapping modularity:

  This type of modularity occurs when two or more alternative types of a component can be paired with the same basic product creating different product variants belonging to the same product family. Examples of this type of modularity in automobile manufacturing would be the availability of different audio cassette decks, windshield glass types, and wheels for the same automobile [Ulrich and Tung, 1991].

- Component sharing modularity:

It is a complimentary case to component swapping modularity. With component sharing the same basic component is used in different product families. Examples of component sharing in automobile manufacturing are the use of the same brake shoes, alternators or spark plugs in several different product families of automobile [Ulrich and Tung, 1991].

Note: Component sharing modularity and component swapping modularity are identical except that swapping involves different components with same basic product and sharing involves different basic products using the same component [Ulrich and Tung, 1991].

- Cut-to-fit modularity:

  This is the use of one or more standard components with more or more infinitely variable additional components. Most frequently the variation is associated with physical dimensions that can be modified (e.g. cut-to-length), although the concept applies to components that can be infinitely varied by any simple production process. Examples of this type of modularity are cable, typewriter frames that can be produces to accommodate any width of paper [Ulrich and Tung, 1991].

- Bus Modularity:

  This form of modularity is used when a product with two or more interfaces can be matched with any selection of components from a set of component types. The product interfaces will accept any choice from the component set of any combination. Bus modularity is exhibited in electrical and electronic systems with busses such as computers and circuit breaker systems [Ulrich and Tung, 1991].

An important distinction between bus modularity and component swapping, component sharing and cut to fit modularity is that bus modularity allows variation in the number and location of the components in the system while other forms of modularity allow only variation in type of components used in identical product architecture

- Sectional modularity:

  It allows a collection of components chosen from a set of component types to be configured in an arbitrary way as long as the components are connected at their interfaces. Each component may have one, two or more interfaces allowing sequences and tree structures to be built from the components. Examples of sectional modularity are found in piping systems (elbows, tees, caps and Legos) [Ulrich and Tung, 1991]. The different types of modularity are shown in Figure 2-5.

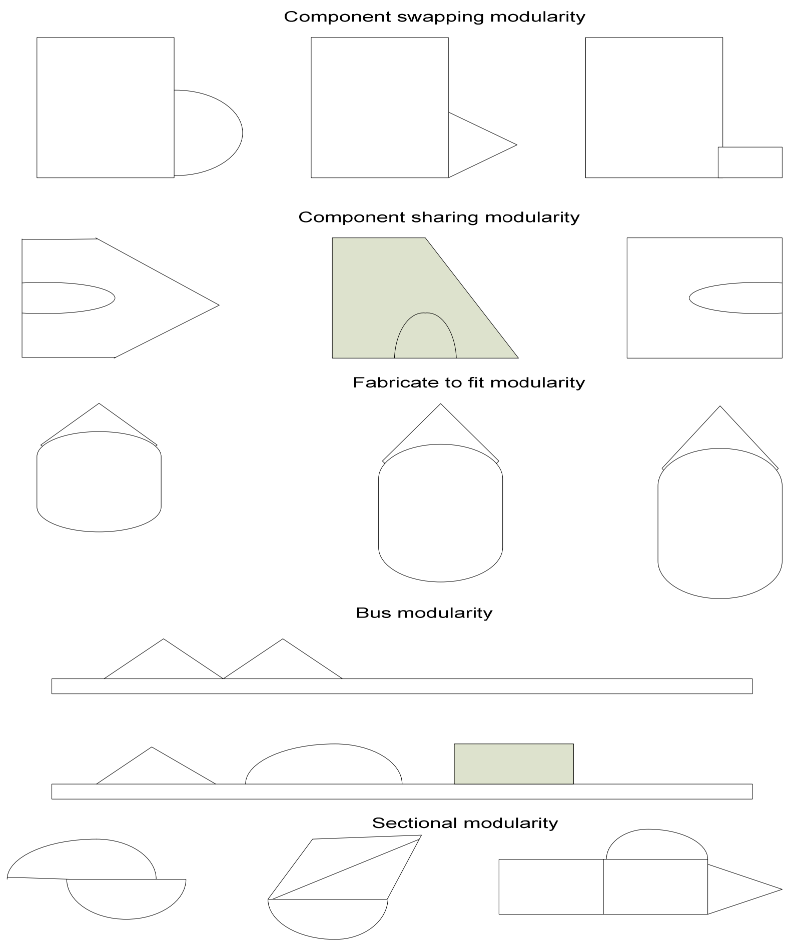


Figure 2-5 Modularity types [Ulrich and Tung, 1991]

Modularity in Value Chain

Cut-to-fit and component sharing modularity require designing components newly or modification. Therefore, this can occur in the design and fabrication stage only. Also in cut to fit modularity a standard product might require change in dimension and this can happen only in the fabrication stage. With the sharing modularity, although a standard base unit is incorporated into the product, additional components need to be fabricated according to the needs of the customer.

In the assembly and use stages, no new components can be fabricated or designed for the customer. Modules are just arranged or combined according to the specification of the customer. Typically, component swapping, sectional and bus modularity use standard modules without any alteration [Duray, et al., 2000].

Customer involvement

Customer involvement is an important tool for mass customization as mass customization simply means manufacturing a product to meet the needs of specific customer. For a company that is trying to move from mass production to mass customization, customer involvement in the value chain could prove real value. Depending on degree of customization and the willingness to pay the involvement of customer could occur in any of the four stages of the value chain (i.e. design, fabrication, assembly, use & distribution). A company can keep at bay the competition from its peers by using this tool.

Volume of customization

As indicated by Spring and Dalrymple [2000], the central classification attribute is the percentage of the volume of mass customization business from the total business. For companies that have implemented mass customization as a profitable business strategy and companies that only offer mass customized products, this percentage is roughly 100%. The other values employed as rough figures are < 10% and >50% (relative mass customization volume) [Spring and Dalrymple, 2000].

2.9 Framework for Classifying Mass Customization Strategies

One of the important factors considered in building this framework is that the attributes chosen to classify companies engaged in mass customization are independent of each other. Thus, there is no ambiguity in identifying the attributes given a company. The importance of the four attributes is discussed above. Each attributes has different dimensions to facilitate the classification of various mass customization companies to a unique location in the framework. The dimensions and attributes are shown in the Table 2-5.

Table 2-5 Dimensions and attributes Considered for Mass Customization Framework

	Attributes			
	Customer involvement in value chain	Modularity in value chain	Business strategy	Volume of customization
Dimensions	Design	Design	B2B	<50%
	Fabrication	Fabrication	B2C	>50%
	Assembly	Assembly		
	Distribution and use	Distribution and use		

In summary we have 4 attributes and 12 dimensions to position a company in the framework. To facilitate comprehension, the four attributes are presented in a simple 2 dimensional grid as shown in the Figure 2-6.

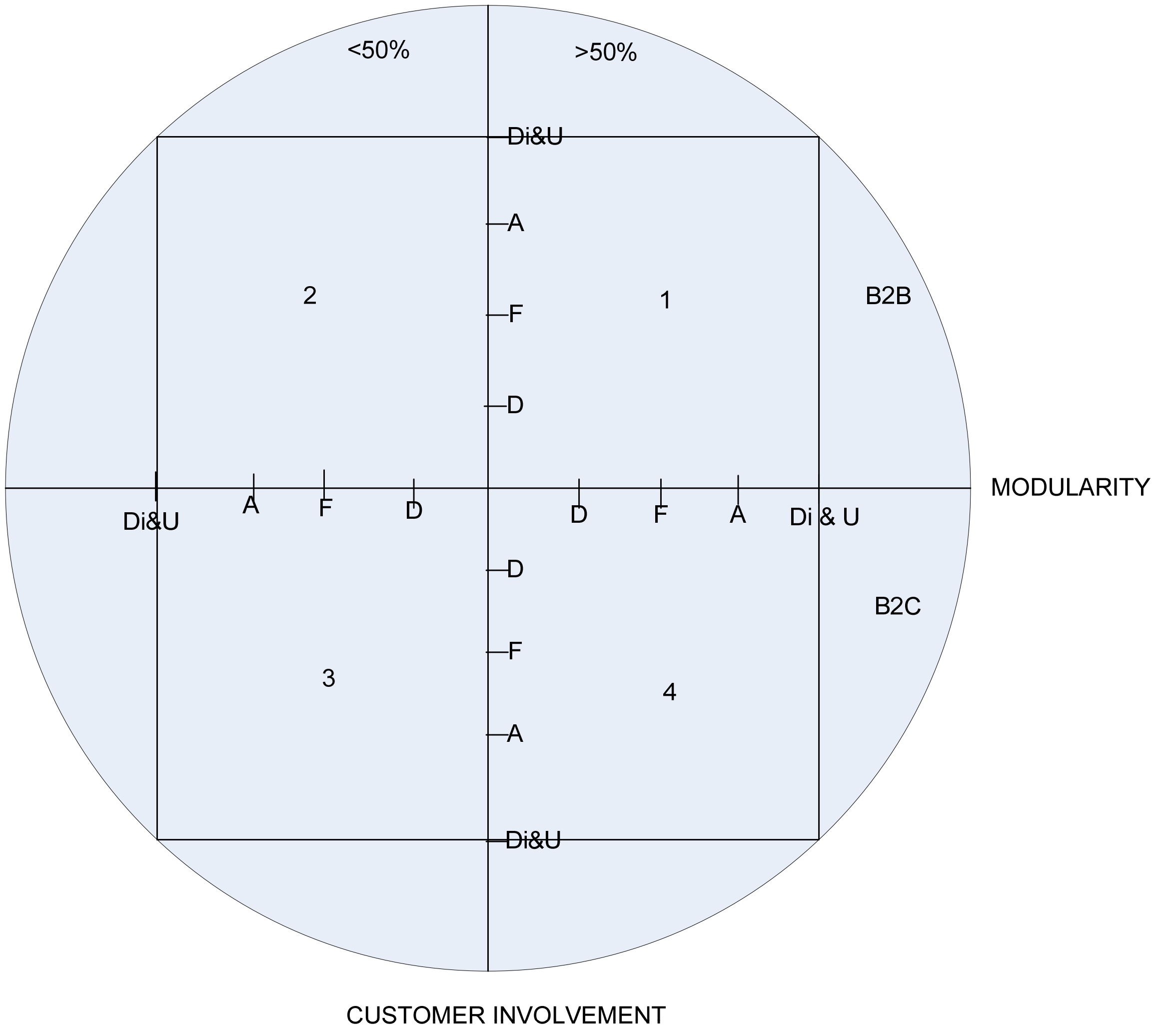


Figure 2-6 Framework for Mass customization

2.9.1 Description of the Grid and Validation with an Example

The grid comprises of four quadrants (point defining each of the four attributes and the dimensions). The X-axis indicates modularity in value chain (with elements of value chain on positive and negative X axes), the Y-axis indicates customer involvement in value chain (with the elements of value chain on the positive and negative Y axes). The quadrants above the X-axis indicates the B2B business approach and the lower half B2C business approach. Either sides of the Y-axis indicate the < 50% and >50% volumes of mass customization.

The mass customization framework above would be validated with a case study of APC Company. The information required to present this validation is taken from the international mass customization case collection [Piller and Moser, 2006]. In addition, many other B2B and B2C companies are located on the framework based on the information gathered from their respective websites and journal papers.

2.9.2 Validation

APC is an industry goods manufacturer producing uninterrupted power supply [UPS] and infrastructure system for data centers. The product range of APC consists of computer racks and cabinets, cable trays, controls, air condition etc. APC's business model is based on highly modular product range, usage of product configurator system for sales and processing and customer initiated assembly of final products with mass production of standard modules. Modularity is achieved by adding and replacing modules [Piller and Moser, 2006].

Mass production of standard parts takes place in the Far East and the assembly in the distribution centers. Based on the data available the assembly occurs in the following proportions.

Configure to order- 70 -80%

Integrate to order- 15-20%

Engineer to order- 4-5%

Classification of APC under different customization strategies is explained in the next few paragraphs.

Considering the Lampel and Mintzberg's [1996] model, APC can be categorized into customized standardization as typically, configure to order follows customized assembly of standard modules. 4-5% of the products can fall under pure customization as they need pre approval from the director before the order is processed. APC's configuration system requires trained salesman to perform the configuration. However Lampel and Mintzbergs's [1996] model does not discuss the aspects of collaboration with the customer. As product line at APC follows mass production of standard modules, it means that the company follows a mixed strategy of mass production and customization. This gives rise to the concept of modularity which is not a part of the Lampel and Mintzberg [1996] model.

APC can be classified as collaborative customizer according to Gilmore and Pine's [1997] model as it involves interaction with the customer during the configuration process. However this model does not clearly identify the customer involvement in value chain. APC, being a business to business enterprise, needs a complex configurator and the assistance of sales person too. Thus there is need to identify the configurator capabilities needed for different business strategies.

Amaro, et al. [1999] classification has three dimensions. The three dimensions can be graphically placed in a grid such that locating a company in the grid is able to define all the three dimensions. APC can be categorized into assemble to order (2) types. According to his chart, the dimension namely, the company responsibility is in terms of design specification and purchasing and activity after receipt of order occurs in delivery and assembly. The attribute seem to be combined imprecisely and need some more clarity.

Duray, et al. [2000] model has two dimensions namely point of customer involvement and modularity in value chain. APC achieves modularity by adding or subtracting modules. Thus, APC must be typically following component swapping, sectional and bus modularity. No new modules are fabricated for the customer. So modularity occurs in assembly and use stages and customer involvement at assembly stage as standard components are configured to achieve a desired combination. This means APC can be categorized as a modularizer. However, the Duray, et al. [2000] model does not discuss collaboration with the sales person for complicated product customization.

APC can be classified in the mass customization generic levels of assembly and 4-5% of products into design. The generic level assembly indicated that the strategy followed is customized standardization and the stages in mass customization are modular production and the types of mass customization would be assembly of standard components into unique configuration. Thought the term modular production is used, the classification does not emphasize on modularity or modularity in value chain. Modular production in this classification means standard components can be configured in a wide variety of products.

According to MacCarthy, et al. [2003] classification APC would fall under MODE A types which is catalogue mass customization. It is explained as follows: Customer selects from a pre-engineered catalogue of variants and products are manufactured by order fulfillment activities. But this mode does not give a clear idea about the degree of customer involvement and the concept of modularity as the classification is not based on the value chain. Also it does not discuss the need for a configurator and a sales person.

On studying the different classification schemes and locating APC in each of them, it feels that not all the attributes in any of the classifications give a complete overview of APC's customization. APC is a B2B company that employs the concept of modularity to achieve mass customization. A configurator is used to configure the product before the order processing begins. The configurator is assisted by a sales person who is trained with the product configuration. APC mass produces the standard parts and then assembles them according to the customer needs. The implementation of mass production and customization is achieved as well. In order to represent all these details, a comprehensive framework is needed. The mapping of APC on the proposed framework for mass customization is discussed below.

Since standard parts are configured, customer involvement occurs in the assembly stage in the value chain. Product modularity is achieved by adding or subtracting components thus modularity occurs in assembly and use stages. It is evident that the company follows B2B strategy, this fact can be useful in judging the type of configurator capabilities needed and how necessary is the presence of a salesman. The volume of customization would enable us to know in which direction a firm can start thinking to progress in the future. It can either increase or decrease the volume of customization offered. It also proves the fact that a same environment can be used to build standard and custom goods. APC's location on the mass customization framework is shown in Figure 2-7.

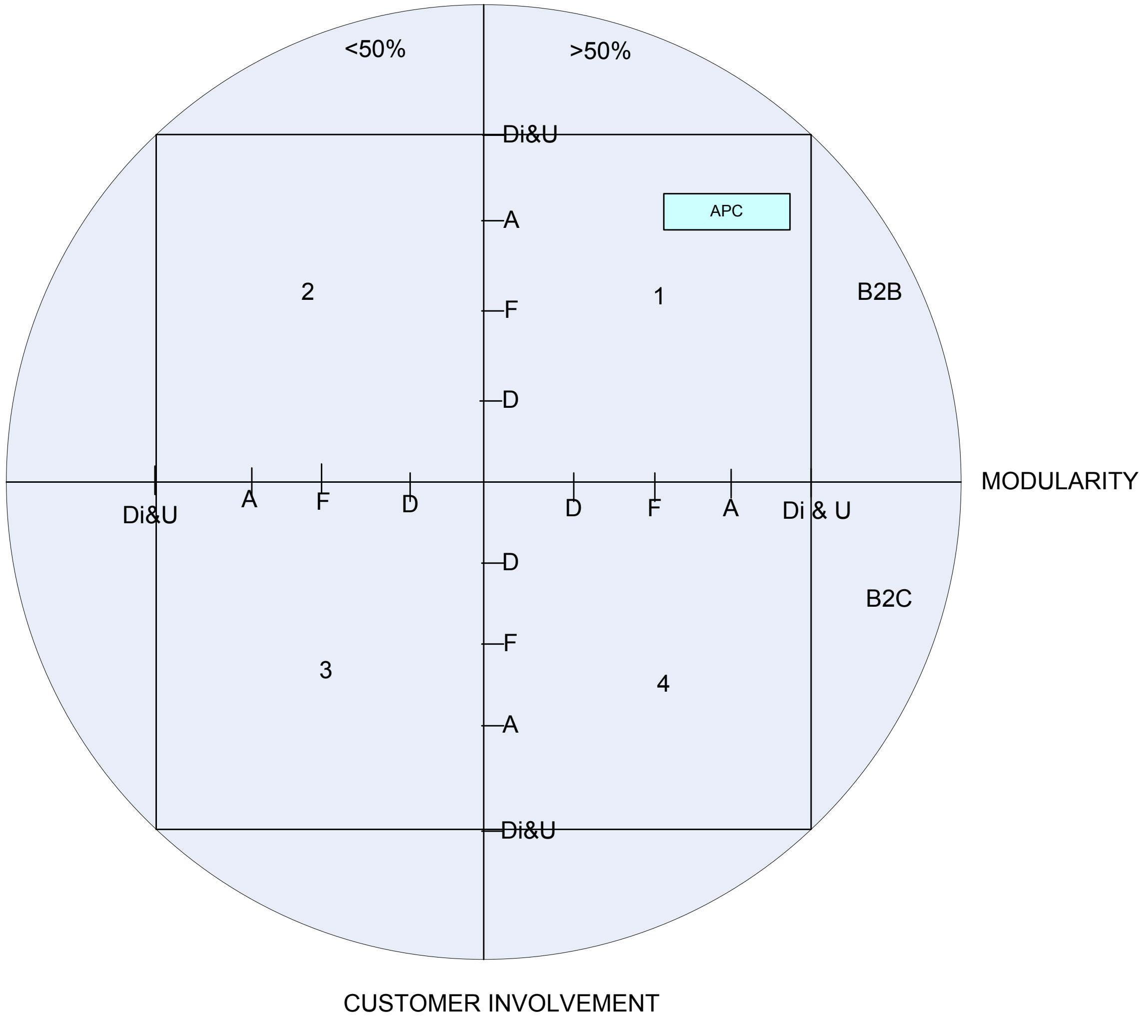


Figure 2-7 APC's location on mass customization framework

2.10 Classification of Other Examples on Mass Customization Framework

The examples discussed in the following lines are obtained from various sources and supplemented with information from company websites. Figure 2-8 shows all the companies on the mass customization framework. The appendix gives further details of the sources from the details of the companies is gathered.

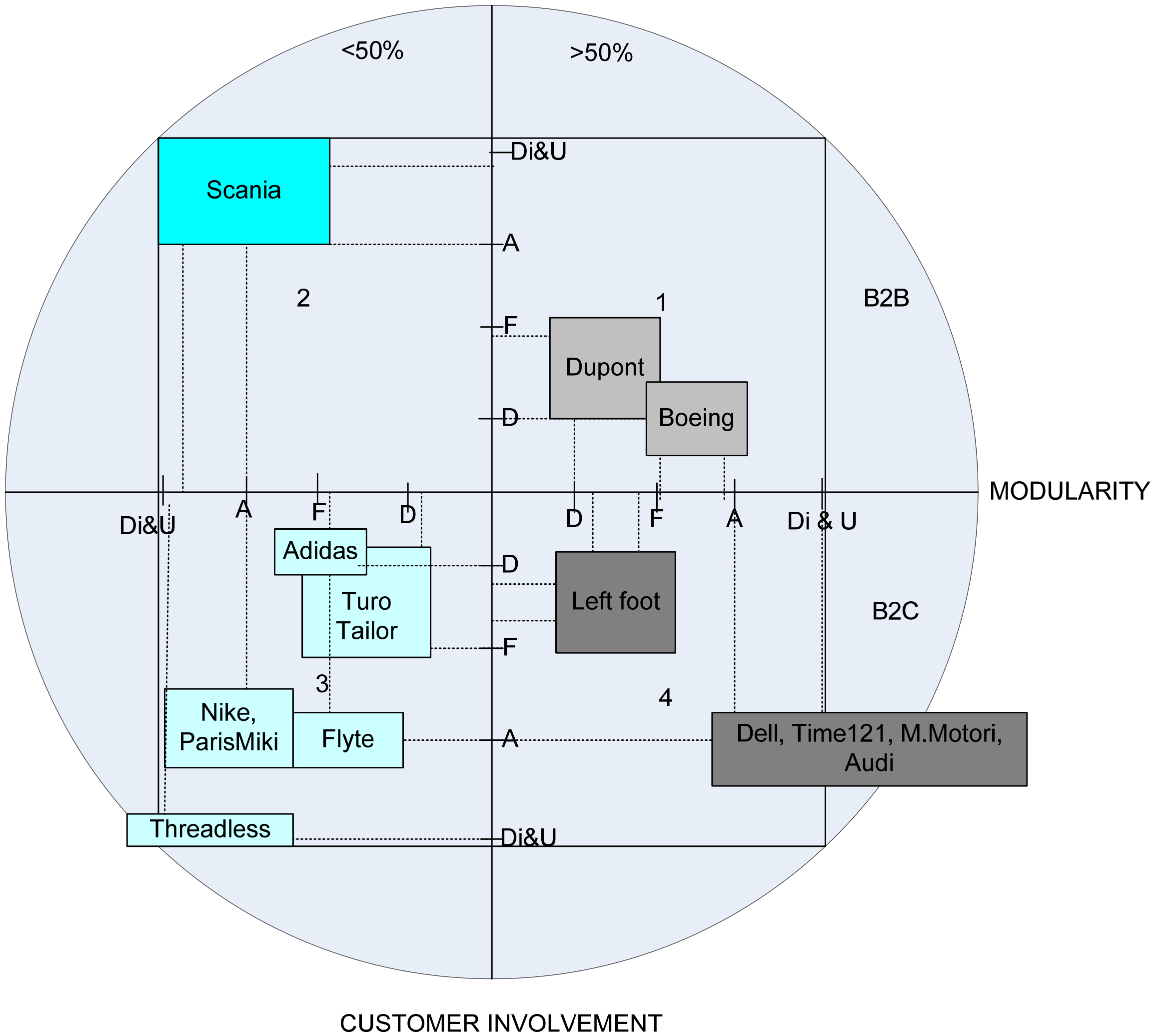


Figure 2-8 Companies on mass customization framework

Table 2-6 Summary of Dimensions

Company Name	Customer Involvement				Modularity				Business Approach		Volume of customization	
	D	F	A	Di&U	D	F	A	Di&U	B2B	B2C	<50%	>50%
Adidas	●					●				●	●	
Time 121			●				●	●		●		●
Dell			●				●	●		●		●
Turo Tailor	●	●			●	●				●	●	
Nike			●				●	●		●	●	
Marelli Motori			●				●	●	●			●
Left foot	●	●			●	●				●		●
Threadless				●				●		●	●	
Flyte			●			●				●	●	
Boeing	●					●	●		●			●
Paris Miki			●				●			●	●	
Audi			●				●	●		●		●
Dupont	●	●			●	●			●			●
ACP			●				●	●	●			●
Scania			●	●			●	●	●		●	

Adidas

Adidas follows B2C business strategy.

Customer involvement: Occurs in the design stage as the image of the foot print is taken for comfort fit and only then the order is processed which requires visiting the store. Other than the foot print there are various options with respect to color and fabric etc that could be done online.

"Customization at Adidas refers to a pilot program which allows consumers to create their own unique footwear based on personal specifications regarding function, fit and design." [Adidas, 2007]

Modularity: Occurs in the fabrication stage as this type of modularity could be considered as cut to fit.

Volume of customization is < 10% [Moser, 2007].

Time 121

"Statement from the website: Standardized and tailored modular components are combined in a customer specific end product." [Time 121, 2007]

The company offers Swiss-made watches with a large variety (3 million possible combinations) of cases, movements, hands, dials, and straps with different styles and colors.

Customer interaction takes place within the assembly phase of the value chain (for details on the different types of customer integration see Duray, 2002). Manufacturing a customized 121TIME watch does not only include the assembly of pre-manufactured parts, but also the (optional) manufacturing of the strap for an oversize width, the engraving and the testing of the impermeability. Regarding these manufacturing steps, the type of mass customization, pursued by 121TIME, is a 'made-to-order' system.

Time 121 follows a B2C strategy.

Customer involvement: Occurs in assembly as the customer configures a watch from a given set of option and also in use because he is allowed to engrave text of his choice.

Modularity: Occurs in the assembly and use stage since no new modules are fabricated and more often component swapping takes place.

Volume of customization is considered to be 100% [Moser, 2007].

Dell

Dell is a B2C company.

Customer involvement: Occurs in the assembly as customers can choose the components from a wide range of options taking compatibility into consideration.

"Dell gets a two to three point cost advantage by delaying assembly until a customer's order is received" [Dell, 2007].

Modularity: Occurs in the assembly and use stage since no new modules are fabricated. Bus modularity is practiced i.e. components are added to a standard frame.

Considering Dell to be a profit taker today the volume of customization is 50%.

Turo Tailor

Turo Tailor is suit manufacturer following B2C strategy.

Customer involvement: Occurs at the design and fabrication stages in collaboration with the assistance of a sales personnel and the customer needs to walk in to the store to place the order [Window shop, 2007].

Modularity: This can be considered as a cut to fit modularity and thus at design and fabrication stages.

The volume of customization considered to be less than 50%.

Nike

Nike is a shoe manufacturer following B2C strategy.

Customer involvement: Occurs in the assembly stage as customer can configure his shoe online by choosing different color options, canvas etc.

Modularity: Modularity in assembly and use stages as more often component swapping takes place.

Volume of customization considered to be <50%.

Marelli Motori

Marelli Motori is motor manufacturer following B2B strategy.

Customer involvement: Occurs at the assembly stage as the customer picks a motor of his specification from a catalogue and can customize the motor in terms of voltage and number of poles.

Modularity: It follows the component swapping and thus modularity occurs in the assembly and use stage.

Volume of customization considered to be >50% [Moser, 2007].

Left foot

Leading European provider of custom footwear for men. Stores all over Europe, production in Finland. Custom fit and design. The company seems to work with the typical match-to-order system. This means that shoes are not produced based on customized lasts, but that the measurements of a customer are matched to an existing last [Piller, 2007].

Leftfoot is a footwear manufacturer classified as a B2C business.

Customer Involvement: Occurs in the design and fabrication stage as the foot print is scanned and then various color options and finish and fabric options are available.

Modularity: Cut to fit modularity is followed thus it falls under design and fabrication stages.

Volume of customization is >50%.

Thread less

Thread less is a customized T-shirt manufacturer following B2C strategy.

Customer Involvement: Occurs in the use stage as the print on the t shirt is customized i.e. the way it is presented is customized.

Modularity: Swapping of components occurs here because the t shirt itself is standard and the prints are different thus in the use stage.

Volume of customization is considered to be <50%.

APC

APC manufactures infrastructure systems and is a B2B company

Customer involvement: Since standard parts are configured, customer involvement occurs in the assembly stage in the value chain.

Modularity: Product modularity is achieved by adding or subtracting components thus modularity occurs in assembly and use stages.

Volume of customization considered to be >50%.

Flyte

Flyte is bicycle manufacturer following B2C strategy.

Customer Involvement: Occurs in assembly stage as the customer can choose from a large pool of options.

Modularity: Typically component swapping occurs and no new models are fabricated for the customer thus in fabrication stage.

Volume of customization is considered to be less than 50%.

Boeing

Boeing is a B2B manufacturer of planes.

Customer Involvement: As per the information online and few general articles, it can be said that the involvement of the customer occurs in the design stage. Taking an example of a fighter plane, lot of customization is required according to specification.

Modularity: Typically cut to fit modularity is followed for the different sizes of the planes and component swapping thus in fabrication and assembly.

Volume of customization considered to be > 50%.

Paris Miki

PARIS MIKI offers a recommendation system for eyewear by artificial intelligence developed 1st in the world "mimir"IA (intelligent agent). This system computes and analyzes even elements such as the facial features, the usage or purpose, and the sensibility, etc., and it recommends the best glasses and sunglasses for you [Parismiki, 2007].

Paris Miki manufactures eyewear and a B2C company.

Customer Involvement: Occurs in the assembly but in collaboration with the sales person.

Modularity: Occurs in the assembly stage with component swapping and no new components are fabricated for the customer.

Volume of customization is considered to be less than 50%.

Audi

Audi is a leading car manufacturer following B2C strategy.

Customer Involvement: Occurs in the assembly stage, customer can choose the type of engine, colors, and various seating fabrics.

Modularity: No new modules are fabricated for the customer; component swapping is more often applied, thus in assembly and use.

Volume of customization is considered to be > 50%.

Scania

Scania is a heavy duty truck manufacturer and is B2B Company.

Customer Involvement: Customer involvement occurs in the assembly and distribution stage.

Modularity occurs in assembly and distribution stage.

Volume of customization is considered to be <50%.

Dupont

Dupont is a B2B manufacturer.

Customer Involvement: Customer involvement occurs in design and fabrication stages.

Modularity: Modularity occurs in the design and fabrication stage.

The volume of customization is considered to be > 50%. Table 2-6 gives the summary of all the above discussed companies.

3 PRODUCT CONFIGURATORS: LITERATURE REVIEW AND METHODOLOGY

Product configurators [Tiihonen, et al., 2001] are knowledge-based systems used to support configuration process. It is an information system that assists in the creation and management, especially in the long term of configuration knowledge [Tiihonen and Soininen, 1997] and with artificial intelligence capabilities makes it less complicated to the customer [Sabin and Weigel, 1998]. In other words a configurator is software with logic capabilities to create, maintain and use electronic product models that allow complete definition of all possible variants with minimum data entries and maintenance [Midrange, 2006]. Product configurator systems are designed to support the process of customization [Kovse, et al., 2002]. For example a car manufacturer could introduce mass customization into his business process on the basis of a set of available engine types, transmission mechanism types, security device types, sunroofs of adjustable dimensions, seat types with different surface materials and colors [Kovse, et al., 2002].

Web-based configurator tools have become an important means of configuring products in the mass customization era. But with more and more variants the configuration process has become complex and confusing for the customer [Stegman, et al., 2003]. The old trend was to choose products from predefined set of variants. The goal of mass customization today is to offer complete personalization of products for individual customers [Pine, 1993; Piller, 2001]. This can be possible if customers participate in the design process as co-designers and configure their product in a product configuration system. Manual configuration would make it a complex task for customers as they lack the know-how of transferring their preferences into product configuration containing detailed technical knowledge. To reduce the complexity experienced by the customer, the configuration system should generate personal recommendations automatically based on customer preferences and interests.

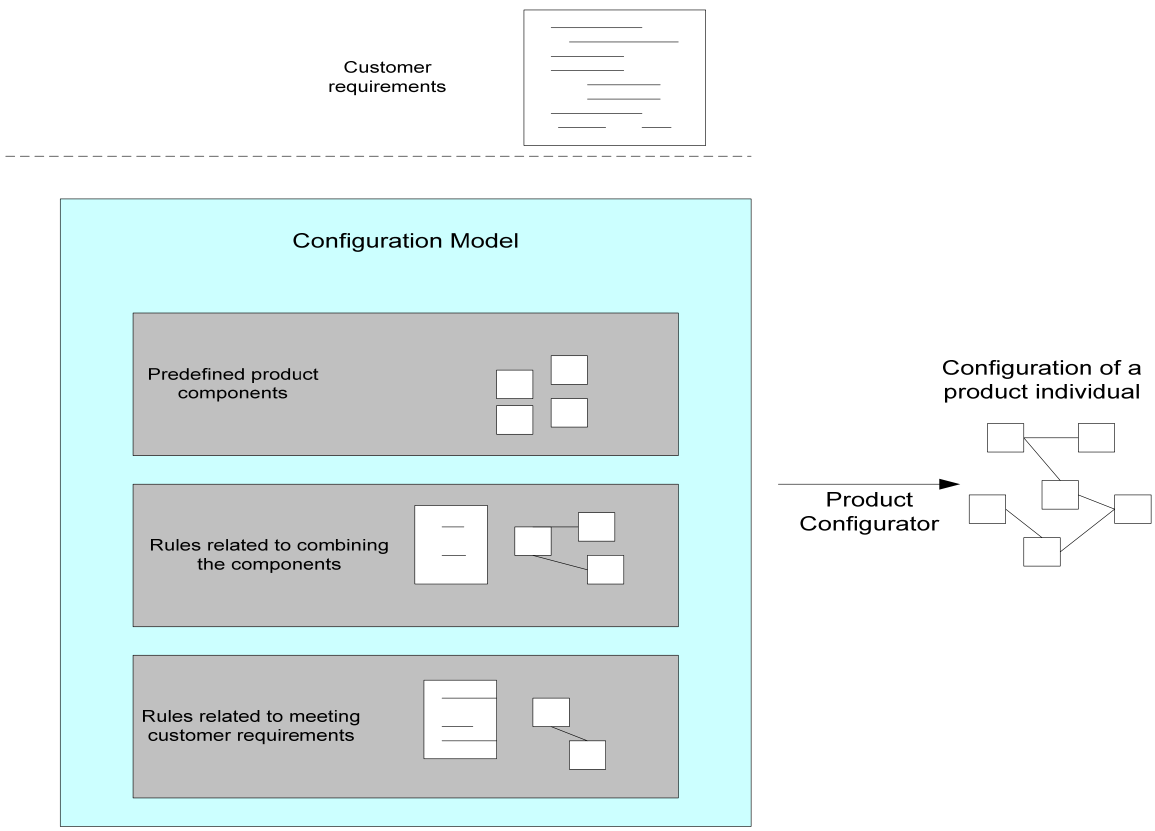


Figure 3-1 Product configuration process [Kovse, et al., 2002]

Configurators can be classified into two classes namely manufacturing model configurator and marketing model configurator approaches [Tiihonen and Soininen, 1998]. Manufacturing model configurators have technical focus and are considered to be complex for customer oriented product configuration. Customers cannot completely understand the technical details and would be overwhelmed with the content. The marketing model configurator is considered dominant in commercial solutions. It focuses on those aspects of the product that would hold the attention of the customer. Web-based configurators of Dell, Adidas and Nike etc fall in this category. In short, marketing model configurator can provide simple choice variants. Ideally, a configurator should have capabilities based on type of customization and volume of customization being offered. Thus it should have both manufacturing and marketing model configurator capabilities based on the product customization. Most of the B2C kind of products should have marketing model configurator capabilities, if the customer involvement occurs early in value chain, the configurator needs to also have some manufacturing model configurator capabilities. So a configurator cannot truly fall in any of these categories but have a mix of both types. Manufacturing and marketing model configurators cannot exist independently. Technically speaking, a configurator should have both these capabilities but one might dominate the other based on the degree of customization and customer involvement [Stegman, et al., 2003].

A right combination of customization and product configurator capabilities will allow companies to offer customized products and services that add value to the customer. An attempt to combine the advantaged of personalizing products and services with mass production costs in one single production system has brought about the mass customization paradigm [Davis, 1987; Toffler, 1970].

Arana, et al. [2005] asserts that the integration of product configuration and product data management systems would help in the implementation of mass customization [Arana, et al., 2005]. One way of implementing mass customization is through configurable products [Heiskala and Paloheimo, 2005]. The design of configurable products specifies a set of rules on how these elements can be combined into products to meet customer requirements [Salvador and Forza, 2004; Tiihonen and Soininen, 1997]. Figure 3-1 depicts the product configuration process.

Customer requirements in the purchase of customized products can be met by applying the process of product configuration. The product configuration potential used in this process can be expressed in the form of generic product structures, commonly known as configuration models [Mannisto, et al., 1996]. They are used to describe a specific product family. Product family is defined as a set of all possible product individuals that allow to be instantiated generically on the basis of a given configuration model.

In order to support the configuration process, there are some aspects that need to be considered during product development. Firstly, if the physical properties or functionality of product parts be represented by a component is adjusted in any way. Secondly, the range between which of the parameters can vary and thirdly checking for compatibility [Kovse, et al., 2002].

Configurators are the systems that use product definition information in sales-delivery process for accurate and fast configuration that fulfils customer requirements and company constraints. Product configurators however don't support full all degrees of customization. This demands the integration of product configurator with CAD/CAM/CAE applications. It's also a difficult to update the product configurator with new release of configuration data. The engineering staff of the company has better knowledge about the product but they cannot always transfer all that knowledge to the configurator because of lack of user friendly tools [Mesihovic and Malmqvist, 2000].

For this reason, the customers should be offered configurators with front-end capabilities and the internal data is dealt with the back-end configurator. For better assistance, front-end and back-end should be linked. Only front-end or back-end capabilities cannot serve all the purposes of the customer. Ideally, the system should have both front-end and back-end capabilities and they should be interlinked. There are numerous advantages of front-end and back-end being connected. Some of them to list are: It would avoid loss of information, accuracy and validity of customer data can be maintained, customer can get better assistance. An effective configuration should have the capability of transferring knowledge from product development process to sales-delivery process.

The front office sale has the capabilities of capturing the requirements of the customer followed by generation of quote sometimes. Back office has capabilities of producing engineering designs [Technicom, 2007]. A product configurator is software that captures and manages the definitions of a unique product. In the absence of a configurator, every unique product is assigned a new part number and a bill of material is created for every customer order. The result is huge database and any errors.

Back-end is mainly responsible for the conversion of configuration into bill of material, quoting and estimating price, and product routing and generation CAD models. The key functions of a configurator can be listed as follows: Product/ service recommendation, constraint and dependencies, calculation of price and bill of materials [Article, 2006].

Back-end configurators have the capabilities oriented to the needs of manufacturing, primarily to create accurate product configurations with minimal bill of materials. Front-end systems are termed as sales configurator systems. To fully address the company's configuration needs, both front-end and back-end capabilities are needed [Bourke, 2000]. The advantages of having front-end and back-end systems are well recognized: accurate and timely quotes and orders for complex products and unassisted customer ordering through web with front-end capabilities that facilitate online ordering [Sabin and Weigel, 1998]. A configurator should have expressiveness and representational power, efficient knowledge application in highly combinational context and coping with a high rate at which knowledge changes [Sabin and Weigel, 1998].

Configurators should be used throughout all the phases of product life cycle like through design, sales, manufacturing and supply chain. The same is classified into front-end and back-end for convenience. Sales, more often need not be via web, it could be offline as well. If sale is possible via web, it means that the configurator has online configuration capabilities. If configuration and sales is performed offline, then it is said to possess offline configurator capabilities [Midrange, 2006].

In the past, basic product configurators were often seen as ERP modules. Today, there are many consulting services offering configuration with many capabilities. But the selection of the right configurator should be based on the requirement of the company and the complexity of the product configuration [Midrange, 2006].

Samir and Johan [2000] classify configurator into assemble-to-order, engineer-to-order types. It is evident from their nomenclature that they support assemble-to-order process and engineer to order process. But the current research of this thesis discusses these processes as degree of customization as part of the mass customization framework. The capabilities needed to achieve these degrees of customization are discussed in the product configurator framework.

According to Mittal and Frayman [1989] assemble-to-order configurators are built after the product development and thus have fixed number of combinations and predefined set of rules. Assemble to order typically includes steps like specification mapping, preliminary configuration and selection of sales-delivery. Engineer to order configuration concept uses assemble to order configuration for some parts while others are designed to customer requirements. These other activities are supported by CAD/CAM/CAE. These definitions speak more about customization types than product configurator capabilities [Mesihovic and Malmqvist, 2000].

A configurator tool alone cannot serve the purpose of mass customization. Because many degrees of freedom are involved in the customization process, it leads to confusion and uncertainty for the customer [Helander and Jiao, 2002]. Many times, customer clearly does not know what they want [Wind, et al., 2002]. Therefore it is always advisable that companies maintain a database of previous customer designs and preferences as it could guide and influence the new customer. It would even save time as the new customer has some idea in mind before he starts the configuration process. When a company is following the mass customization strategy, it faces a number of challenges in manufacturing, logistics and another issue that arises is involving customer in value chain. For this reason, customers need to be aware of the product and some basic functionality.

Also, customers do not know what they really want, until they see it [Wind, et al., 2002]. It is important that the configurator has graphical capability along with textual as well as graphics that would act as good visuals. Since the customer is configuring something that is new and which he cannot see, feel or test until he buys it, graphical ability is absolutely helpful. This would not only reduce the complexity but overcome uncertainty [Leckner, 2003].

Leckner [2003] discusses about customer communities to assist the customers in configuration. He discusses asynchronous collaboration and synchronous collaboration is provided by the database of previously configured products in the form of participatory catalogues [Schubert, 2000]. These catalogues contain the rating and comments of group members. Synchronous collaboration speaks about shared workspace [Miles, et al., 1993] which enables collaborative design to develop products.

Irrespective of the amount of collaboration provided by customer communities, it is of greater value if a consultant or a sales person assists the customer in the technical aspects. Depending on the complexity of the product customization, consultation can be provided to the customer that would ease the process. If the decision is just in terms of color and other things, the graphics ability of a configurator can handle the situation. If the product has something to do with the technical features, more than any database, consultation can work the best [Leckner, 2003].

Customers often do not have a clear knowledge of the solution their needs correspond to. At times, their needs are not apparent to themselves [Piller, 2007]. Additional uncertainties include costs. To avoid these confusions the configurator should have both front-end and back-end capabilities connected. Companies need to implement those capabilities in a configurator that can drive consumers to spend time in configuration process and provide capabilities that intend to give an outcome of the design process [Piller, 2007].

Other than maintaining a database of designs, customer profiles can help in understanding customer preferences. They can contain information about basic and demographic attributes, information about specific product interests and information about general interests [Leckner and Lacher, 2003].

One of the most successful applications of the product configurator is artificial intelligence. Based on the configuration knowledge, the conceptualization can be classified into rule-based, model-based and case-based approaches. Rule-based approach works on executing rules in the form of if–then conditions [Blecker, et al., 2004]. At each step the system verifies all set of rules and proceeds to those steps that can be executed next. As there is no separation between relationships and actions, they contain both domain knowledge and the control strategy to compute the solution [Sabin and Weigel, 1998]. The drawback of rule-based system is problems encountered during acquisition, consistency checking and knowledge maintenance [Hitec, 2006]. Model-based approach is mostly implemented in configurators which are logic-based, resource-based and constraint based [Sabin and Weigel, 1998]. Case-based approach works on the assumption that similar problems have solutions. A current problem is solved by finding and adapting to a similar previous problem.

Based on the business strategy configurators can be classified into assemble-to-order, fabricate-to-order and engineer-to-order. Assemble-to-order has finite number of standard modules for combining. Fabricate and engineer to order may have infinite configuration possibilities but would have complex configurators to allow parameterization of dimensions.

Internal configurators and external configurators are the next category [Blecker, et al., 2004]. Internal configurators support sales aspects in capturing customer requirements.

External configurators are designed with front-end with direct assistance during configuration.

Online configurators enable communication with the customers over the web. The configuration knowledge is stored in the web server. Offline configurators work with CD ROM or other data carriers. They work independent of the network [Blecker, et al., 2004]. More often offline configurators are accompanied with consultation.

Further, configurators can be classified based on the updates execution into push or pull. In push mode the supplier central unit communicates with the customer's local unit. In contrast in pull mode, local unit can retrieve the updates if required. Based on the scope of use, configurators can be classified into single purpose and general purpose systems. Single purpose has capabilities to support the sales-delivery process of the product. Special purposes are designed to a particular industry [Tiihonen and Soininen, 1997]. Based on the design complexity, configurators are classified as primitive, interactive and automatic. Primitive types allow basic configuration without checking the validity of decisions. Interactive types are capable of checking the validity of decisions while automatically generating parts or even entire configuration.

Taking the integration level into consideration, we have stand-alone, data-integrative and application-integrative configurators. Stand-alone don't dispose interface to other information system and thus cannot be integrated. Data-integrative helps in avoiding redundancy of information. Application-integrative enables integration of applications like CAD systems to the configurator [Blecker, et al., 2004].

Based on the solution searching approach there are two categories. One, based on technical elements and the other based on features. In the system based on technical elements, customer starts with a standard product and then specifies product options. Configurations working by features provide facility to specify requirements in terms of functionality [Blecker, et al., 2004].

Though configurators are classified into various categories, some of the terms are redundant. Papers discussed previously name the same capabilities differently. The internal and external configurators are identical to front-end and back-end configurations. Few classification discussed above speak more about the technical aspects than generic capabilities. The classification based on business strategy is more discussed in the mass customization framework in this thesis research.

Leckner [2003] discusses that individual needs and preferences can be categorized into measurable physical aspects, immeasurable but descriptive aspects and vague aspects. Measurable physical aspects are measurable by the customer like height, place of residence etc. Customer clearly knows what it is. Immeasurable but descriptive aspects are interests, hobbies etc. They can be read form the customer profile. Vague aspects are preferences which the customer cannot see it but want it [Wind, et al., 2002]. This is where the configurator comes into play. Though the product is virtually created, the customer should be able to visualize it. The graphical capabilities can serve this purpose [Leckner, 2003].

Skjevdal and Idsoe [2007] proposed a three dimensional framework for classifying product configurator systems based on a two dimensional framework of Hansen [2005]. The variables considered for this two dimensional framework is “degree of knowledge modeling” and “degree of graphic modeling”. He admits that an n dimensional framework would better justify the classification. Using Hansen’s [2005] framework, Skjevdal and Idsoe [2007] proposes a three dimensional model with the following variables: Degree of knowledge, Degree of graphics and Front-office versus Back-office. Degree of knowledge determines the constraints and rules for combining components. Degree of graphics describes the 2-D, 3-D interactive visualization capability. Front-office and Back-office discuss the sales and technical aspects of configuration. The model is presented in the Figure (3-2).

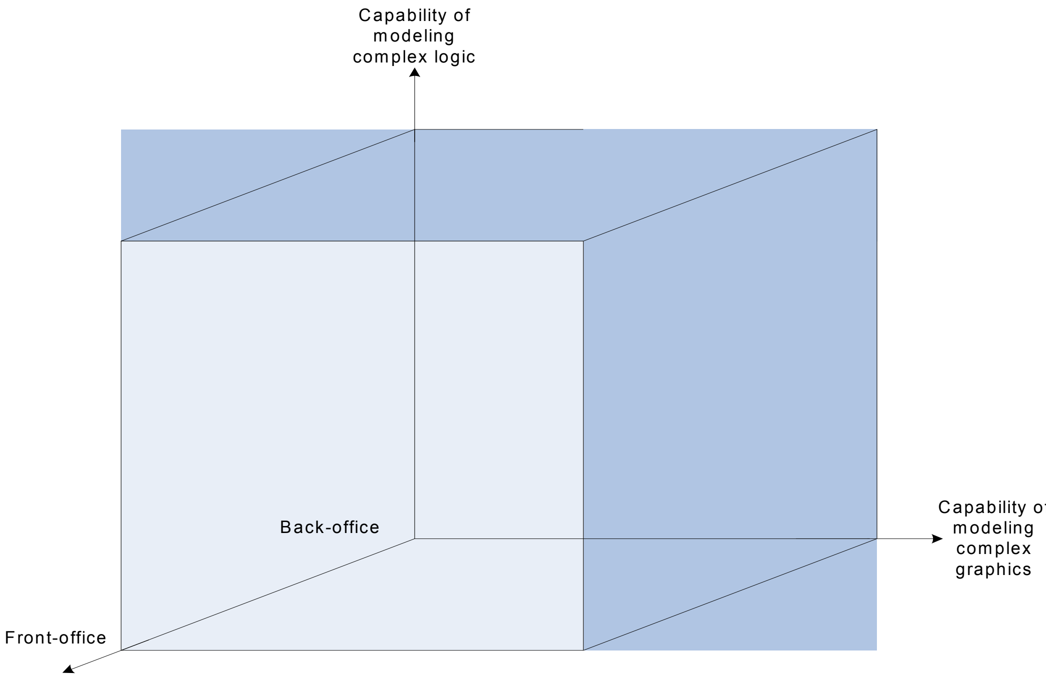


Figure 3-2 3- dimensional classification tool for product configurator systems [Skjevdal and Idsoe, 2007]

The discussion emphasizes on connecting the front-end and back-end. Thus the configurator abilities cannot be independent of each other. An ideal configurator should posses all capabilities based the product and the degree of customization offered.

3.1 Description of the Model

There are not many frameworks to categorize product configurators and there is need to capture all the capabilities of a configurator in a single framework. Also, the capabilities discussed so far cannot exist independently. They vary based on type of customization and product. For example, the importance of front-end and back-end are discussed in the literature but the importance of these being connected is not on focus.

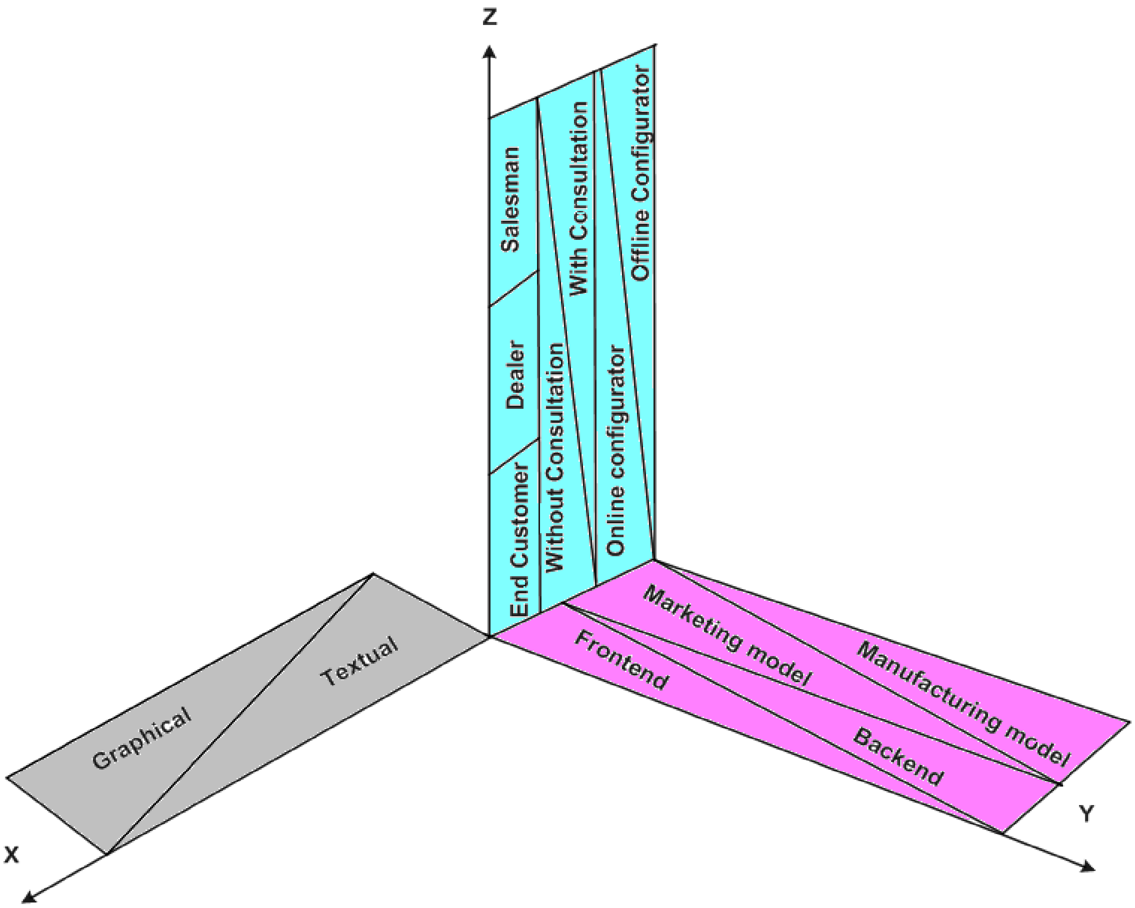
The product configurator model that would be discussed in the following paragraphs would represent the generic capabilities required and shows that the variables are dependent on each other.

The X-axis represents the collection of information for customization [Piller and Stotko, 2003]. Graphical and textual based capabilities are focused on this axis.

The Y-axis represents the Knowledge capabilities of the configurator. The primary focus is on the front-end and back-end capabilities. These can be extended to represent the manufacturing and marketing capabilities of the configurator as well. Because front-end is often an interactive platform for the customer and the marketing models concentrate on the same abilities. So are the back-end and manufacturing models; they discuss the intricate details of the product which are complex.

The Z-axis represents sales channel [Piller and Stotko, 2003]. The sales channel discusses the online and offline capabilities of a configurator. As explained earlier, offline configurators do not allow online sale or purchase where as online configurator do. These can further extended to discuss the user which could be the end customer, the dealer or the salesman and also, the consultation process. Considering the offline configurators, these are mostly used by the salesmen when the customization of the product is complex and cannot be handled by the customer and since the salesman assists the customer, there is elicitation and consultation occurring. For online configurators, the user is more often an end customer, thus the consultation process in not needed in this case.

An important feature of this framework is that, it focuses on inter-dependency of different capabilities. For example, a configurator will have textual and graphical abilities but how much each of them is required is dependent on the customization complexity and product. Same is the case with attributes on the other axes. The model is presented the Figure (3-3) showing all the three axes.



X-Collection of information for customization
Y- Knowledge capabilities
Z- Sales channel

Figure 3-3 Framework for product configurator

Based on the capabilities possessed by configurators used by different companies, the companies are located in the framework. The process of locating is based on an approximate rating on a scale of 0 -10 and the information taken from different sources and their respective websites. Figure (3-4, 3-5) shows the unique location for the companies discussed in the mass customization grid (Figure 2-7) as well. The companies are pointed in two graphs to avoid confusion.

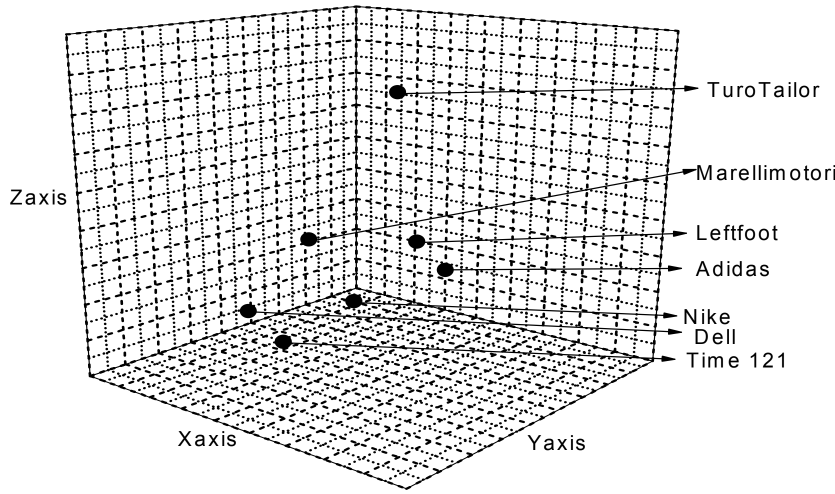


Figure 3-4 Locations of companies in 3-D grid

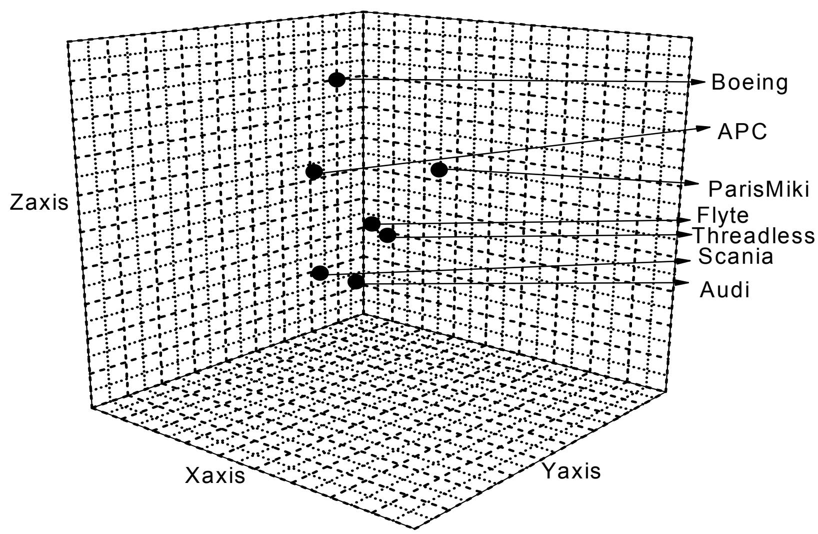


Figure 3-5 Locations of companies in 3-D grid

X-Collection of information for customization
Y- Knowledge capabilities
Z- Sales channel

4 ASSESSING PRODUCT CONFIGURATOR REQUIREMENTS

The current research work is an attempt to propose a generic framework for mass customization to determine the configurator capabilities required to successfully pursue their chosen strategy. These frameworks would provide a road map for companies to identify the right configurator capabilities to achieve successful mass customization and identify the right configurator capabilities.

Based on the point of customer involvement in the value chain, how product modularity is addressed, the volume of mass customization sales and the business strategy, a company could be placed on the mass customization framework. Thus, for any company it is possible to identify a unique location on the framework based on the attributes and dimensions as shown in Figure 4-1. Similarly, based on the features of the product configurator currently used by the company, it can be positioned (current location shown in Figure 4-2) on the product configurator framework. In addition, it is also possible to map the ideal or expected position (ideal shown in Figure 4-2), the company should be located at, in the product configurator framework, based on where it lies in the mass customization framework. Guidelines to identify this ideal position for product configurator have been discussed in the literature so far. Difference in the current and ideal positions would give an idea of how good the current configurator is and then the company can plan accordingly for improvement.

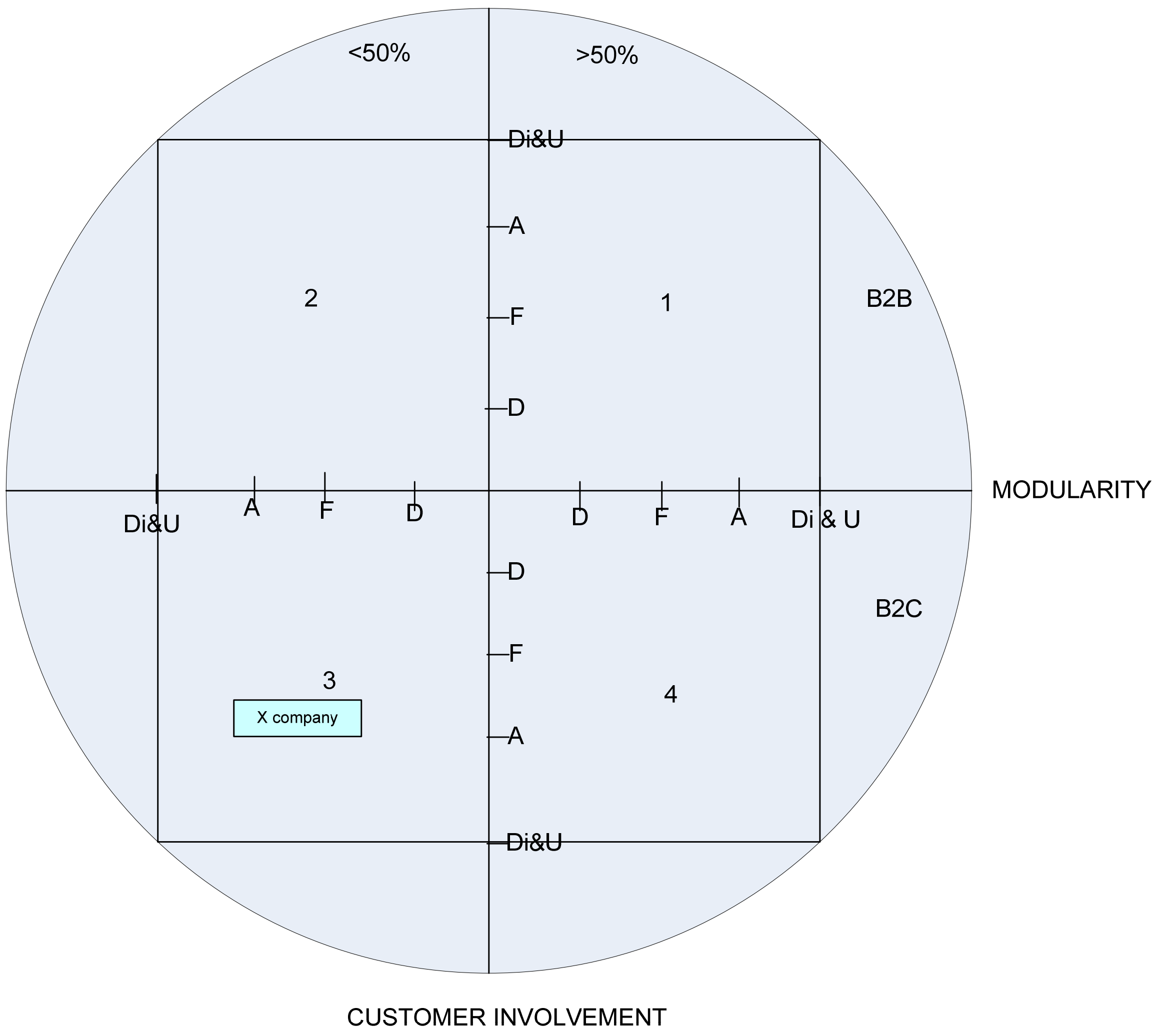


Figure 4-1 Location of company in mass customization framework

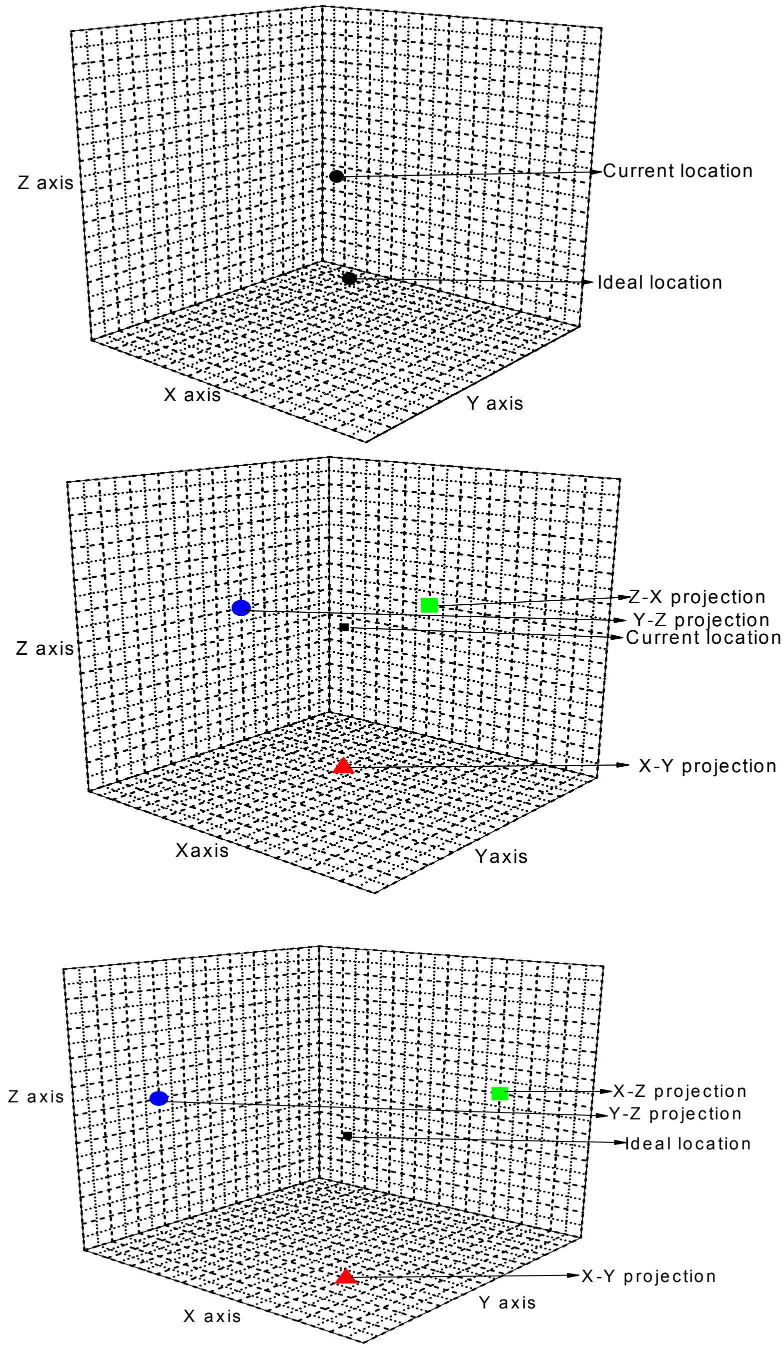


Figure 4-2 3-D view of current and ideal location of company X

X-Collection of information for customization
Y- Knowledge capabilities
Z- Sales channel

For example, if a firm is offering a complex product, it might want to make sure that, the configurator has a well built graphical interface and to reduce the confusion and complexity, it might want to provide assistance during the process and for that reason it might not want to offer online sale of products. On the other hand, if the customer involvement is in the distribution stage, the company might want to focus on the marketing and front-end capabilities and at the same time it might want to have online purchase possible.

The frameworks can also be used to determine the strategic location for companies. For example, a firm might want to narrow down its product variety and increase the degree of customization or, it might want to bring the customer involvement early in the value chain or it might want to shift its position with respect to modularity. With the knowledge of current status, firms can identify their strategic point and work on achieving the target.

Thus, the proposed models can be used to assess the product configurator capabilities for a given company and the path for future development.

Various companies have been discussed in the mass customization framework section. However, sufficient information is not available to analyze all these companies with respect to their position on the product configurator framework. To demonstrate this process in detail, a case study is presented in the following chapter.

4.1 Guidelines

Discussion on how to assess product configurator needs would be dealt here in the form of ‘if and then’ statements.

If the customer involvement occurs in the design stage, then a company might have consultation provided during product configuration. Because of complexity, it would prefer an offline configurator and since the configurator is offline it is operated by a salesman or a dealer. For this reason the configurator would have dominating manufacturing model capabilities. For sure it would want to have back-end and front-end connected to avoid loss of information and quick information on costing.

If the customer involvement is in assembly stage, then the configurator needs to have dominating marketing model capabilities. Since the end user is the customer, there needs to be more graphical representation than text. The front-end needs to be effective and connected to the back-end. The configurator has to be online and have the capabilities to make sale online. Since the configuration is relatively simple the customer would not need any consultation. The company might want to allow the customer to access the database of previous models for easy understanding of configuration.

If the product is a B2B type and customer involvement is in design stage, the customization is very high and complex. Thus the configurator needs to have dominating manufacturing model capabilities. The process is assisted with consultation and hence the end user is the salesman. The configurator is mostly offline and sale of the product is not possible online. The front-end and back-end have to be connected for better low of information.

If the product is B2C type and the volume of customization is < 50% then the configurator is mostly online and has dominating marketing model capabilities without consultation. To help the customer, the company might want to provide a strong graphical interface with front-end and back-end connected for costing information and online purchase.

If the volume of customization is > 50% then the company might want to go for a configurator with both manufacturing and marketing model capabilities. It might prefer offline configuration to assist the customer with consultation if the product is complex. Since the configuration is offline, it is operated by a salesman or a dealer. Depending on the customer involvement in value chain, the company might want to have dominating front-end and graphical interface.

If the customer involvement is in the distribution stage and the company is a B2C type, the configuration process is relatively less complex. The company might want to have a rich graphical interface with moderate textual. The company might want to provide online sale option and would look at a configurator that is online and has marketing model capabilities. Since the end user is the customer, there is no need of consultation. For a giving customer a better idea on the product, the company might want to give the customer, as access to database to view other customer choices as well.

If the modularity occurs in design and fabrication stages, new models are built for the customer, thus the configuration process is complex. The company might want to give assistance to the customer with consultation. The end-user in this case is often a salesman. To avoid complexity, a manufacturing model configurator with offline capabilities should be preferred. The configurator should possess effective back-end capabilities with front-end linked. Based on the type of product the company might want to make a balance between graphical and textual capabilities.

The guidelines proposed are generic and need a case by case examination for decision making.

5 CASE STUDY: GARRARD WOOD PRODUCTS

This case study addresses the issues involved in manufacturing custom kitchen cabinets. Today, custom manufacturing customer specific products has become a trend in the wooden cabinet industry. Often standard cabinets cannot meet the requirements of individual homes and the wooden cabinet industry is attempting to provide customized goods for its valued customers to customer preferences. Shorter lead times with wooden manufacturing compared to that of, for example custom appliances or furniture, has made customization more feasible. However, there are many challenges involved in mass customization of wooden cabinets. One of the challenges is the integration of the customer into the design and development phase, proper identification of customer preferences, data acquisition for dimensions of the kitchen, drawing room, etc before the design is finalized and the order is processed. Apart from order processing there are manufacturing related challenges as well. Secondly, it is a challenge to avoid loss of information as there is a lot of communication involved back and forth between the customer and the designer. It is the task of the designer to record the information accurately and convey it to the shop floor before the order is processed.

5.1 Case Company Profile

The case company used for this research is a wooden cabinet manufacturer in Kentucky, USA. The company was established in 1986 and operates in a 22,100 Sq Ft facility employing about 30 persons. It has a growing market share in and around Kentucky with their customers being end users, construction firms and resellers. The approximate annual sale of the company is about $1,300,000.

The majority of their sales is in the middle to upper price range, as shown in Table 5-1, and is aimed at upscale customers. The production line is designed to accommodate highly customized products that the company can produce at competitive prices when compared to semi-custom products. The product range mainly consists of cabinets for kitchens, doors, entertainment centers for televisions, bath, vanity products etc. Customers can choose between a range of wooden materials (Oak, maple, hickory, cherry and MDF) and surface treatments. Maple is the wood most preferred by the customers followed by cherry, hickory and oak and MDF.

Table 5-1 Price - Sales percentage

Price range (in Dollars)	Volume of sales
7000-8000	20%
12000-30000	70%
40000-50000	10%

The surface treatments such as paints and coatings are used on the wood according to the customer’s preference. Wood supplies are mainly from suppliers in Jeffersonville and a few smaller suppliers in the vicinity. Hinges are imported from Italy. The lead time to obtain raw materials is generally not more than ten days. The summary of the company profile is summarized in Table 5-2.

Table 5-2 Overview of company profile

Name	Garrard wood products
Address	Kentucky, USA
URL	www.garrardwoodproducts.com
Year founded	1986
Annual sales	$1,300,000
Employees	30
Industry	Wood products
Products	Kitchen cabinets, doors, entertainment centers, bath and vanity products

Kitchen cabinets produced by Garrard wood products could have three units; base cabinets, wall cabinets and tall cabinets. Certain dimensions of these units are fixed by specification but customers are allowed to change other dimensions. For example, base cabinets have standard height and depth but variable width to customize cabinets to meet the needs. Wall cabinets and tall cabinets have standard depth but width and height are variable. The modularity concept of mass customization comes into picture here and this is how the term mass is achieved in cabinet manufacturing.

5.1.1 Order Initialization

The order processing for mass customized wood cabinets is outlined in Figure 5-1 below and explained in the following section.

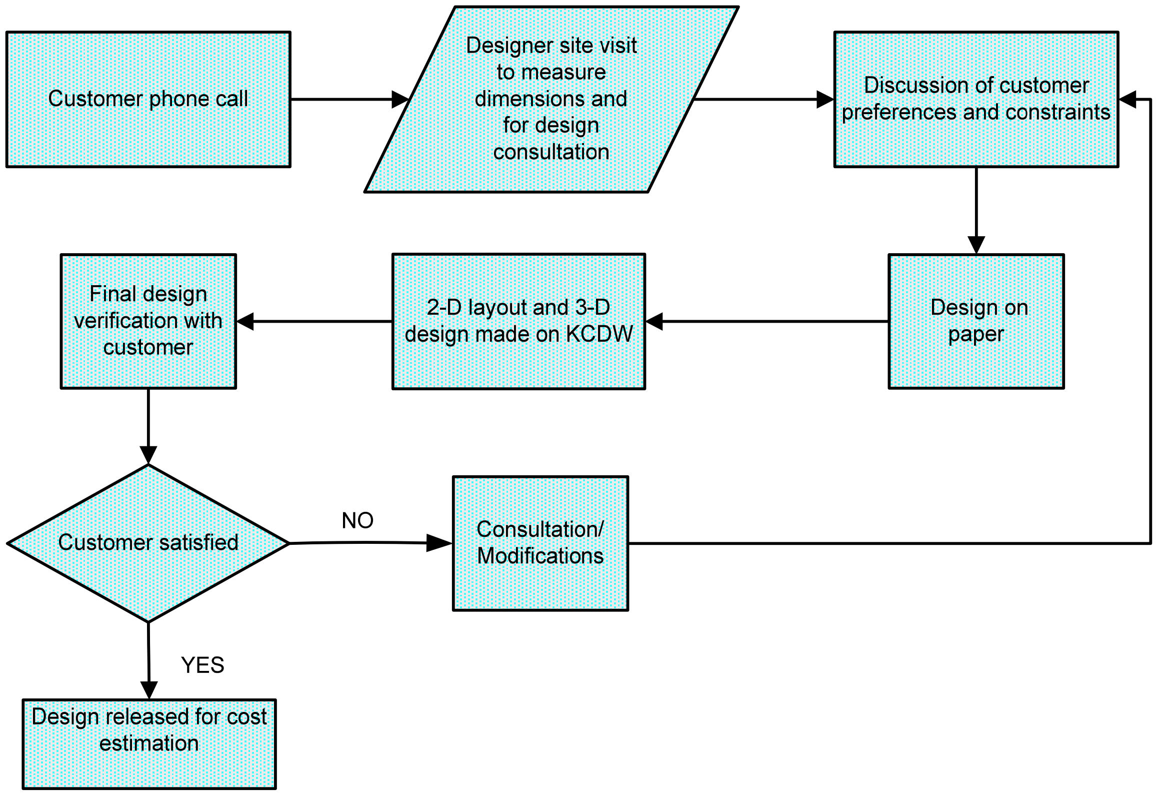


Figure 5-1 Flow chart for order initialization

The order processing is initiated with a phone call from a customer. A designer from the company visits the site and takes the dimensions of the area and discusses customer preferences through a question and answer session. Once the elicitation of information on customer needs is complete an initial design is sketched out on paper. Customer satisfaction with the initial design shortens the time required for the configuration. Else the designer meets with the customer until a satisfactory design is obtained. The initial design is based on customer preferences with respect to wood, treatment and color preferences and other accessories. There is a lot of communication involved between the customer and the designer during this process. The customer preferences, design requirements and other information gathered during the elicitation process are used to prepare a 2-D layout (A sketch of 2-D in shown in the Figure 5-2), in keeping with the kitchen triangle concept. The company uses the Kitchen Cabinet Design Ware (KCDW), a parametric software program to generate a 3-D view (Sketch shown in the Figure 5-3) of the kitchen design. Screen shots of KCDW for a sample design are shown in the appendix. It takes approximately four hours for the layout design on KCDW and the process is carried out without the presence of the customer.

This layout is presented to the customer and refined several times until the requirements of the customer are met. The time taken for final design truly depends on the familiarity of the customer in kitchen cabinetry. If the customer has an idea and has already viewed few models, it would let him visualize the features and communicate the same to the designer, else the designer has to rework many times on the design. The customer has to decide the type and color of wood at this stage. The designer carries samples of wood and strips of paint colors for illustration. When the design, type of wood and surface finish is approved by the customer, it is conveyed to the wood center for the next steps in order processing. The changes in the initial and final design are shown in Figures 5-5 through 5-8. The interaction between the key personnel at the company during the mass customization process is outlined in Figure 5-4. Costing is performed by the project manager based on the design. The cost estimation software requires manual data entering on the dimensions and other resources such as labor requirements.

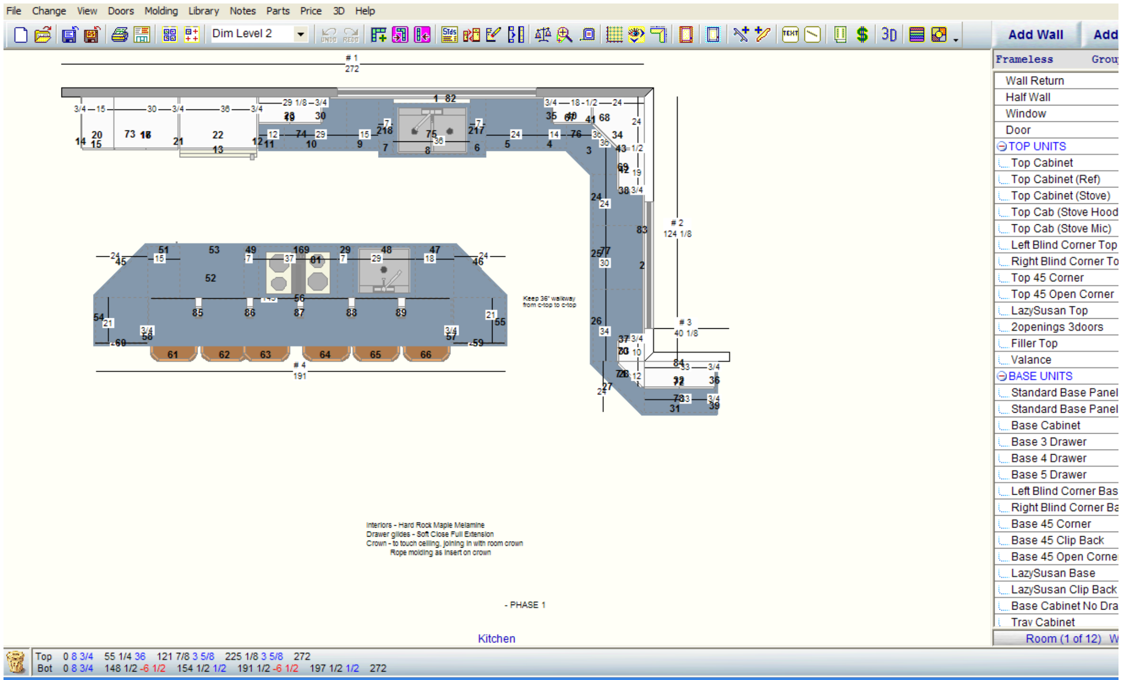


Figure 5-2 2-D layout for kitchen cabinets

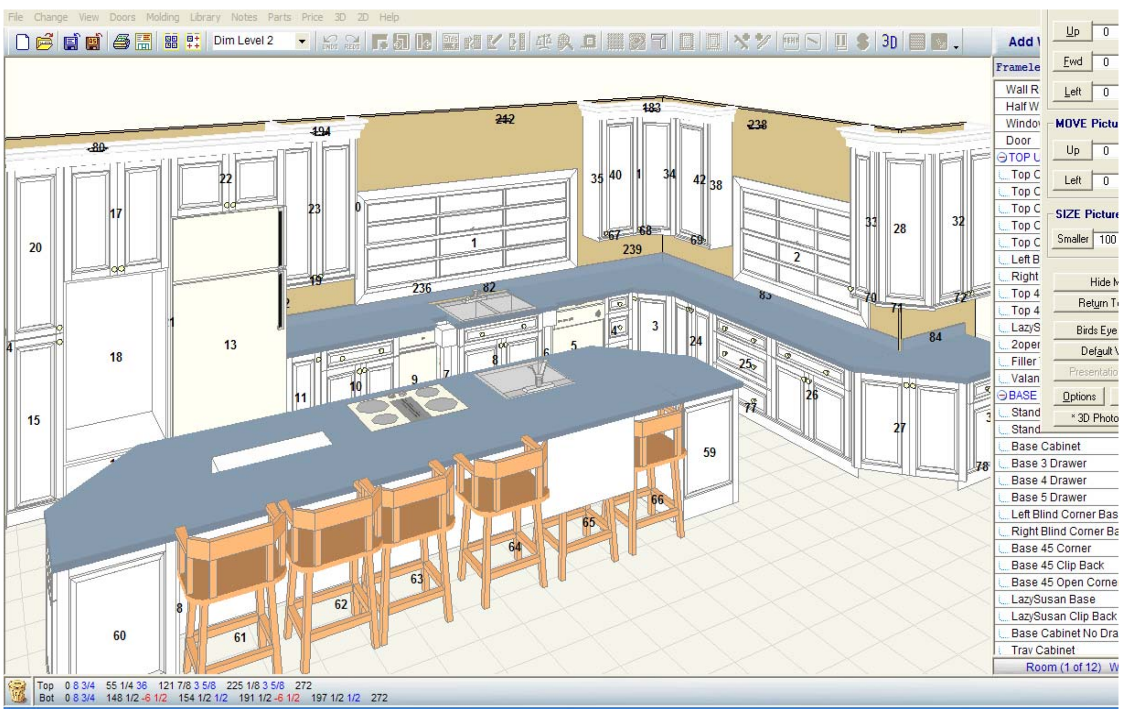


Figure 5-3 3-D view of kitchen cabinets

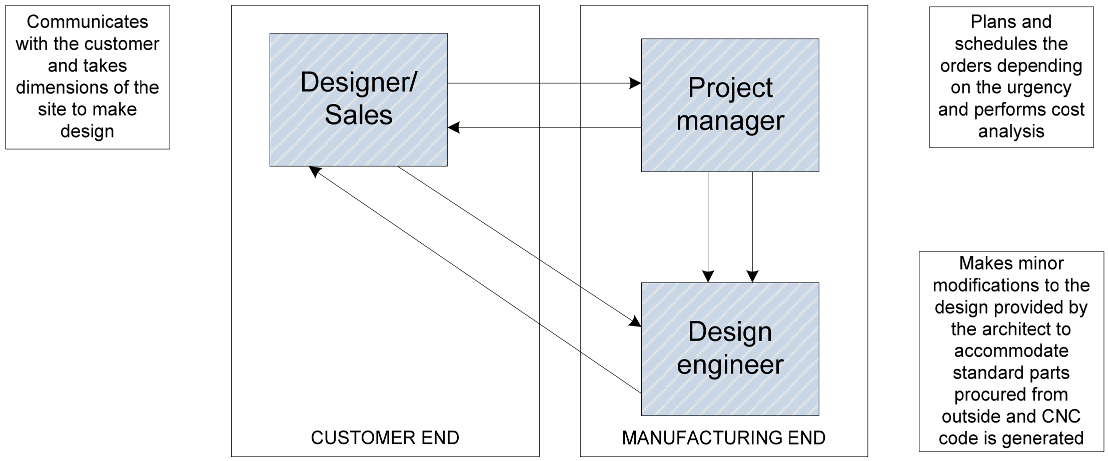


Figure 5-4 Communication in the organization

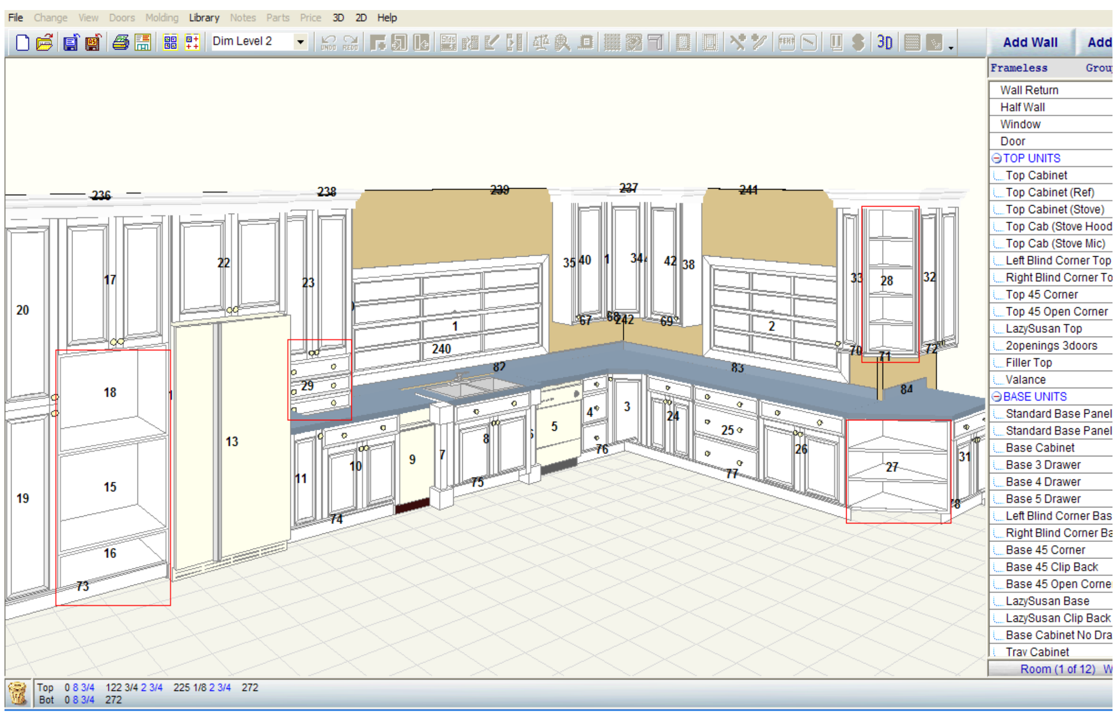


Figure 5-5 Initial design (changes marked in red)

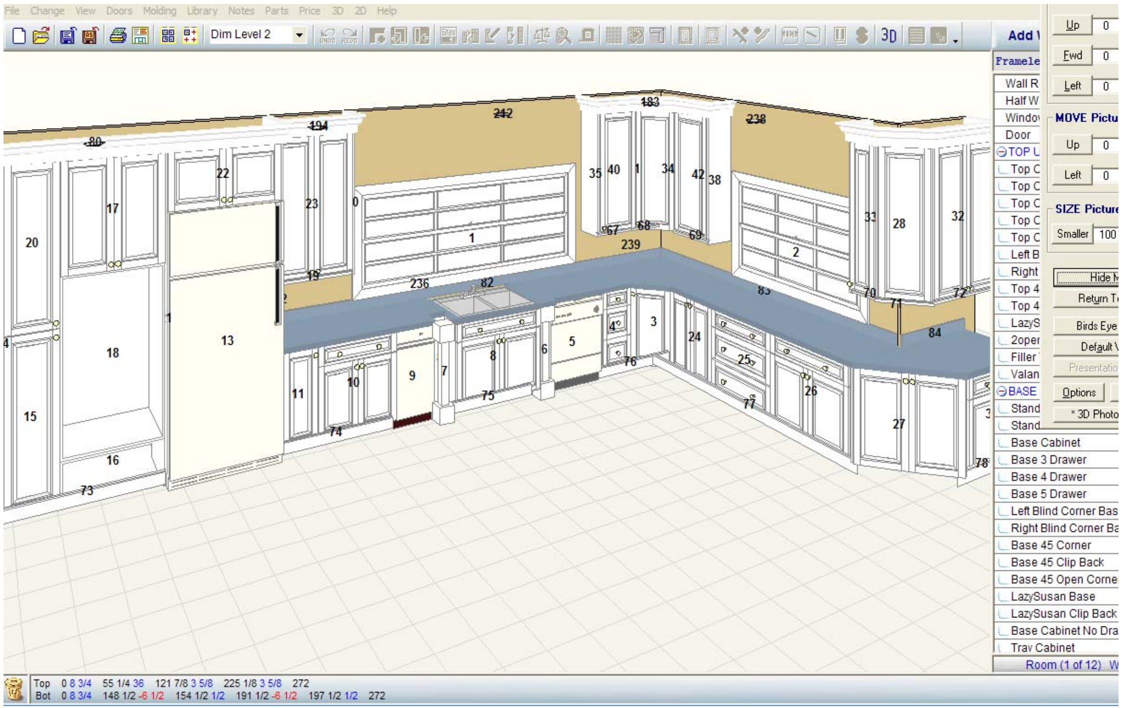


Figure 5-6 Final design

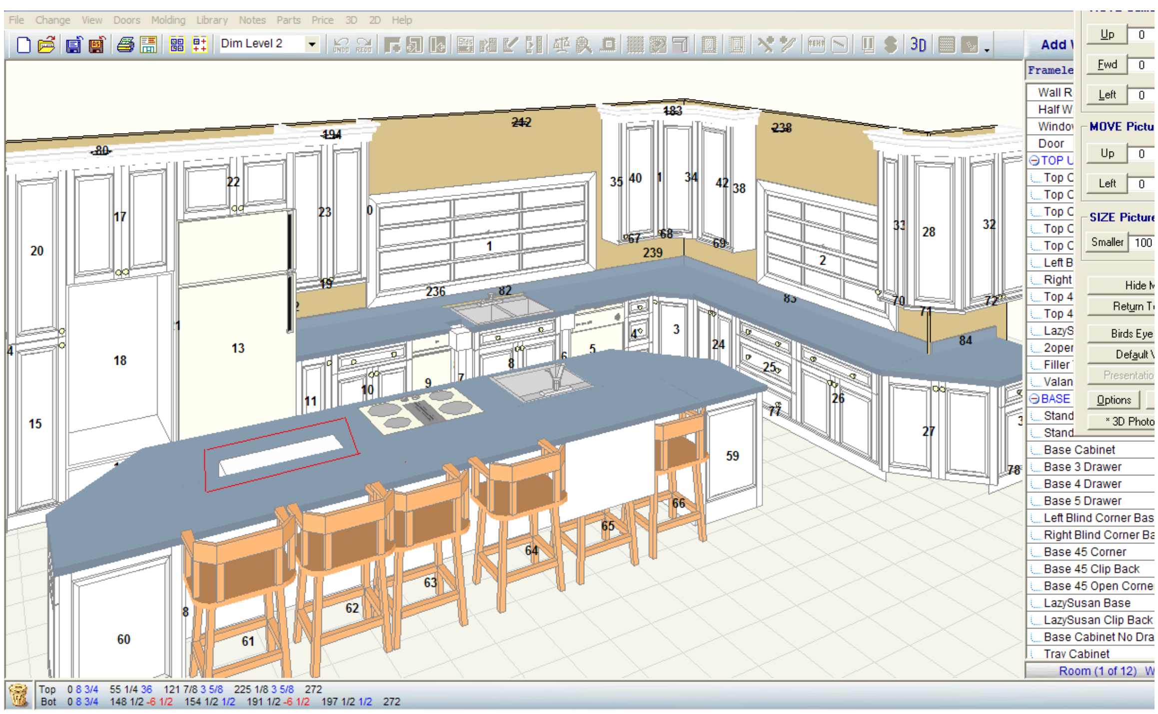


Figure 5-7 Preliminary Island design (Changes marked in red)

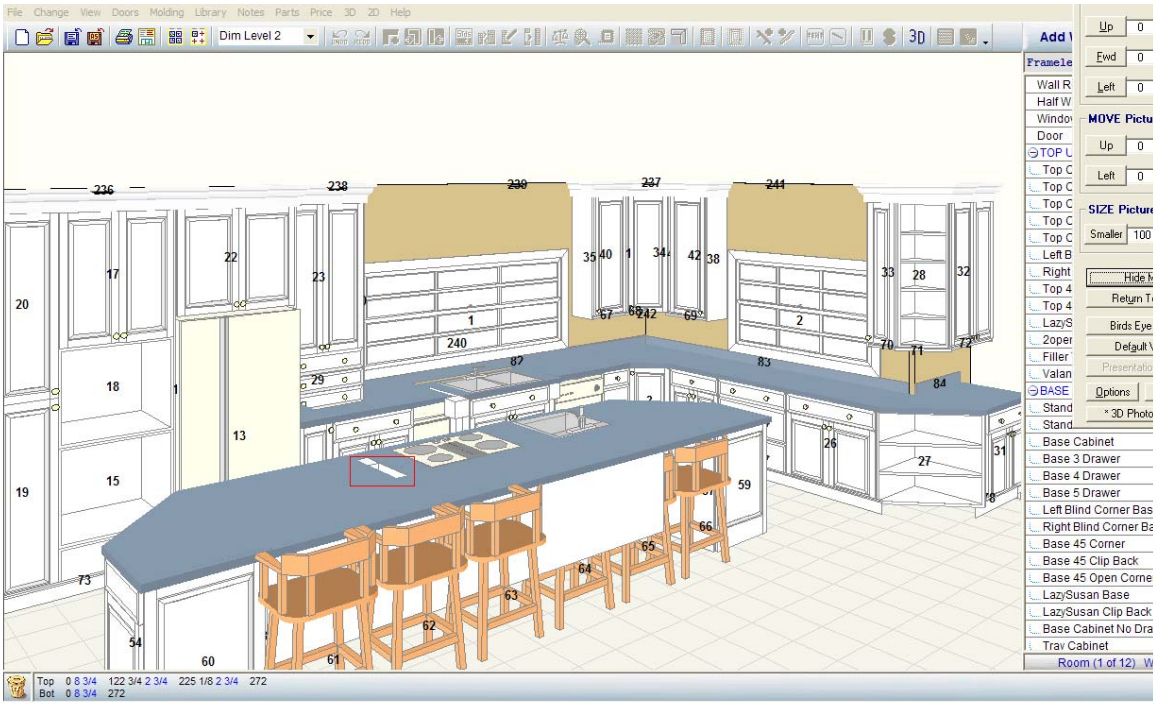


Figure 5-8 Final Island design

5.1.2 Order Processing

The order processing procedure, after product configuration is outlined in Figure 5-9 and discussed here. Raw materials for processing the design are obtained from the local wood suppliers. The company follows a kaban system for ordering the material and typically the lead time is about ten days. At the wood center, the design received from the designer is redrawn to accommodate product dimensions that are not manufactured in house. The design engineer performs this task and makes sure that the dimensions are accurate and compatible. Dimensions are modified to a finer scale using AutoCad, Autosketch, Quick Cad softwares. The new set of dimensions is exported to the router and used to generate the CNC code which is feed into the CNC machines to perform the cutting operation.

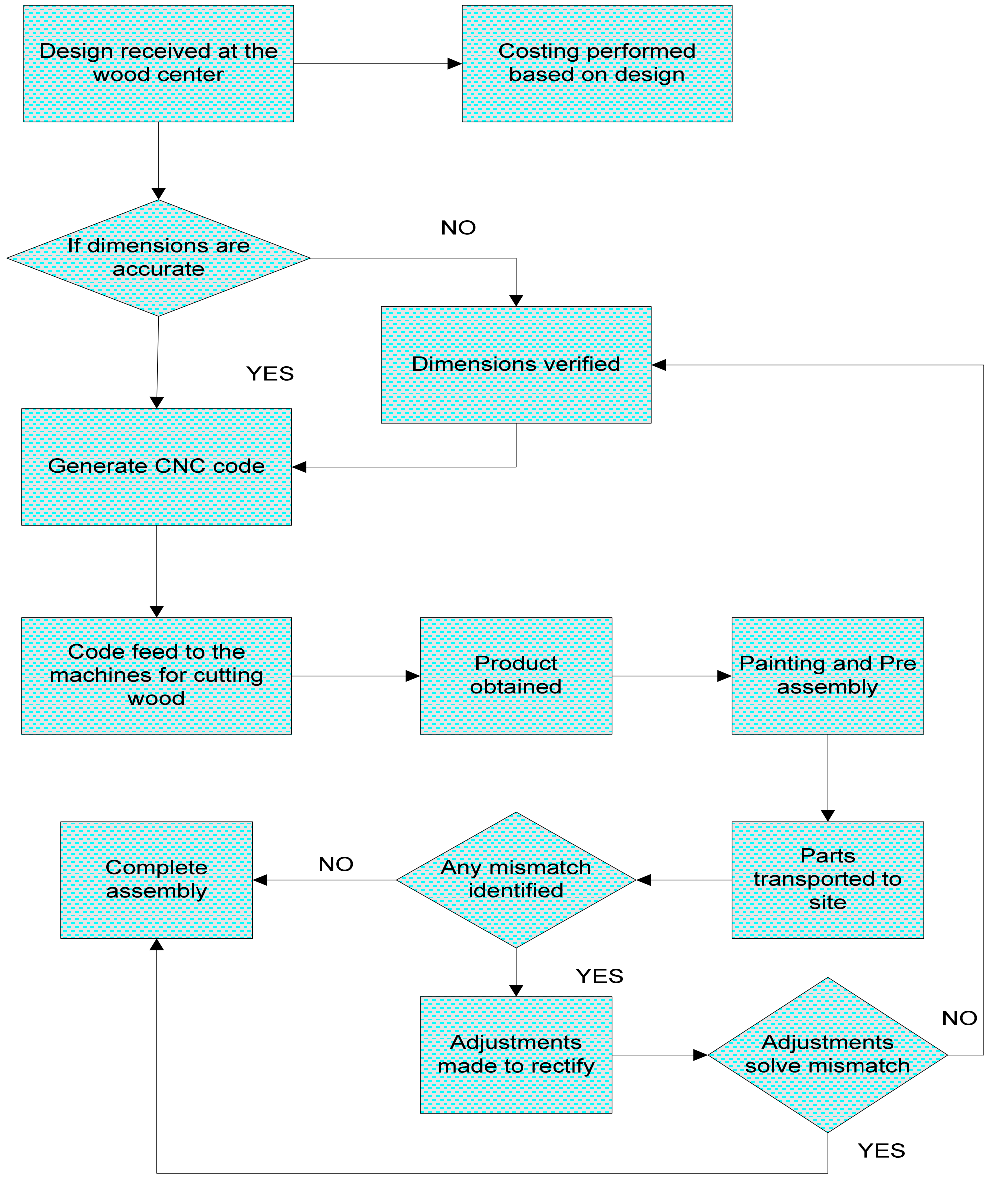


Figure 5-9 Flow chart showing order Processing

The project manager works on production planning for cabinet making. It involves scheduling for raw material procurement, delivery date of the product etc. The next step following fabrication is obtaining a required surface finish followed by painting according to the customer's choice. The parts are now ready for semi-assembly.

<u>Description of layout and operations:</u>

The facility has dedicated floor space for doors and cabinets. Figure 5-11 gives an overview of the current layout. All the operations are performed in a sequence to obtain the final product. The operations for cabinets start with CNC machining of raw material to required dimensions. It is followed by edge banding, where the edges are banded with a banding tape. Assembly of the sides and finishing is the next process. Doors for these cabinets are obtained from the doors section. These doors are given necessary surface treatment and finish before they are assembled to the cabinets. The sequence of operations carried out for cabinets is shown in the Figure 5-10.

The facility has two lines in the door side. One line machines panels and the other machines door sides which are then assembled Fabrication and finishing of the doors start with gang rip sawing where lumber is ripped into strips with parallel edges. These strips are then feed to the chopper to cut into a certain length. The strips of finite length are glued together to a required width in a machine. Glue which is usually a water based adhesive is applied using a roll coater. The bonded wooden plank is now passed through a planer to remove the adhesive burrs and obtain a proper thickness. The plank is next sent into sander to attain a smoother surface finish followed by radial arm saw which cuts the panel to desired length. A finishing profile is cut on the panel before it is assembled with the door sides.

The strips of wood obtained from the gang rip are sent to molder machine to make a molding profile to clamp the strips together. These are assembled with the panel to complete the door. Finishing operations are performed to hide any gaps during clamping. Further this could be an end product leaving the facility or it is sent to the cabinet section for painting and assembled with the cabinets. Figure 5-10 gives a brief idea about the sequence of operations.

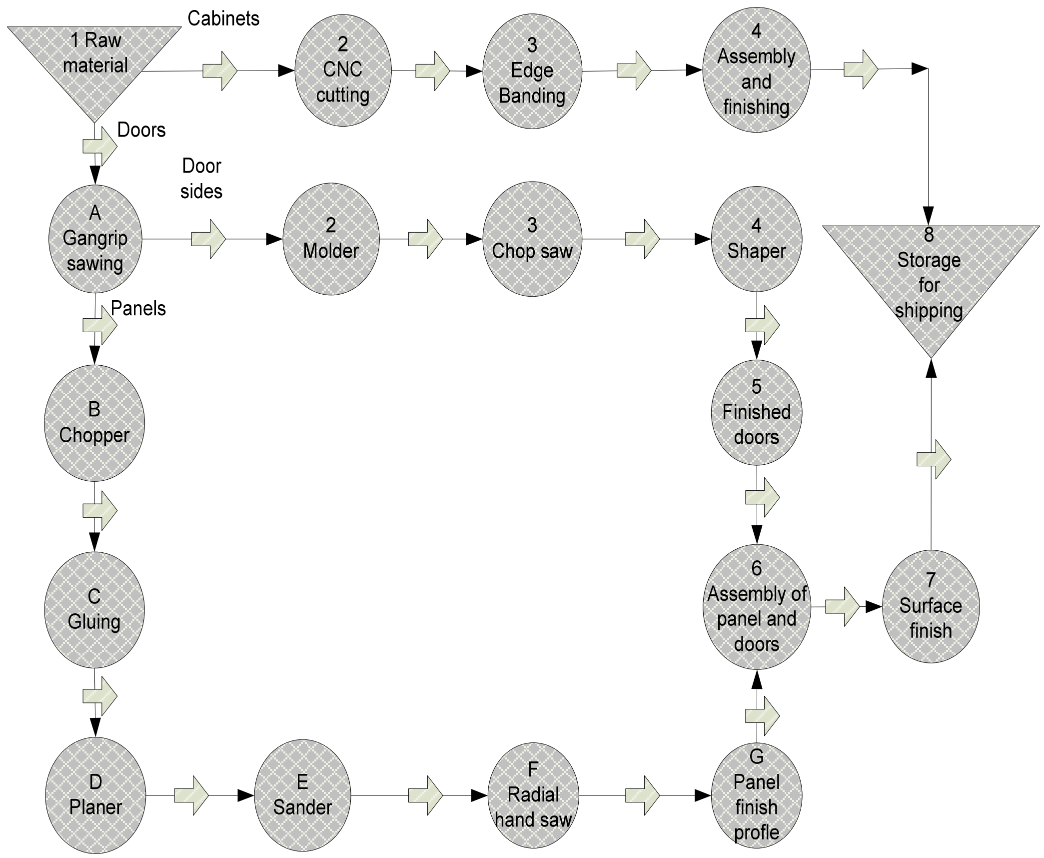


Figure 5-10 Flow process chart

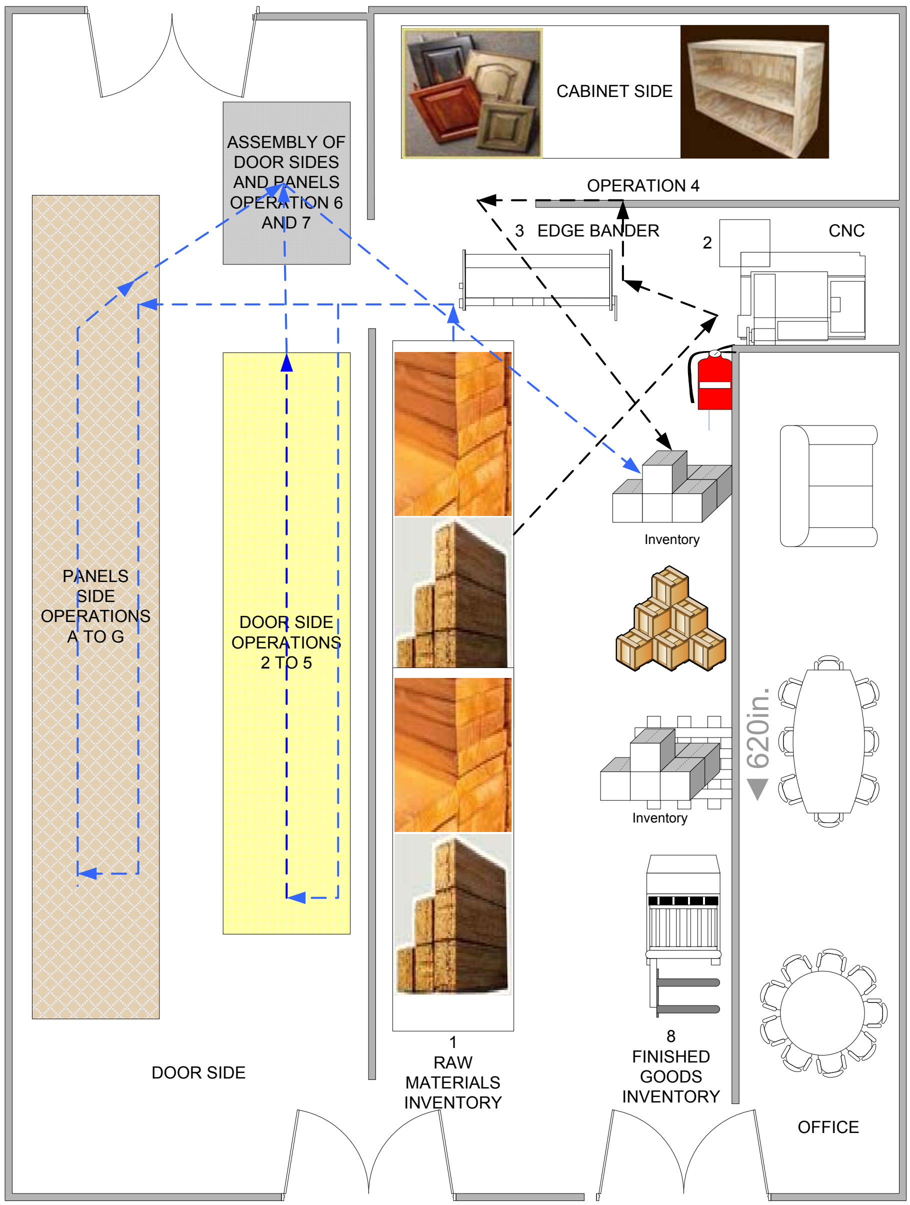


Figure 5-11 Facility layout with flow process superimposed

5.1.3 Assembly and Post Production

Parts are partially assembled at the final station and transported to site. Company personnel go on site and dissemble the semi assembled parts before they are mounted on wall and assembled completely. The installation of the total unit takes about 3 to 5 days depending on the size and complexity. Figure 5-12 shows the post production process.

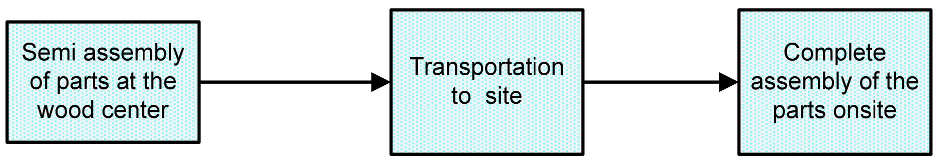


Figure 5-12 Post production

5.2 Case Study Analysis

Case study is one of many ways of doing social science research. Other ways include experiments, surveys, multi histories and analysis of recorded information [Yin, 1994]. Case studies involve systematic observing of the events, collecting data, analyzing and reporting the results. It is considered as a suitable method to study mass customization as the research in this field is still in its beginning stage [Eisenhardt, 1989; Piller, 2005]. The data collected is based on the information provided by different sources at the case company. The case company is described in the earlier pages to give a detail idea about the products, processes, operations and marketing. The following paragraphs would give an analysis of the company with respect to the mass customization framework.

The case company has been following customization to satisfy the cabinet needs of the customer. They have a wide range of choice and the design and order processing system is product configurator based. It is a manufacturing facility where the design process is initiated as per customer specific requirements and constraints. The distribution, installation and sales follow the design and fabrication.

5.2.1 Case Company in Mass Customization Framework

In the case company, flow of business occurs in the order of sales and configuration, logistics planning, manufacturing, distribution and after sales. Like any other manufacturing unit it has design, fabrication, assembly and distribution stages involved along the value chain. The business is not simply assembling standard modules according to the customer but involves him in the design stage. Kitchen cabinetry is such an industry where customer co-creation plays an important role in deciding the design. As the company has no retail centers for business, it has been able to establish good collaboration with the customers with the co-design process. The supplier interacts with the customer to obtain specific information and translate them into a product form. The co-design process involves communication and co-ordination [Hibbard, 1999; Zipkin, 2001] between every single customer and the sales person which adds value to the product from the customer integration point of view [Piller and Stotko, 2003; Piller and Moslein, 2002a].

The sales person/ designer collaborates with the customer and notes down the customer preferences and works around the wishlist to decide the final design. This is not a one step process because the sales person keeps incorporating changes until the customer is satisfied with the design. Starting from the type of wood, the design, to paint color, and accessories are all the customers choice. A product configurator is used as platform to display the 3-D view of the layout. Fabrication is not started until the approval of the customer is received.

Customization in a B2B market is surplus but it is a different scenario in the B2C market as it is just a starting trend. But mass customization can be more significant and innovative in the B2C market than B2B. The case company is in the B2C market offering a wide variety of products to its customers. Without modularity, it is not highly possible to achieve mass customization. The case company follows the cut to fit modularity in design and fabrication stages. Components are altered according to the specifications of the customer. When it comes to volume of customization, the case company had most of its product range customized, thus it would fall under greater than 50% volume being customized. The location of the company in mass customization framework is shown in Figure 5-13.

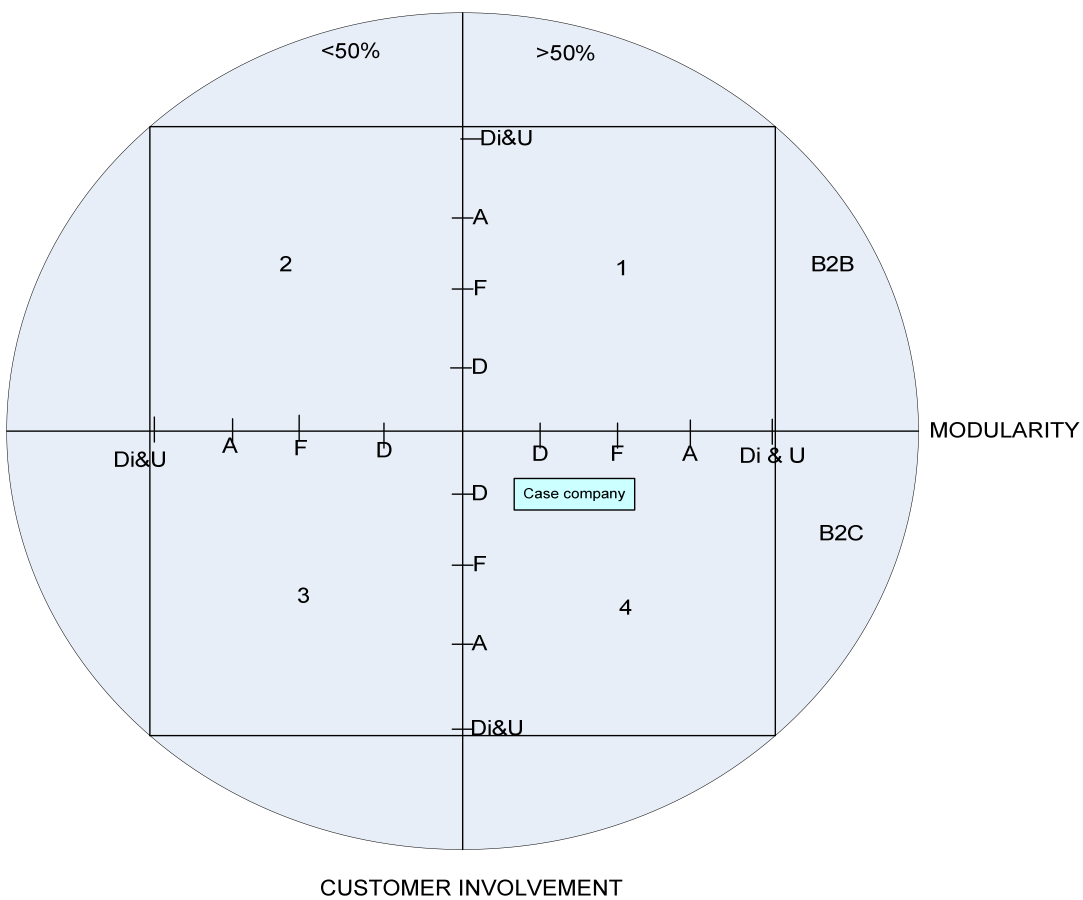


Figure 5-13 Case company's current location in the Mass customization framework

5.2.2 Case Company in Product Configurator Framework

The customer becomes a co-producer with his involvement with the supplier in the process of value creation [Toffler, 1970]. Companies offering mass customization are making use of interactive web systems and customer interfaces for value co-creation.

The interactive tool used by the case company is KCDW. It has many features to visually show the customer how the design would look. The software has both 2D and 3D features for sketching the layout and design. Thus the configurator has both graphical and textual capabilities. The following lines would discuss the capabilities on the Z-axis, which is sales channel, of the framework. The configuration process takes place in collaboration with the designer. As described earlier, the designer communicates with the customer and takes the measurements on site. The customer cannot independently build the design, thus the entire configuration procedure is interactive and occurs with consultation of the designer. The case company's configurator system in not connected to the web, the customer cannot access the configuration online. Thus the configurator falls in the offline category.

Considering the Y-axis on the product configurator framework, the case company has a front-end configuration system. Though it is an offline configurator it has front-end capabilities of visualizing the design and features. The backend of this system performs the cost analysis and generates the bill of materials. But the same software is not used to perform costing because it is inaccurate. The front-end is however not connected to the back end system. The front-end of this system focuses on the marketing aspects of design and the back-end, typically concentrates on the manufacturing aspects of the product. The current location of the case company in the product configurator framework is shown in Figure 5-14.

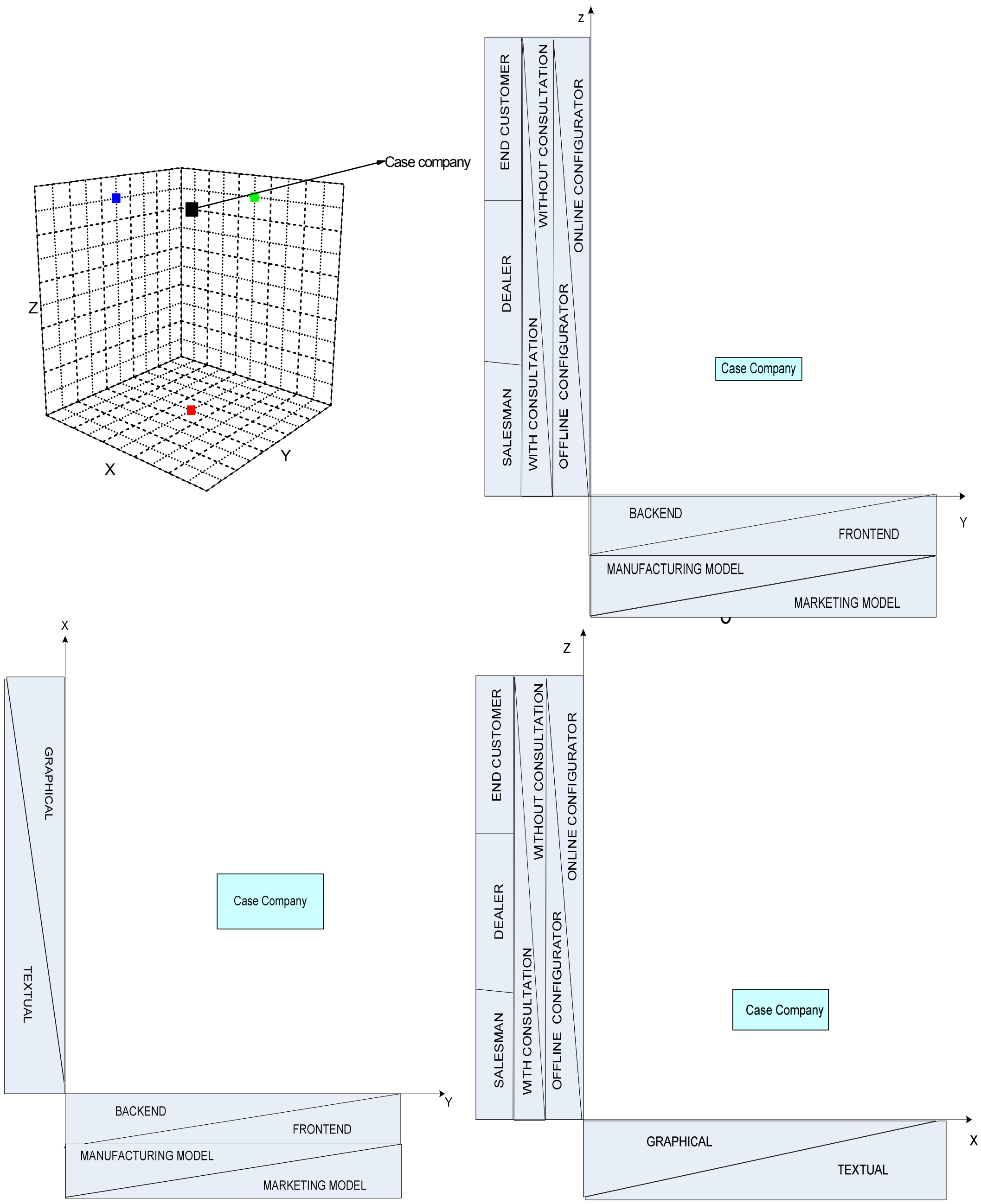


Figure 5-14 Current Product configurator capabilities of the company

5.2.3 Strategic Planning: SWOT Analysis

The current business strategy is explained so far with the mass customization and product configurator frameworks. The next few paragraphs address the particular strengths, weaknesses, opportunities and threats with a SWOT analysis and conclude with recommendations.

SWOT analysis is a scan of internal and external environment of a company for the strategic planning process. Strengths and weakness are considered as internal factors to the firm. Opportunities and threats are considered as external factors to the firm. A SWOT matrix shown in Table 5-3 would help a firm in identifying competitive strategies and pursue efficient business [Fleisher and Bensoussan, 2002].

Table 5-3 SWOT matrix [Fleisher and Bensoussan, 2002]

	Strengths	Weaknesses
Opportunity	S-O strategies	W-O Strategies
Threats	S-T strategies	W-T Strategies

S-O strategies help in pursuing opportunities that are a good fit to the strengths of the company. W-O strategies overcome the weaknesses to pursue opportunities. S-T strategies to identify approaches to overcome the external threats with the strengths they possess. W-T strategies that help in devising counter plans to defend the company's weaknesses from making it highly vulnerable to external threats. Figure 5-15 shows the

SWOT framework indicating the relationship between strengths, weaknesses, opportunities and threats [Fleisher and Bensoussan, 2002].

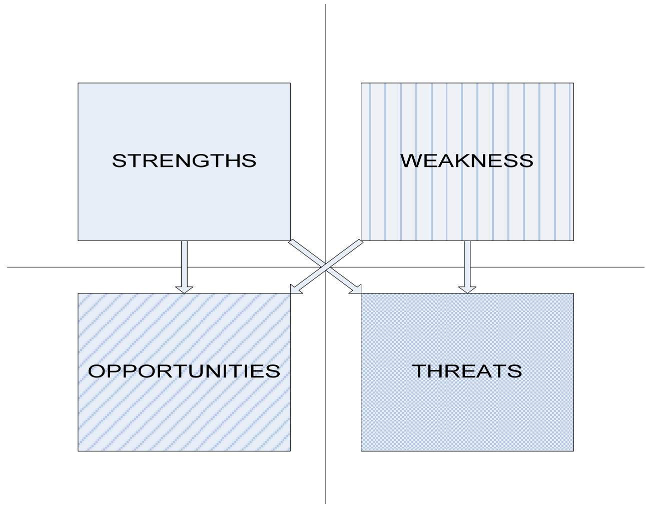


Figure 5-15 SWOT framework [Fleisher and Bensoussan, 2002]

Strengths:

- The designer communicates with the customer and involves them right from the design stage in the value chain which means that the customer acts as a co-designer in the designing process. This helps in building strong customer relations and loyalty. Also, the absence of retailers integrates individual customers into the manufacturer’s system of value creation and allows bonding.
- This facility has been founded in 1986 and since then they are focusing on adding value to the product by customer innovation and integration. They are experienced with the trends in the wood industry.
- The raw materials, mainly wood, are supplied by local suppliers and thus they have less lead time. Another reason is that the company follows a kanban system for ordering their supplies. This allows flexible scheduling.

- The company has been using a product configurator to build the design which allows the customer to visualize the final product. The product configurator that is used currently can help in minimizing the errors and also prevent loss of data.

Weakness:

- Though the company has a website, customer cannot purchase any kind of products online as they do not have an internet based product configurator. Also, customer cannot configure products without the assistance of the designer because of absence of an online configurator. Online configurator can act as a collaborative tool and would assist the customer to view the previous designs and models of cabinets.
- Because of the absence of a show room, models cannot be displayed and the orders are initiated with a phone call followed by a site visit by an architect which makes it a tedious process.
- Currently the company is not using any software or mechanism for production scheduling.
- The absence of a customer database makes it difficult for the designer during the design stage as they cannot retrieve the previous models built by the company. They can make the design process more visual and simplify by co-designing the customers previously configured products.

Opportunities:

- The company is into manufacturing custom kitchens cabinets which is one of the growing market segments despite the volatile housing market.

- By moving towards standardization, the company can meet the requirements of customers who prefer standard, semi-custom and custom products. This would also enable online purchase of some products. Customers value suppliers offering both standard and custom goods.
- Opportunities exist to implement high technology and automated machinery for improving quality and reducing labor cost.
- Currently, the company is located only in a single manufacturing and sales location; they can expand their sales market to different regions.
- The existing configurator capabilities can be further improved for better co-design.

Threats:

- Other cabinet manufacturing companies can become potential competitors in the business.
- If the company is aiming at only high end manufacturing, willingness to pay from the customer end can pose a threat.

The case company is following a successful mass customization strategy offering a wide range of choices to the customer. With the kind of strengths the case company possesses, the company can work on manufacturing semi-custom products that appeal to a greater number of customers. The case company is currently located in the fourth quadrant. Strategic transition to a location further down in the same quadrant, by involving customers in the assembly and distribution stages, or the third quadrant [where the volume of customization is less than 50%] by narrowing the product variety would provide opportunities to offer some standard products. This would help in facilitating an online product configurator through which online sales can be possible. This would also result in avoiding the threat of customer's willingness to pay for high end products. The future strategic location of the company in the mass customization framework is shown in Figure 5-16.

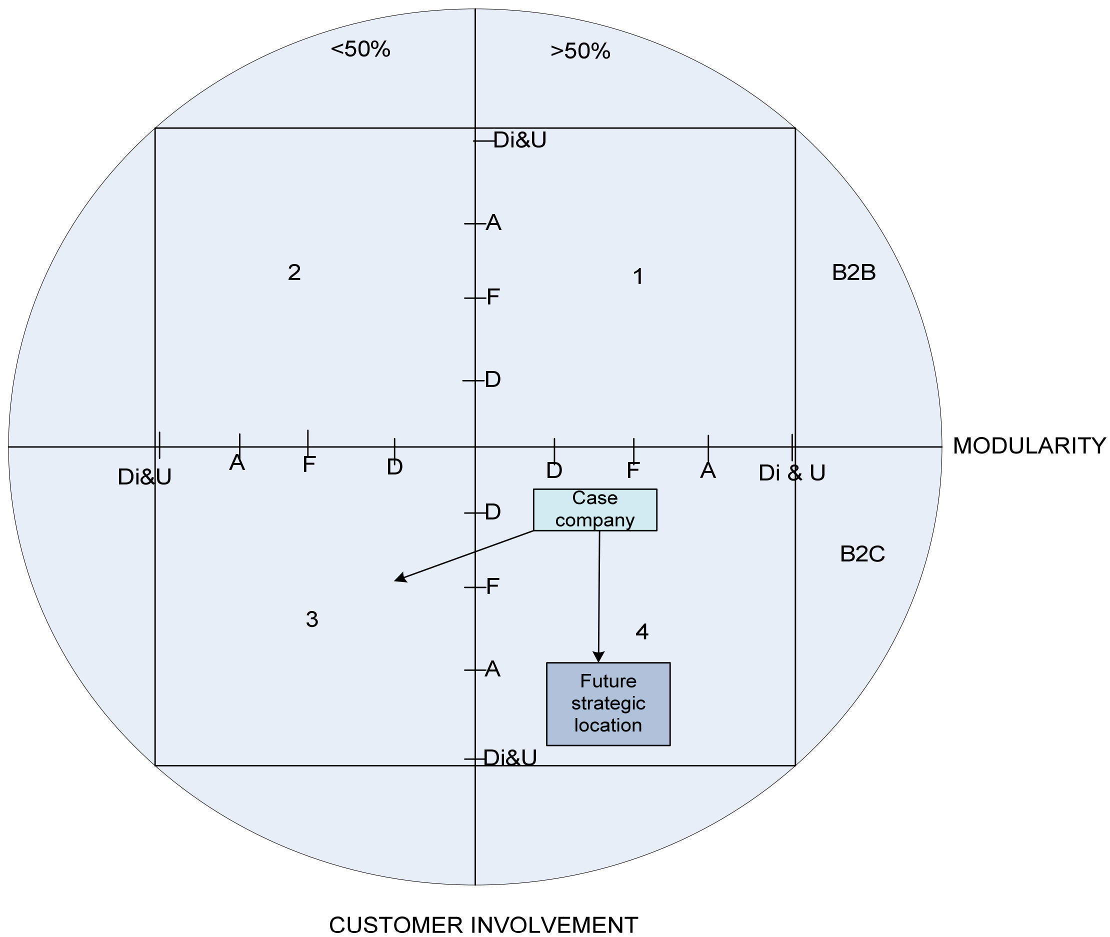


Figure 5-16 Future strategic location in mass customization framework

The company is already supporting the customization process with a configurator. The capabilities of the configurator can be further improved. The company can maintain a database of the customer designs which is accessible not only to the company but also to customers. This can play a vital role if the case company is planning to narrow down its product variety and chooses to do business online as well. Added to this, preliminary data collection through an online form would assist the designer to interpret customer preferences adding value to the elicitation process. The future strategic location of the case company in the product configurator framework is shown in Figure 5-17.

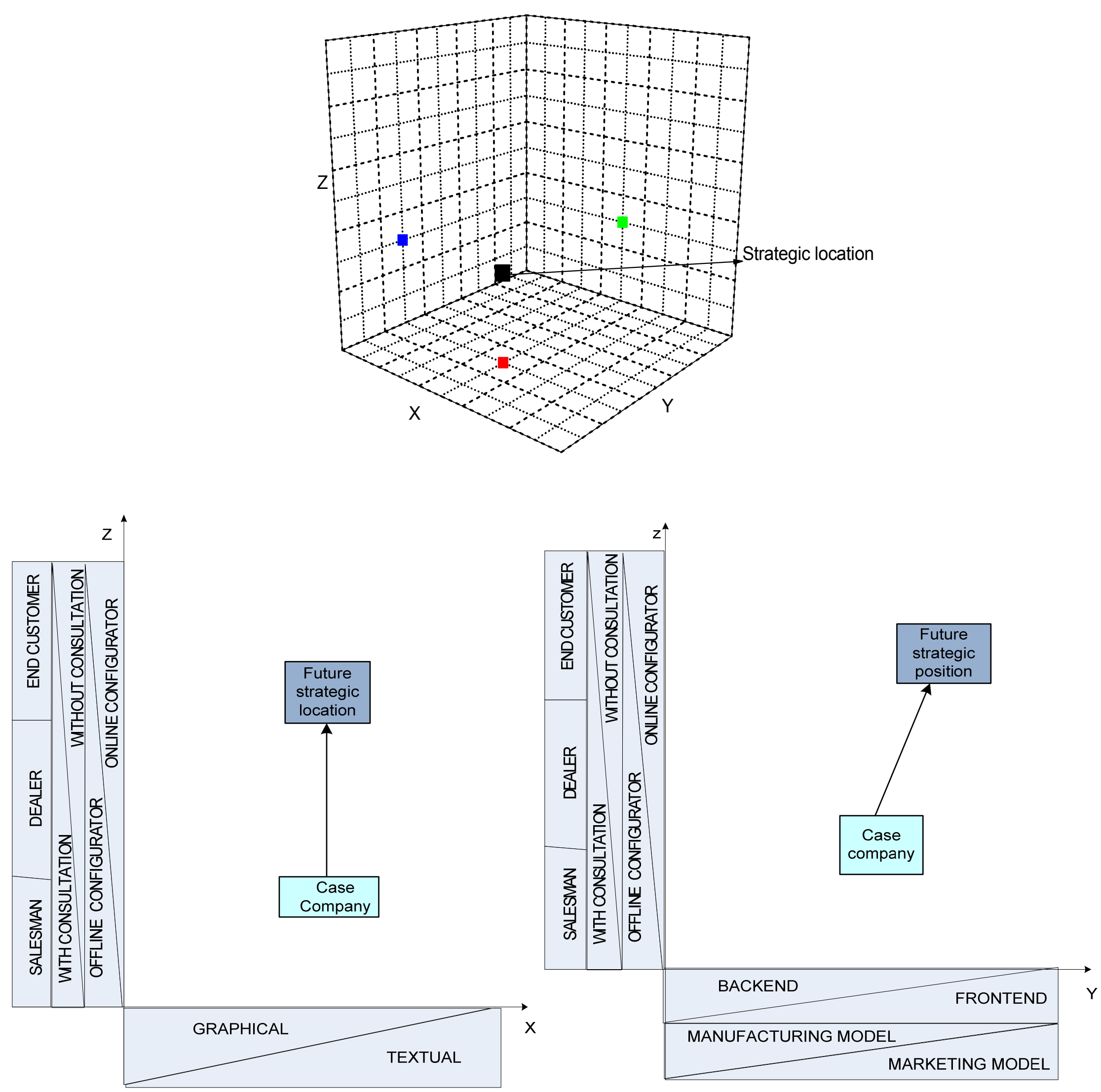


Figure 5-17 Future strategic location of the case company

The project engineer uses Autodesk to make further changes to the design before the CNC code is generated. Ideally configurator should have capabilities to incorporate changes in design without the application of other design softwares.

The current configurator is graphical and facilitates in communicating with the customer and this interface acts as a front-end, the costing part of this process constitutes the back-end. As discussed earlier, the front-end and back-end are not connected and are independent. Improvising the configurator to connect the front-end and back-end would facilitate faster communication and avoids delay to the customer in getting the price quotes. Also, this can prevent loss of information and maintain accuracy.

Presently, the company does not have a display showroom for customer walk-ins to have a glimpse of cabinet models. However, it plans to open a showroom in the near future. This would save time for the designer in going back and forth to the customer's home except for measurements. It would be a good idea to make sale possible at the showroom by narrowing down the product line.

6 CONCLUSIONS AND FUTUREWORK

6.1 Conclusion

Mass customization is becoming a competitive strategy for companies that are offering individualized products. Many companies are using mass customization as a business strategy to meet changing customer needs. Primarily, companies need to realize what degree of customization is needed by customers and the extent of customization that can be offered competitively. Not all products can involve customers in the design stage of the value chain and the degree of customization offered would also vary from product to product based on the complexity of manufacturing the product. Mass customization can lead to potential benefits and additional costs. Therefore, effective production and operations management is vital for success.

Product configurators provide a platform for companies to do interactive product configuration for its customers and are essential for successful mass customization. However, depending on the degree of mass customization offered, a company needs to select a product configurator with appropriate capabilities that will allow customers to configure products as desired.

This research was an effort to develop an approach to ascertain the product configurator capabilities needed for successful mass customization. Two frameworks, one for classifying companies based on the extent of mass customization and another to identify the various product configurators based on different criteria, were developed.

The product configurator capabilities really can then be identified by locating the company on the mass customization framework and mapping it on to the product configurator framework to determine where it should be positioned. The two frameworks can also be used for strategic planning and further improvement. The application of the frameworks is illustrated and validated through a case study. This work can act as a roadmap to companies following mass customization and suggest the required product configurator capabilities needed. Companies can assess their current strategy by locating themselves in the frameworks using the guidelines and project their future location and plan to succeed accordingly.

6.2 Future work

It must be noted that the location of companies in the mass customization framework (except the case company) and product configurators used are based on available literature and information provided in their respective websites. Also, more examples of B2C companies are discussed because of lack of sufficient data on B2B companies. Further, the operations management strategies of mass customization have not been the primary focus. The case company that has been used to validate this scheme is a B2C company. So, future research can work on validation of the current scheme on B2B companies. Also, the current model can be further refined. The guidelines proposed are very generic and often would have to be addressed on a case-by-case basis. There is lot of scope for research on mass customization and product configurators as they as still emerging concepts.

APPENDIX I

Screenshots of kitchen views in KCDW are presented below.

Initial design

Figure A: Initial design 1

Figure B: Initial design 2

Figure C: Initial design 3

<u>Changes in design according to customer preferences</u>

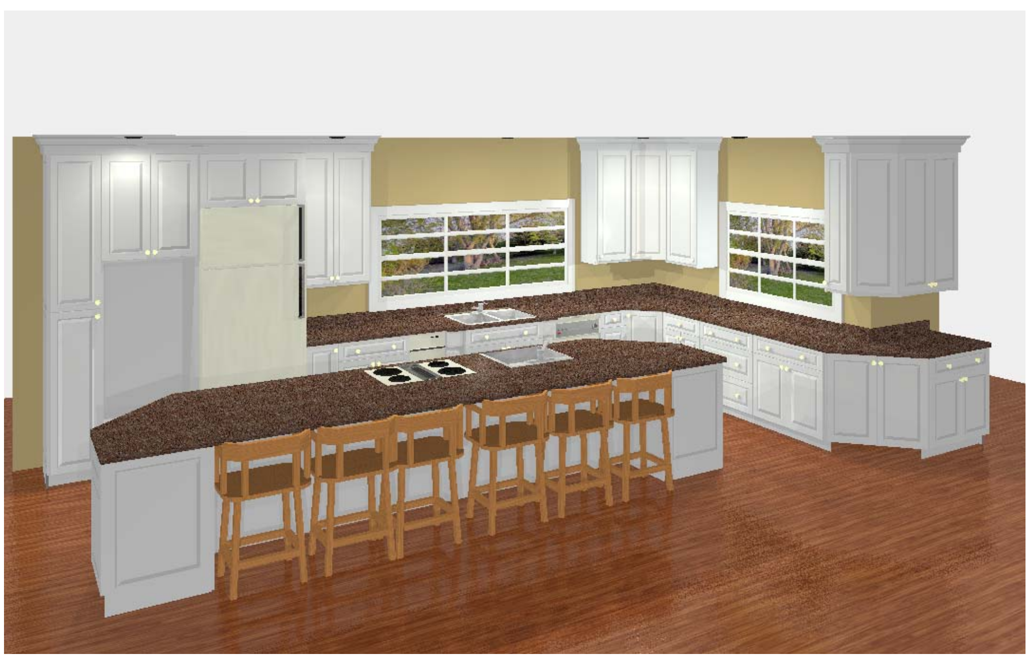


Figure A: Final design 1

Figure B: Final design 2

Figure C: Final design 3

Pictures taken onsite

Figure A: Onsite picture 1

Figure B: Onsite picture 2

APPENDIX II: SOURCES FOR CASES

Boeing	http://www.corporatetreat.com/2006/10/boeing_business_jet_bbj_interi.html
Adidas	www.adidas.com, Moser, K., (2007), "Mass customization strategies, development of a competence based frame work for identifying different mass customization strategies", Piller, F., Moser, K., (2006), "Mass customization case studies: Cases from the international mass customization case collection", International Journal of Mass Customization, Vol. 1, pp. 1-141, Piller, F., T., Reichwald, R., Moslein, K., (2003) "Co-designing the customer interface: Learning from exploratory research".
Dell	http://www.glscs.com/archives/10.02.TaylorMade.htm?adcode=5, http://www.managingchange.com/links/masscust.htm
Threadless	www.threadless.com, http://mass-customization.blogs.com/,
Time 121	www.time121.com, http://mass-customization.blogs.com/, Moser, K., (2007), "Mass customization strategies, development of a competence based frame work for identifying different mass customization strategies"
Leftfoot	Moser, K., (2007), "Mass customization strategies, development of a competence based frame work for identifying different mass customization strategies", Leftfoot corporate website, Sievanen, M., Peltonen, L., (2006), " Mass customizing footwear : the lef
Marelli Motori	Moser, K., (2007), "Mass customization strategies, development of a competence based frame work for identifying different mass customization strategies", www.marellimotori.com, www.adidas.com, Moser, K., (2007), "Mass customization strategies, developmen
APC	Moser, K., (2007), "Mass customization strategies, development of a competence based frame work for identifying different mass customization strategies"
Turotailor	Moser, K., (2007), "Mass customization strategies, development of a competence based frame work for identifying different mass customization strategies", Turotailor corporate website, Sievanen, M., Peltonen, L., (2006), " Mass customization as a marketing
Audi	Moser, K., (2007), "Mass customization strategies, development of a competence based frame work for identifying different mass customization strategies", Audi corporate website
Nike	www.nike.com
ParisMiki	www.parismiki.com
Flyte	http://www.flyte.ca

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Presentations and Publications:

- Haritha Metta, Arvind Goyal, Brandon Stump, Kundana Inala, Smitha Thuramalla, Fazleena Badurdeen "A Simple Simulation Model to Demonstrate Mass Customization Strategies", 2007, Third World Conference on Mass Customization & Personalization, October 07-11, 2007, Boston, MA.

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