USING THE INTERNET TO SOLICIT CUSTOMER DESIGN INPUT IN ORDER TO SUPPORT MASS CUSTOMIZATION THROUGH MODULAR DESIGNS

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A thesis submitted to the System Design And Management Program in partial fulfillment of the requirements for the degree of

Master of Science in Engineering and Management

ABSTRACT

In the course of the last decade there has been a growing movement away from traditional product development and manufacturing associated with mass production to entirely new processes required to support Mass Customization. Mass customization is both a product development and manufacturing process that is being mandated by increasingly heterogeneous customer needs. It requires very flexible designs, and manufacturing and delivery processes that reduce the economic order quantities to a single customer order. It also requires a means to identify the elements of the product that should be customization capable. This thesis seeks to define Mass Customization, its relationship to the automotive industry, and its increasing importance in turbulent markets. It also considers two key enablers required to effectively implement Mass Customization: product modularity and customer preference measurement through the use of innovative Internet applications and tools. A significant focus of this thesis is to investigate the use of Mass Customization methodologies and of Internet based preference measurement methods for product design (e.g. conjoint analysis) to facilitate the timely incorporation of customer preference information further upstream in the PD process.

An Internet based Conjoint Study, Kano Models and Trade-off Analysis was designed to determine customer preference for customizing certain attributes and their willingness to trade-off customization against delivery speed. Data illustrating the possible customer responses shows how the conjoint analysis results can be analyzed to aid product development teams in making the necessary design trade-offs by understanding the customer preferences and associated homo/heterogeneity of the population. In addition a framework for understanding manufacturing complexity was developed. It proposes a way to understand the
relationships between the customer value created by an attribute vs. the cost of providing the attribute. A Value/Cost map was created to assist teams in making necessary tradeoffs regarding where to customize and where to standardize from a development and operational perspective. Also, an original approach for identifying the complexity related to product and process design was developed and proposed. Through this framework, development teams can more readily assess the true effect of product options on product combinations and discrete decisions related to complexity. Finally, a Customer vs. Product map was developed to help teams understand and implement the various methods of Mass Customization proposed by both Pine and Andersen.

This thesis focuses how to implement Mass Customization by simultaneously incorporating engineering, marketing and management views. Designing for customization using modular product design and managing product development with complete customer preference data, points the way to successful Mass Customization, satisfied customers and profitable operations.

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ACKNOWLEDGMENTS

I would like to express my appreciation for the undying devotion of my family, especially that of my wife Sharon whom without I am nothing.
Chapter 1

MOTIVATION AND INTRODUCTION

"Every business today confronts the problem of product diversification. Increasingly fragmented markets and intensified competition due to economic pressure and the ongoing globalization process, force companies to meet more closely diverse customer needs at lower cost. It is no longer possible to cost-efficiently serve homogenous markets with very few product variants like Henry Ford could with the legendary 'any color as long as it is black' Model T in the beginning of this century."

State of the US Automotive Industry

The automotive industry in the US is moving very quickly to implement a Build to Order model (A.K.A The Dell Model). This is so much the case that a leading industry publication has boldly predicted; "two-week cars should start appearing in high and low volume markets in 2001 and 2002. Thanks to a confluence of Internet, manufacturing and retailing technologies that's starting to make it all possible." This rush has been fueled by the promise of greater efficiency and improved profits. In fact, automotive analysts have quoted savings ranging from $1,200 to $3,700 per vehicle in the US, $600 in Europe and $500 in Japan. While no one has emerged with a magic formula detailing how this can be done, there are early indications that the customer may pay the price in terms of selection and choice and ultimately - customer satisfaction.

One automaker in particular, is looking to vastly 'simplify' its entire market offering by reducing the number of options and combinations of those options available to

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the end user. The thinking is very simple - 90% of all automobile purchases (based on data from Ford, GM and Chrysler) are bought directly from dealer stock. The implication here is that either the automobile dealers (who actually order these units) have an extremely uncanny sense for what customers want in a market that can be characterized at best as fickle. Or, more likely, customers make a fundamental trade-off between the immediacy of driving a vehicle off the lot today and meeting the exact requirements that fully satisfies their value equation. Therefore by limiting the number of possible combinations that a particular vehicle can be ordered, the chances of a dealer having the 'orderable' combination that comes closest to meeting the customer's desired selection is greatly increased – so the thinking goes.

On the surface, this course of action seems quite logical. If a company offers several million different combinations of a particular product, the likelihood of finding the offering that exactly matches a given customer's value equation on the neighborhood dealer lot is small. However, if that same company offered only a hundred unique combinations, the odds of finding the best fit from the available choices increases dramatically. (This, of course, presumes that the customer cannot order a custom vehicle and have it delivered in a timely fashion.) The issue is at first subtle. It is the difference in what Joseph Pine refers to as customer sacrifice and customer trade-off. Pine defines customer sacrifice as "the gap between what each customer truly wants and needs and what the company can (or will) supply". A customer sacrifice is a concession required of the consumer. In contrast, a customer trade-off is a legitimate choice between different aspects of

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3 This number is very consistent within the group of 'American' automotive manufactures. It does, however increase slightly when 'Japanese' automotive manufactures are included. This is largely due to the practice of 'Japanese' companies personalizing vehicles through their dealer networks. In Europe, only 70% of vehicles are purchased directly from dealer stock and in Japan it is even lower at 40-50%.

a product or service that a customer makes freely. This choice can be between several features, price, or in the case mentioned above – time.

George Stalk et al, purposed seven methods through which companies can find and take advantage of sacrifice bridging opportunities:

1. Shop the way the customer shops.
   "In the auto industry, executives of the Big Three do not buy cars. Their secretaries do it for them, over the telephone. The cars are delivered to the executives clean, full of gas and ready to go. For most Big Three executives, buying a car the way ordinary customers do would be an out-of-body experience."\(^5\)

2. Pay careful attention to how the customer really uses the product or service.
3. Explore customers' latent dissatisfaction.
4. Look for uncommon denominators.
5. Pay careful attention to anomalies.
7. Look for analogous solutions to the industry's compromises.

It is this author's belief that a customer-oriented organization should expend its energy on minimizing customer sacrifice - not increasing it, and Mass Customization is the way. By all accounts, making the transition from Mass Production to Mass Customization is a difficult one. If it is not implemented judiciously it is as likely to increase costs, as it is to increase product differentiation and customer choice. I have identified two significant enablers that can greatly aid

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an organization determined to drive down this path. These are product modularization (to enable easy and inexpensive product variation) and Internet based tools for identifying customer wants and needs much earlier in the product development process during the critical phase of product architecture development and concept selection.

This thesis seeks to briefly explore the implementation of Mass Customization through the use of modularity concepts and more importantly through the complete and unambiguous understanding of customer needs and wants utilizing a set of User Design based analysis tools, in addition to conjoint analysis.
Chapter 2

MASS CUSTOMIZATION – OVERVIEW

"Mass Customization is a paradigm shift that will forever change customer's expectations. Today, customers may be reluctantly buying the product that comes 'closest' to meeting their needs. Offer them exactly what they want at an attractive price and they will no longer be content with close."⁶

Introduction
Mass Customization is still largely considered by the US automotive industry to be an oxymoron. It is viewed as impossible to produce products in high volume that are tailored to individual customers and make a profit simultaneously. What has been demonstrated by other industries (particularly the PC industry), however, is that it is not only possible but also a matter of survival. What these companies have discovered is that Mass Customization is not about adding enormous complexity. It is about managing complexity in a customer-focused manner to deliver the exact product that each and every customer wants at a reasonable cost. A fundamental question that needs to be addressed in this chapter is what Mass Customization is and how it relates to the product development activity.

Mass Customization vs. Mass Production
At the turn of the century, mass production moved manufacturing from a craftsmen base of highly skilled labor to a more specialized base of unskilled labor. With the assembly lines came economies of scale that brought down the price of goods to the masses. Today, continually increasing competitive pressures are forcing

companies to develop new ways to differentiate the value provided by their products over the value provided by the products of their competitors. In the automotive industry cost, quality and indeed styling have converged. In this position, customization is a promising avenue for differentiation (and growth) – creating unique customer value. Firms capable of tailoring their products to specific customer needs while remaining competitive on cost and quality will establish a unique point of differentiation and customer value. Firms that do this well will establish a strong competitive advantage, cultivating an intensely loyal customer base.

Mass Customization moves away from today's highly structured market segmentation practices in a dramatic way. Rather than designing for the needs of a handful of customer segments made up of thousands of individuals, mass customized products are designed for the needs of thousands of customer segments made up of one individual each – thereby establishing 'segments of one' as described by Gilmore and Pine [1997]. Mass customization requires very flexible designs, manufacturing and delivery processes that reduce the economic order quantities to a single customer order. It also requires a means to identify the elements of the product that should be customization capable. As will be discussed later, customer design methods utilizing the Internet are one technique that may be applied to collect this data.

**Recognizing Market Turbulence**
The US automotive industry is an outstanding example of an extremely competitive market experiencing tremendous turbulence. Market turbulence is characterized by rapidly changing and diverging customer needs, technological advances and shrinking product life cycles. The following quote in an exert from a weekly communication sent out to the employees of Ford Motor Company by their CEO Jac Nasser (June 2000):
“So right now the global economic conditions are favorable in most of our markets. But the competitive environment is also very intense—the most intense I’ve seen in my career. We’re seeing a tidal wave of innovative, creative products hitting the market. And it’s not just the number of products. The industry is bringing out leading-edge technologies, creating more new segments and offering more new functionality.

I think the competition is great for the industry and great for us. It sharpens our skills. It increases our focus on the consumer. The winners in this competitive environment are going to be those companies that satisfy even more specific consumer segments—that don’t create just new products but whole new classes of products. And we are now positioned to do just that, with our new Consumer Business Groups and Global Centers of Excellence—which allow us to more closely target consumers’ needs for each of our brands and react more quickly to changing conditions in the markets where we do business.”

To Mr. Nasser’s point, the number of distinct vehicle models offered increased from 151 to 205 just from the period of 1982-1990.7

The Role of the Internet in Mass Customization

The Internet in particular, has fundamentally changed the way consumers view products by greatly increasing customer’s expectations for custom made offerings and order fulfillment response time. As more and more companies learn how to efficiently serve these customers, the less satisfied they naturally become with standard offerings. The Internet itself is inherently customizable and users have overwhelmingly embraced it, logging on to all things ‘my.com’. From myweather.com and mycnn.com to personalized investment sites the Internet is training an entire generation of consumers to expect and demand personalized service and products that are provided in days (or weeks) not months and that are provided at no or moderate price premiums. This personalization has become the

minimum price for entry into this burgeoning media and it is pervading every other aspect of consumer's lives. In fact, it was not that long ago that the idea of ordering a computer to your individual specifications was thought to be too expensive, too complex and quite unnecessary. Then came Dell with a unique idea. Suddenly, computers built-to-order became cheaper, less complicated, mandatory and highly profitable. Today, you cannot find a computer manufacture that does not allow some level of customer specification and more importantly, those that have been slow to react to this trend have paid dearly in lost profits and market share.

Much has been made of the phenomena of 'Frictionless Economics' created by the free flow of information via the Internet. Fundamentally, shopping for a better product with exactly the right attributes at a more competitive price at the next store/website is a mouse click away. The Internet makes it difficult (if not impossible) for mediocrity to hide. As renowned business thinker Gary Hamel pointed out in a Wall Street Journal article:

"While the Internet may be the enemy of companies that make run-of-the-mill products, it's the ally of companies making unusual ones. As the Internet reduces friction, companies will learn that there are only two kinds of competitive advantage: those that are based on offering customers something truly wonderful and unique, and those that aren't. Weak or ignorant customers, high search costs, local monopolies, forced tie-ins, and price discrimination are of the second variety. The Internet will render them worthless."\(^8\)

An understanding of market turbulence should awaken an industry's incumbents to the realization that it is no longer acceptable for the Voice of the Customer to be dictated by an organization's operational capabilities. In fact, it should become clear that any organization that continues to function in such a fashion will surely witness their market share erode as smaller more agile competitors move to fill

market niches previously ignored. Unfortunately, history has shown time and time again that the large incumbents in any industry are unable or unwilling to recognize this threat from below until it is too late. Very predictably, once this ‘niche’ competitor establishes a foothold, it will consistently look to the higher profit segments and expand.

In recent history, this exact scenario has already occurred once before in the US automobile industry - during the 1970’s oil crisis. At the time, the leaders in Detroit became complacent and were convinced that customers did not want small, highly affordable vehicles that had great gas mileage. They wanted large, expensive gas-guzzlers. Those that wanted the smaller vehicles were considered a minority who could be, and were, readily ignored. The inability of the US auto giants to exploit this initially insignificant but growing niche, gave rise to an increased presence of Japanese competitors which have competitively moved up to luxury vehicles, as well as, Detroit’s bread and butter truck market. This example serves to illustrate that understanding market changes and the rapidity of those changes must be an integral part of any incumbent’s product development and operational strategy.

**Misconception of Complexity in Mass Customization**

It would be negligent to discuss the topic of Mass Customization without also discussing one if its major perceived drawbacks – Complexity. Complexity is a difficult concept to readily define. This is primarily due to the fact that it has so many different meanings and understandings. It should prove useful then to define the various forms of complexity in order to discuss this concept properly.
There are five common forms of complexity:

- The first form of complexity relates to items that are inherently difficult to comprehend, I refer to this as *Concept Complexity* (these items are more perhaps appropriately defined as 'complicated').

- The second deals with the number and required skill of associated tasks, I refer to this as *Process Complexity*.

- A third form of Complexity involves the overall number of product elements; I refer to this as *Scale Complexity*.

- A fourth form of complexity relates to product ambiguity and conflicts in requirements, which I refer to as *Requirement Complexity*.

- The final form of Complexity has to do with the variety of ways in which elements can be joined; I refer to this as *Associative Complexity*. Associative Complexity can be further broken down into *Complexity of Choice* and *Complexity of Restriction*.

One way of looking at the difference between the two forms of Associative Complexity is through a simple example that is easily relatable – a salad bar. In this example imagine there are two salad bars each with contrasting philosophies. One salad bar, let's call it 'Fresh Choice' offers a choice of lettuce and/or spinach, 10 different toppings and 5 salad dressings. Because the operator of this salad bar believes in customer choice, there are no rules (restrictions) to limit the way the various ingredients may be combined. This allows $2^{(2+10+5)} = 131,072$ different combinations for the customer to select from.

Another salad bar down the street called 'Salad Rules' carries the exact same types of green (lettuce or spinach), 10 toppings and 5 salad dressings. The
operator of Salad Rules has a very different philosophy however. The operator's belief is that the customer is unable to process the number of combinations allowed by free association. To reduce the number of choices the customer must understand, the possible combinations are restricted. A subset of those rules might be as follows:

1. You cannot choose both lettuce and spinach.
2. If you choose lettuce, you cannot top it with sunflower seeds.
3. No salad can be topped with carrots and alfalfa sprouts.
4. No two dressings can be mixed.
5. A salad with cucumbers cannot be dressed with ranch dressing.

Several important questions arise from this example: Which salad bar is more customer friendly? Which salad bar is less costly to operate? And which salad bar is more complex from a customer perspective? The answer to the first question should be readily apparent. Restricting free customer demand can never be as customer friendly as allowing for free demand — that is customer sacrifice. The answer to the second question is perhaps no less obvious since both salad bars carry the same number of ingredients and therefore they have the same inventory handling and carrying costs. The final question, however, is much more difficult.

Fresh Choice salad bar offers a staggering number of choices yet customers seem to manage this complexity with relative ease. Salad Rules salad bar offers a much more restricted number of choices, but at the same time, it is intuitively more complex to manage these restrictions. The fundamental difference between the two different forms of complexity has to do with tradeoffs. At Fresh Choice, there are no tradeoffs (other than the customer's own tastes and plate size). The customer makes a very simple binary choice around each element — Do I want it? Yes/No. At Salad Rules, there are several tradeoffs. The customer must now
balance their desire for one element with the inability to get another. Additionally, they must absorb a tremendous amount of information regarding the product and their own preferences in order to effectively trade-off the various arrays of allowable multi-attribute combinations that each valid offering represents. This type of information overload can persuade a perspective customer to remove these offerings from their selection set altogether.

It is indeed useful to understand the difference between the number of orderable combinations and the number of decisions that a customer must make in order to complete the selection of a particular product. Fundamentally, while the number of possible combinations is exponential at $2^n$ (where $n$ is the number of stand alone options), the actual number of choices is simply $n$. In other words, the number of decisions that must be made increases linearly with the number of stand alone options. This is illustrated in the following graphic:

Figure 1 – Effect of Options on the # of Combinations and on the # of Discrete Decisions
Measuring Complexity

Regardless of the actual form or definition of Complexity, it is universally viewed as undesirable. In order to better understand and control any product or system attribute – such as Complexity, one must first derive a method with which to measure it. At one leading automotive manufacturer, Complexity has historically been measured by Buildable Combinations and more recently by Orderable Combinations. These metrics are essentially the calculated total of every potential combination in which a particular vehicle line can be produced or ordered. If only one part is changed or added, it counts as a completely new combination. The primary focus of these metrics relies heavily on Associative Complexity by looking to gain a better understanding of the ways in which various features are associated within the context of the overall vehicle.

Unfortunately, these metrics are inconsistent with operational complexity concerns. For what matters most to vehicle assembly has little to do with Associative Complexity, but everything to do with the complexity of assembly processes in the skill required (Process Complexity), the complexity of assembly processes in the number or processes required (Process Scale Complexity) and the complexity of assembly processes in the number of parts required (Part Scale Complexity). In thinking through the vast number of possible combinations that can be built, one can seek simplification with the realization that the individual assembly line workers are not concerned with, nor need they be, every possible combination. For example, a door trim assembler is only interested in the 10 or so variations of door trims from which he is required to select and assemble onto a given body. He is not concerned with the steps taken by upstream or downstream activities related to the total vehicle solve. Simply stated, he is concerned only with the number of parts he must install, the degree of skill required and the number of unique processes he must follow.
The fact that Buildable/Orderable Combinations, as metrics, have no direct correlation to the process skill level or the number of processes can be easily shown in an example of 4 components that are universally adaptable such that they can be combined in any configuration. In this example, the total combinations with just 4 parts is $2^4 = 16$ possible combinations. Nothing, however, can be said of process complexity with respect to either size or the skill that is required (only that 16 unique products can be built).

The fact that buildable/orderable combinations do not take into account the number of parts, can also be shown with little effort in an example of 4 vehicles (a subcompact, a midsize sedan, an SUV, and a luxury sedan) built at the same assembly plant. Unlike the previous example where association was completely unrestricted, this example requires only 1 valid part association for each of the 4 vehicles (It should be pointed out that such a broad market segmentation is 180 degrees out of phase with the fundamentals of Mass Customization, yet it is very consistent with Henry Ford’s 'any color as long as it is black' mass production system). Here, because of this restriction, there are only 4 valid buildable/orderable combinations (1 for each product type), yet the number of unique parts the assembly plant must process is roughly 4 times that required for any 1 vehicle (this is because the basic designs of these products limit the number of shared components). In this example the number of parts far outweighs that of the number of build combinations. The uniqueness of the 4 separate vehicles also brings an enormous level of process complexity into the assembly plant. That this level of complexity would never be brought into a single automotive assembly facility is not clear (given the technical advances in flexible manufacturing), nor is it the point. The point is, as stated previously, that there is no direct correlation between a metric like theoretical buildable/orderable combinations and actual manufacturing complexity which manifests itself in three ways – Number of Processes, Process Skill, and Number of Assembly Parts.
Additionally, and of equal or greater concern, any attempt to 'design out' seemingly unnecessary flexibility within the engineering and manufacturing systems based on such crude metrics, will increase operational costs dramatically. That is unless the restrictions can be 'fixed' in place. For clearly, as soon as these product rules/restrictions are allowed to shift (and in order to meet the changing market requirements – they must)\(^9\) then any system optimized to a previous rule set will become de-optimized with the new rule set. This is an inherent property of optimized designs, which tend to be difficult to modify and remain optimal at the same time (it is the fundamental difference between integrality and modularity). Furthermore, these systemic design changes will add a lag time to the responsiveness of the organization thereby opening the market to competitors who are not so rigid or constrained by unworkable internal processes.

Another question associated with Mass Customization and buildable /orderable combinations has to do with whether a high level of buildable/orderable combinations is itself an indication of Mass Customization. Here again, the metrics of buildable/orderable combinations fall short. A recent example would be useful to clarify this statement. During a study preformed in 1998, it was revealed that a particular US vehicle had over 1.5 million possible buildable combinations. During that same model year, less than 500 thousand units of this vehicle were actually sold. These 500 thousand vehicles required less than 16 thousand actual unique buildable/orderable combinations. Additionally, it is known that 90% of all US vehicle purchases are made directly from dealer stock. This is clearly an indication that automotive dealers are especially adept at deciphering customer demand patterns or that customer’s are unwilling to accept the 2-3 months required to custom order a vehicle from the factory and therefore trade-off against time and accept a sub-optimal offering. The large amount of vehicles that are held in dealer

\(^9\) To convince yourself that these rules cannot and will not change is to commit to a business process without customer focus or regard. These organizations have little chance of survival in today's increasingly 'frictionless economy'.
inventory is probably a good indication that the former is unlikely. More to the point, customers are not ordering their vehicles, dealers are — so that the 16 thousand unique configurations are not representative of the true customer demand. What must be understood here is that Mass Customization is not about having the capability to produce a large number of unique product offerings, but rather it is about having the capacity to produce products that meet the needs of each and every unique customer? Additionally, reducing buildable/orderable combinations, in and of itself, does not reduce the number of parts, the difficulty of the assembly processes or the number of processes required. These attributes are best controlled through the use of modular design approaches that will be discussed in a subsequent chapter.

Customer Choice
A seemingly inconstant principle brought forth by Pine is that fundamentally, customers do not want choice. They only want what they want. They do not want to negotiate through thousands of product options to find the perfect offering. Understanding customer preferences is therefore integral to achieving this principle while simultaneously maintaining the variety necessary to satisfy a multitude of customers with different needs. An example to help illustrate this principle is house shopping. Most consumers in the market for a new home have a very good idea of what their ‘Dream Home’ would be — if they could find it. Instead they go through what can be a rather lengthy and laborious process of parading through prospective house after house after house and eventually settle for something that is acceptable or simply less undesirable than any of the other choices. Who among us would not gladly forego the endless lost weekends shopping for a house and instead be shown the home of our dreams the first time? We only want what we want. The problem may not even be the availability of our ‘Dream Home’. In fact, it may have been around the next block. The problem is
most likely in the realtor's lack of understanding of our true preferences. Finally, if we cannot find an acceptable offering - we have it built to our specifications.

**Good Variety vs. Bad Variety (Empty Complexity)**

It is important to understand that variety does not equal customization. Customization implies the manufacturing of a product *in response* to a particular customer's needs while variety is simply providing customers with increased choice, hoping that they will find an offering that is acceptable to them. Fundamentally, variety is not bad – if it is valued by the customer and can be implemented within a cost structure that does not surpass that customer's personal value. However, variety for the sole sake of variety is not an effective business plan. It adds unnecessary cost and is in fact 'Empty', devoid of any value from the customer perspective and therefore, from the organizational perspective as well. The trick is to determine the type and level of variety that maximizes customer value yet minimizes the associated cost of complexity by identifying and eliminating that which is 'Empty'. This process is referred to as 'product rationalization'.

Going back to our salad bar example, imagine a salad bar where the only option was the color of the plate of which there are ten different colors to appeal to a wide set of color preferences. Everything else however, is limited to some subset of the most popular toppings that must be combined in a certain way. In this example there are no choices that represent any value to the customer, for the only thing the customer really cares about is the content of the salad. At the same time, the salad bar operator can rightly claim that he offers ten unique offerings. He offers variety and choice. The problem is the variety offered is meaningless and unnecessary which thereby will likely drive up the cost of operating the salad bar without providing a corresponding value to the customer to help offset this cost through increased customer loyalty, larger market share, or premium pricing.
A widely recognized real world example of empty variety relates to the automotive firm Nissan. Nissan allowed the number of steering wheels it offered to jump to 87. Of these, only 15 accounted for approximately 85% of the total steering wheels installed. The remaining 72 steering wheels offered no real value to the customer and drove up manufacturing costs. Nissan learned an important lesson of Mass Customization: Just because you offer variety in the form of options, does not mean that you offer real choice or real value.

Organizations looking to embark down the path of Mass Customization should only customize where it adds customer value. This is easier said than done, for it requires companies to identify those product dimensions where significant customer value can be created for each customer. Pine refers to these dimensions as “Points of Common Uniqueness”. Quite simply, these points are those attributes that all customers universally agree are important but commonly disagree on what the level of the attribute should be. They are therefore Common in their desire for something Unique. Designing a product with this understanding enables a producer to differentiate its offerings by matching its individual customer’s needs exactly and in a way that adds significant value.

Understanding customers attribute values is only half of the equation. The other half is understanding what the complexity associated with the additional variety will cost from the perspective of operations. Blindly accepting customer wants can prove disastrous if the value placed on this customization is less than the cost of implementing it. At a high level, the costs related to varietal complexity can be decomposed into a number of smaller elements including:

- Engineering Costs
- Testing Costs
- Facilities Costs
- Tooling Costs
- Inventory Carrying Costs (costs associated with financing, handling, floor space, insurance, damage, taxes, depreciation, obsolescence)
- Material Handling/Freight Costs (includes delivering parts to the line)
- Direct Material Costs (due to lower volume per piece)
- Administrative Costs (costs associated with part release and management and part system maintenance)
- Repair/Warranty Costs (costs associated with operator mis-build which may be offset by the reduction in the pipeline effect)
- Direct Labor Costs (costs associated with operator setup-part decision-part pick)

While all of these costs are valid, the key driver for the cost of variety comes down to lot size. Lot sizes are usually determined by operation setup (changing fixtures or instructions or programming). Larger setup costs require larger lot sizes in order to amortize the associated charge across a greater number of parts. This in turn increases the cost of work in process inventory (WIP), floor space and quality costs due to the longer ‘pipeline’ of unfinished product that allows quality defects to be built into several products before the concern can be identified. Therefore, effective Mass Customizers work diligently to eliminate setup and the associated labor costs, which allows them to reduce defects, reallocate extra floor space to expanding the product line and reduce both WIP and FG inventory. The ultimate goal is to drive the lot size down to a unit of one.

The following graph is an illustration of how to begin mapping out an effective customization strategy by mapping the added value created for the customer against the associated cost:
The Customer Value vs. Cost of Complexity relational matrix can be divided into 4 distinct quadrants. The first quadrant represents those attributes, which have high customer value and are inexpensive to incorporate (Note: this recognizes that all variety is not created equal). These attributes lie in the Customize region. The 2nd and 3rd quadrants represent attributes that need further assessment either because they have low customer value and low complexity cost or high customer value and high complexity cost. Ultimately these features must be traded-off between customer value such as: key customer needs, competitive offerings, brand image, product differentiation, technological trends and component/platform reuse and the cost of complexity. This complexity cost may effect:

- Price
- Incremental Sales
Variable Marketing

The 4th and final quadrant represents those elements that should be made standard, eliminated or installed at the dealership or other distribution facility. Because the value derived by the customer is low and the associated costs are high, there is no need to provide variety with respect to these attributes. In this instance an organization would be wise to offer a standard feature or no feature at all if the environment allowed it. If the marketing group remains adamant regarding the importance of this added variety, then it may be useful to add this complexity at a point further down the distribution channel where the cost structure maybe more amicable to this variety. This solution touches on the concept of postponement, which will be discussed in greater depth in the next chapter.

One of the greatest difficulties of mass customizing a product is not only understanding what to customize but what not to customize. While the old adage "The Customer is always right!" still holds, it may be that the customer cannot afford being 'right'. Clearly there are situations where the customer's desires and the cost associated with meeting those desires collide with the customer's willingness to pay for that cost in whole or in part. When this occurs the necessity of providing a customized offering as determined by customer value must be considered against the cost of providing the associated level of variety and the strategic implications.
Chapter 3

MASS CUSTOMIZATION – IMPLEMENTED

Approaches to Mass Customization
Gilmore and Pine [1997] define 4 different approaches for effectively implementing Mass Customization. These are - Collaborative, Adaptive, Cosmetic, and Transparent. Each will be discussed in turn. Other approaches to incorporating Mass Customization deal with point in time implementation or postponement, which will also be addressed in this chapter.

Collaborative Customization:
This approach is most useful for companies whose customers cannot easily articulate their needs and is most often associated with the term Mass Customization. Collaborative Customization involves a steady dialogue with individual customers to help them define their needs (and understand trade-offs that may indicate points of customer sacrifice), then identify the exact offering that meets those needs and finally produce the product tailored to those needs. By practicing collaborative customization, back-end solutions to standardized products (i.e. tailoring) are replaced with front-end specifications that result in production of exactly the right product for each and every customer. Examples of this form of customization in the automotive industry are primarily limited to large commercial accounts whose sheer buying clout forces manufacturers to capitulate. These accounts include taxi operators, police and rental fleets. In these cases, several vehicles are designed and built to unique customer specifications.
Adaptive Customization:
This method of customization is best suited for companies whose customers want the product to perform differently at different times or are significantly varied in their wants and needs. In order to satisfy this need, the product is designed so that the user can alter it by themselves. In this way, a standard product is produced and delivered to the customer who then enables the customization of function or representation through the product's inherent flexibility. This form of customization is exhibited in some automobile products in features like selectable suspension (sport-luxury), adjustable vehicle ride height, changeable seating configurations, and adjustable pedals. An additional example is a cellular phone product line developed by Nokia, which comes with several different colored faces that can be snapped on and off easily.

Cosmetic Customization:
The cosmetic approach is useful when all customers have similar functional needs and only differ in how the product looks. Rather than being customized or customizable, the standard offering is custom packaged specifically for each customer, changing only the form of the product. This requires an understanding of the unique ways in which each customer likes the standard product to be presented and is typically the way the automotive industry applies Mass Customization in conjunction with postponement techniques, which will be discussed later. This type of customization is often very superficial. Examples include things like wheels and spoilers and trim treatments.

Transparent Customization:
This approach to customization is most appropriate when customers' specific needs are predictable or can be easily derived. A Company can practice transparent customization by providing individual customers with unique goods or services without letting them know explicitly that those products and services have been customized specifically for them. This is accomplished by using a standard
representation of the product to hide the actual customization. Examples of this form of customization include vehicle calibrations that are adjusted based on the individual driving patterns of the consumer or vehicle ride height that automatically adjusts with speed for consistent handling characteristics.

It is impossible to conclude that one method is necessarily better than any other. Each has its pluses and minuses and they need to be considered carefully before implementation. Collaborative Customization is great for developing extremely close relationships with consumers\(^{10}\) and to tailor products exactly to their needs, however, it can be very time consuming when each order is essentially unique as is the case in most Business to Customer transactions. The deeper the customer interaction, the more the customer teaches an organization about his/her needs. Having this information enables the organization to provide the customer exactly what he/she needs and makes it more difficult for the customer to leave. Even if a competing organization were to develop the same capabilities, the customer would experience strong lock-in due to the high switching costs associated with teaching another organization the same information about themselves. Clearly, this is a very powerful form of mass customization produces a strong competitive barrier through high switching costs.

On the other side of the spectrum, Cosmetic Customization is relatively easy to implement because it primarily impacts the product's form only and not it's actual function. This makes this method of customization inherently shallow and of lower customer value with the exception of products whose main attribute is appearance. Somewhere in between lies Adaptive Customization which can be an extremely powerful method of customization because it not only recognizes that every individual is unique in their needs, wants and interests; but that these individual needs can (and do) change over time. Adaptive customization empowers the customer by putting them in control as the adaptation occurs based on the
interaction between the customer and the product. Think of the minivan owner who needs to haul sheets of plywood on the weekend and the kids to school and other activities during the week. This requires a fairly detailed understanding of how the customer will want to change the product, however, this understanding can be complicated due to the lack of direct interaction with the company that is required for the customer to modify the product. (It is difficult to determine how frequently customers actually modify their products when they do not require the company's assistance in the modification process.)

Finally, Transparent Customization goes a step further than Adaptive Customization because it doesn't even require customer intervention/effort – it just happens. This, of course, has similar (and more pronounced) drawbacks to Adaptive Customization and may be under appreciated by the end user who does not necessarily understand that the product has changed in some fundamental way or who understands but does not like the change that has been foisted upon them. Imagine a vehicle that automatically changes the position of the driver's seat for maximum visibility based on eye position.

The Product Approach to Mass Customization
Anderson et al [1997] proposed 3 different methods of customizing products/services. He defined these customization approaches as: Modular, Adjustable, and Dimensional.

- Modular – As the name implies, this method relies on modular designs to customize products through the combination of various modules. This method of customization can yield significant economy of scale improvements.

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10 Pine refers to these as "learning relationships".
• Adjustable/Configurable – This method takes advantage of designed in adjustments to reversibly customize an offering. These adjustments can be automatic or in response to actions taken by the operator, distributor or customer.

• Dimensional – Dimensional customization involves a cut to fit, mixing or tailoring approach. Unlike Adjustable customization, these alterations are permanent. This form of customization is most effective at satisfying customer’s exact needs, but cannot be easily adjusted throughout the product’s life cycle.

At first glance, Anderson appears to be proposing an alternative strategy that is inconsistent to the approach set forth by Pine. More careful analysis, however, quickly leads one to the understanding that they are not only consistent with one another - but they are in fact the same. The difference between the two is simply a matter of perspective - not objective. Pine’s method of customization (Collaborative, Cosmetic, Adaptive and Transparent) focuses on the Customer (how does the customer view the customized offering?), while Anderson’s method clearly represents a Product view (how is the product customized?). That said; it is difficult to say which perspective is best. Certainly, it is not clear whether there is a significant difference between collaborating with customers around a modular product and designing a modular product with which an organization then collaborates with the customer. This preference between the two will likely differ from organization to organization.
Additional insights can be gained by investigating the intersections between the two views of Mass Customization. There are seven key intersections that define a significant percentage of Mass Customization strategies. They are:

- Collaborative/Modular (Ex: Dell)
- Collaborative/Dimensional (Ex: Custom fit suit – Land's End Virtual Model)
- Adaptive/Modular (Ex: USB or Software modules)
- Adaptive/Adjustable (Ex: Selectable Ride height)
- Cosmetic/Modular (Ex: Wheels on an automobile, Snap-on/exchangeable Nokia phone covers)
- Cosmetic/Dimensional (Ex: Paint mixed at a store)
- Transparent/Adjustable (Ex: Vehicle logic that adjusts to the driver)
The method of customization chosen is greatly dependent on the point the customer is brought into the product development process. This could occur during design, fabrication, assembly or point-of-sale. It should not take much convincing to accept that interjecting customer requirements early on in the design phase allows for the design to be developed for customization (modular design). By the time the product is in the fabrication stage, customer specific requirements can only be made by altering standard designs. If customer preferences are not established until the point-of-sale, then customization is restricted to varying combinations of features and options. This is also largely the case for customer input at the postproduction phase.

The approach that makes most sense for the automotive industry today is not necessarily the approach that will make sense in the future. Of the 4 approaches described by Pine, Adaptive and Transparent customization are perhaps the most appropriate methods. Adaptive provides flexibility in design and use. This allows for varying customer requirements without expensive and timely redesign or manufacturing complexity. Transparent must be done appropriately and preferably on items the customer will notice and appreciate. Cosmetic Customization includes mainly trim and superficial styling features, but could be coupled with Adaptive Customization with examples such as automotive paints that change color at the whim of the customer. These methods are of course, much easier than truly Collaborative Customization that requires a strong dialogue with each customer. While there are tremendous benefits to incorporating collaborative design, the US automotive industry is not currently capable.

**Postponement Techniques**

Postponement (or Late Point Personalization) can be simply defined as delaying the point of product differentiation. The benefits around this concept are related to the costs associated with operating the supply chain with reduced inventories. In
fact, because of their unrelenting disdain towards excess inventory, many Japanese automotive companies operating in the United States still operate a significant amount of their product differentiation through installation within their dealer networks. This practice was necessitated prior to establishing factories in many of their foreign markets because the transpacific shipping lines would have prevented them from responding effectively to varying market demands and resulted in significant inventories.

The American Automotive industry – unhindered by long supply lines – has ensured that their customer demands are satisfied by producing and storing 'just-in-case' inventory. Vehicles are typically pushed through the supply chain before a customer order is received (only 10% of vehicles purchased in the US are customer ordered). In fact, a 60-day supply of any particular vehicle is considered ordinary and 'desirable' inventory. This practice ensures that the amount of stock-outs are minimized and transfers the cost associated with inventory ownership to the dealerships who naturally transfer this cost on to the consumer (some estimates put the cost of carrying this inventory at an average of $400 per vehicle.)

There are significant advantages to postponement with respect to meeting customer demand requirements, which by nature are inherently variable. Postponement can be accomplished primarily from two perspectives:

1. Delay changes in form and/or function to the latest possible point in the distribution chain.
2. Delay changes in form and/or function to the latest possible point in time.

By delaying the personalization of a product offering until the latest point possible, you reduce the probability of having the wrong stock in the wrong place at the

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11 It is estimated that GM alone holds $20 Billion in finished goods inventory in its dealer base, while Ford holds $15 Billion and Chrysler $10 Billion. Assuming a standard 25% inventory and handling charge, this represents significant costs.
wrong time because a highly customizable standard product is available in a few main configurations throughout the supply network. The ultimate point of postponement is, of course, the customer. Where the customer actually completes some differentiating portion of the products assembly. (It is unlikely that the customer would be willing to go along with such a strategy unless the task was extremely simple or that significant perceived benefits were derived by doing so.)

Customization then can occur in a variety of points along the distribution channel:

1. Factory – flexible manufacturing can quickly build any configuration required.
2. Dealer/Distributor – insure dealer capability to protect quality.
3. User – product design needs to be robust against a variety of potential users and skill levels.
4. Self Adjusting In Use – products automatically adjust themselves to meet the users unique requirements

Of these customization points, dealer/distributor installation can be a very powerful competitive advantage because it allows for the customization of a product in a time frame that may be more acceptable to a customer so that maximum value is derived by the customized offering. This implementation is actually closely aligned to a point of sale postponement strategy, providing the only way to instantly satisfy customers with the exact product of their choosing.

There are however, significant concerns regarding the quality that can be maintained with this approach. These concerns can be overcome, at least partially, by using modular designs that make assembly a simple error resistant process and by designing the product and installation process so that the differentiating module can in fact be added at the end of the distribution channel. (An engine would not be an appropriate choice of a postponeable component!)
Another method of avoiding concerns within the dealership network is through the use of modification centers where partially completed vehicles can be shipped in response to a customer order to be completed per that customer’s specifications. This may allow for better control of outgoing quality.

The objective of Mass Customization is to deliver the right product at the right time to the right place. By shifting the point of differentiation to the point of sale – the probability of meeting this objective is almost guaranteed. As mentioned earlier ‘late point personalization’ is common practice among Japanese auto companies operating in the US. The table below illustrates how they have shifted this operation out of their assembly facilities into their dealerships.

<table>
<thead>
<tr>
<th>Build Combinations</th>
<th>98 US CAR</th>
<th>98 Honda Equivalent</th>
<th>98 Toyota Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Plant</td>
<td>1,100,000</td>
<td>101</td>
<td>1,696</td>
</tr>
<tr>
<td>Dealership</td>
<td>-</td>
<td>5,800,000</td>
<td>28,000</td>
</tr>
</tbody>
</table>

Figure 4 – Table Depicting Typical US Build Combinations vs. Japanese Automotive Firms

Fundamentally, Postponement strives to:

- Reduce inventory
- Carry inventory (WIPS and FG) in the least expensive form
- Allow manufactures to respond quickly to customer and market variations.
- Optimize cost trade-offs in the supply chain

**Benefits of Mass Customization**

The benefits of Mass Customization should be clear and are summarized in the following graph:
Benefits of Mass Customization

- Elimination of unnecessary complexity
  - Focused engineering/testing costs
  - Focused facilities and tooling costs
  - High value material supply and inventory costs
- Shorter product development cycles
- Higher capture rate of customers through the showroom
- Lower Dealer inventory/increased inventory turns
  - Reduced lot rot
  - Higher market share
  - Higher customer satisfaction and loyalty
  - Higher price realization with less need for discounting
  - Reduced Marketing Costs
  - Higher residual values

Figure 5 – Benefits of Mass Customization

It is unlikely that customization along any one approach will yield a perfect solution for an organization or that Mass Customization in and of itself is a solution at all. Rather, it is more likely that each organization will need to study these various approaches with respect to their product offerings, capabilities, customers and industry competitors in order to determine the most appropriate course of action. Indeed, Mass Customization can increase production and material costs if not applied judiciously. Keys to implementing Mass Customization lay in component reuse across several product lines and postponing the assembly of differentiating elements of a product until the latest possible point in the supply channel. This could be done at the end of line in response to a customer order, at a distribution center or at the point of final sale. Instead of taking an ad-hoc approach, companies must rethink and integrate the principles of Mass Customization into
the designs of their products (using modularity principles), the processes used to make and deliver those products, and the configuration of the entire supply network. Finally, the question for many consumer products (including automobiles) should not be ‘Is Mass Customization Right?’ but rather ‘Where should it be used?’ As Eric von Hippel pointed out [May 1998], “Mass Customization offers value when the demand for a final or intermediate good or service is heterogeneous”, which is a characteristic of many consumer products.
CUSTOMIZATION OF END PRODUCTS THROUGH MODULARITY

"Modularity – building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole."  

I am not sure who initiated the original study, but any product development or project management textbook will contain the same graph depicting the translation of product cost over time. The point of the chart is to illustrate the importance of product design and product architecture, which lock in 80% and 60% of the product’s final cost, while realizing only a fraction of the actual project spend.

![Product Cost Vs. Time Graph](image)

Figure 6 – Graph of Product Cost (Committed and Incurred) vs. Development Phase

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Underlying the brief above discussion is the fundamental understanding that initial concept and architectural decisions have a tremendous impact on the flexibility of the project that is necessary to insulate the product development team from the tide of continually changing requirements throughout the project's lifetime. There are of course several ways in which to deal with the dilemma that requires a decision to be made with data that is either incomplete or prone to changes. Toyota practices an approach referred to by Ward et al as "set-based concurrent engineering."\(^{13}\) As Ward points out, "Traditional design practice tends to quickly converge on a solution, a point in the solution space, and then modify that solution until it meets design objectives. This seems an effective approach unless one picks the wrong starting point; subsequent iterations to refine that solution can be very time consuming and lead to a sub-optimal design." Set-based concurrent engineering essentially keeps this solution space open for a longer period to ferret out the weaker solutions and take in better levels of data for more accurate decisions. This is a method that may not work for every organization.

Another approach is to 'design in' flexibility up front so that critical decisions can still be made further downstream in the PD process – even up to the point of delivery. This design flexibility can be most readily achieved by creating modular architectures that are comprised of exchangeable components, which can be configured into a wide variety of products or services. These flexible – modular architectures are perhaps the best method for achieving Mass Customization. Modular product designs provide a supply chain with the flexibility that it requires in order to modify a product quickly and inexpensively by allowing changes in product functionality/appearance through unique exchangeable modules that are mapped to varying functions. Products built around modular architectures can generally be

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easily changed without incurring significant complexity in the manufacturing system. Development team decisions regarding the level of modularity and integrality determine a project's flexibility and must be made during the definition of product/process architecture, as this will ultimately determine how the product/process can be subsequently changed.

The key benefits of Modularity are 1) Interchangeability through flexible designs and 2) Reduced setup through well-specified, standardized interfaces. These specified interfaces are defined by Karl Ulrich [Dec. 1993] as the “protocol for the primary interactions across the component interfaces, and the mating geometry”. They are detailed descriptions of how different modules interact through fit, connection and communication. By implementing a modular design approach, economies of scale can be achieved through the components rather than the products. Economies of scope are gained by using/sharing modular components over and over in different products. Customization is gained with the large array of products that can be configured utilizing the standardized modules.

There are two high level forms of modularity: Function-based and Assembly (geographic) based. Function-based modularity relates to the intrinsic functionality of a product and how those functions are distributed. Assembly-based modularity focuses on the manufacturing techniques and assembly operations associated with a given product. The focus of this chapter will be to gain a better understanding of the six forms of function-based modularity defined by Ulrich and Tung [1991] and how they can be leveraged to enable the efficient application of Mass Customization.

Component-Sharing Modularity
In component-sharing modularity, the same component is used across multiple products to provide economies of scope. This type of modularity is unlikely to result in true individual customization unless used in conjunction with other types.
It does, however, enable the low cost production of a large number of products and services. Component-sharing modularity is best used to reduce the number of parts and thereby the costs of an existing product line that already has high variety. An example would be a common door handle used across several different vehicles.

**Component-Swapping Modularity**

This method is the complement to component-sharing modularity. Different components are matched with the same basic product, creating as many products as there are components to swap. An example would include different radios, CD players, cassette players and telematics equipment that are exchangeable within the context of a particular vehicle line. For a company providing a standardized product or service, the key to taking advantage of component-swapping modularity is to find the most customizable part of the product or service and separate it into a component that can easily be re-integrated. For greatest effectiveness, the separated components should have the following 3 characteristics according to Pine\(^{14}\):

1. Provide high value to the customer
2. Once separated, be easily and seamlessly reintegrated
3. Have great variety to meet differing customer needs and wants.

**Cut-to-Fit Modularity**

While similar to the two previously mentioned types, this method involves one or more components that are variable within established limits. Cut-to-fit modularity is most useful for products whose customer value revolves around a component that can be continually varied to match individual needs and wants. In an ideal case, the current product family may have components, which incrementally

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increase size in discrete steps. By applying cut-to-fit modularity, a strong competitive advantage could be gained by mass customizing the products to fit individuals thereby eliminating the compromises customers must otherwise make.

**Mix Modularity**
This type of modularity can engage any of the previous types, with the clear distinction that the components are so mixed together that they themselves become something different. The key factor in assessing the applicability of mix modularity is recipe. Anything with a recipe can be varied for different markets, different locales, and indeed for different individuals. A popular example of this is household paint, which is mixed to any defined recipe (color) at the point of sale.

**Bus Modularity**
This method utilizes a standard structure that can attach a number of different kinds of components through a standard interface. Because the bus is usually hidden and often somewhat abstract, this form of modularity is more difficult to grasp. The key distinction of bus modularity is that a standardized structure allows variation in the type, number, and location of the modules that can plug into it. The popular personal computer architecture popularized by IBM incorporates a bus modularity architecture.

**Sectional Modularity**
Sectional modularity provides the greatest degree of variety and customization. It allows for the configuration of any number of different types of components in arbitrary ways, provided that each component is connected to another using standard interfaces. In a sectional modular architecture, there is no single element to which all the sections attach. A classic example of this is Lego building blocks where its standard interface allows for the construction of an infinite number of objects. A more modern example is sectional office partitions. With sectional modularity, the structure or architecture of the product itself can change thereby
providing tremendous possibilities for customization. The key to implementation of sectional modularity is the development of an interface that allows sections or objects of different types to interlock.

Choosing to implement a modular architecture and the appropriate method of modularity are only the first step. The next step of determining where a module should begin and where it should end is less straightforward of an exercise, especially for highly complex products. Design Structure Matrices (DSM) is one tool that seeks to answer this very question by mapping relationships and interdependencies among various design parameters. A DSM can be constructed by assigning the individual parameters of a design to the rows and columns of a square matrix. If a parameter is an input to another, a mark (usually an ‘X’) is placed in the column of the output parameter and the row of the input parameter. This process is repeated for each parameter pair. Once the entire matrix is completed, it should look similar to the one below 15:

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This matrix can be used to improve the fundamental structure of the design by analyzing the 'X's in the row of a parameter which indicates what other parameters affect it and the 'X's in the column of a parameter which indicates which parameters are affected by it. The object of DSM is to arrange the functions into groupings in such a manner as to minimize the interactions between groupings – supporting a fundamental tenet of system architecture – "The greatest dangers are in the interfaces". These independent functional groupings should establish the natural module boundaries. The black box design of the internal module functionality allows many modules to be designed in parallel thereby significantly reducing overall product development time.
As Ulrich [1993] points out, the spectrum of design can range from fully modular, where each functional element of the product can be changed independently by changing only the necessary component; to the fully integral, where changes to any single functional element requires changes to every other component. bus-modular and sectional-modular architectures are both rather useful for products that must accommodate a wide variety of configurations. Deciding whether, when and where to design in modularity must be made before the architecture is defined and must be linked to understanding customer needs and Pine’s “Points of Common Uniqueness.” If applied appropriately, modularity can reduce overall engineering costs, testing costs, material costs, quality costs and manufacturing costs (by reducing setup and change-over times to drive Economic Order Quantity (EOQ) to 1) while increasing product-to-product customization.

Utilizing modular design methods is clearly a key enabler for supporting an effective Mass Customization strategy. It is not the only method however. In the previous chapter, other methods were discussed – including adjustable and dimensional designs. These are simply designs that are constructed to be easily modified either reversibly or non-reversibly. Furthermore, module systems do often have drawbacks that may make them less desirable than one of these other approaches. To begin with, modular products are generally more difficult to design than their integral counterparts. This is because modular systems require a deep understanding of the interrelatedness of each design parameter in order to minimize the interfaces and to develop the interface requirements necessary to allow the modules to function together in a seamless fashion. Additionally, because of their standardized interfaces, modular designs are frequently more expensive because they incorporate additional components or higher spec components. This often translates into a cost, weight, and/or size penalty. Finally, modular designs tend to be easier to copy. However, there remain several compelling reasons for adopting a modular design approach other than the pure pursuit of manageable customization:
- Product upgradeability
- Add-ons for product enhancements
- Component standardization
- Wear-out (ease of service/repair)
- Consumption (ease of replacement)
Chapter 5

IMPLEMENTING USER DESIGN THROUGH INTERNET BASED TOOLS

Arguably one of the most difficult functions in Product Development is the accurate and timely translation of customer needs into product specifications. This is because customers usually detail their needs in very subjective and qualitative ways, if they are able to articulate them at all. To help minimize this concern, new tools are constantly emerging that significantly enhance customer participation in the development of new products. Market research techniques, product development tools and Internet based manipulation tools are evolving to enable an integration of elements which engage the customer in the overall design process and give them easy to use mechanisms with which to explore the product design space in order to identify design solutions which best satisfy their needs. User design may be an effective tool for facilitating customer participation in the design of new products and to improve the product development team’s fundamental understanding of customer needs. This form of soliciting customer input will become increasingly important, as competitive pressures demand improvements in product development time and in customer satisfaction.

In many product development processes there exists a lack of a capable mechanism for facilitating the perfect transfer of knowledge or skills between customers and product development teams. Eric von Hippel [May 1998] described how to design a new product, the necessary information, and the design solutions, which need to be brought together. Today, the product design team works diligently to get into the customer’s mind and design a product that meets all of the customer’s articulated and unarticulated latent needs. The PD team performs this function possessing strong technical understanding but weak and incomplete
knowledge of actual customer needs. What von Hipple describes as “sticky” local information prevents the development team from ever completely capturing the customer’s needs. von Hipple defines “sticky” information as data whose meaningful transfer from source to recipient in a useable form is constrained by 1) the absorptive capacity of the recipient, 2) the ability to translate the information and 3) the indirect or distant relationship between the source and the recipient. Using Customer Design techniques, customers can apply their understanding of their needs that are influenced by tacit knowledge, which they have difficulty providing within the traditional confines of the normal design process, by using the Internet as an enabler to work in the PD team’s design space for a given product.

An essential mechanism for stimulating the exchange of information between customers and the design team is a common language. Customers and engineers each have unique ‘languages’ in which they come to understand and associate with a product. The typical car buyer cannot communicate in the engineer’s language of fluid mechanics, material composition, or NVH acoustics. In a similar way, the engineer has difficulty grasping the nuances of the customer’s language of touch, feel and sense. One can put forth then, that establishing a common language that would enable the customer to easily manipulate the established design space while simultaneously translating that information into design parameters will tremendously improve the overall incorporation of customer needs into new products. A proposal might be to investigate the use of graphical images and symbols as a form of language that can be easily understood by both the customer and the product development team. This is the essence of user design.

Through the medium of the Internet, several design concepts can be ‘tested’ simultaneously for a fraction of the cost associated with traditional concept tests involving physical prototypes. Concept selection is often one of the most difficult phases in the product development process precisely because designing a concept that embodies the exact needs and wants of the customer is extremely
time consuming (time, of course, is a commodity that few product development teams have much of) and often involves discontinuous attributes such as appearance which can be varied dramatically across functionality. Such attributes that involve consumer judgments get at the heart of von Hippel's concept of 'Sticky' information. These attributes are often difficult for consumer's to express their reasoning regarding the characteristics behind their specific likes and dislikes. Dr. Marielle Creusen from the School of Industrial Design Engineering at the Delft University of Technology in the Netherlands has described a process called Interactive Concept Testing (ICT) as a method for addressing this concern regarding product appearance.

ICT was first proposed by G. H. Loosschilder in a 1998 article. ICT relies heavily on computer technologies to transfer visual information and allow for consumer interaction to modify product concepts around certain characteristics (or attributes). Each change by the respondent results in a change in the overall virtual product, thereby enabling the consumer to visualize the effect of each decision on the product. This process continues until the respondent has designed their most preferred product.

The inherently low marginal cost of each incremental customer interaction on a web-based system makes it possible to simultaneously elicit and compare information from a large number of physically dispersed customers at a lower cost than traditional market research. And by utilizing a highly interactive environment that incorporates Internet technologies, a company can provide its customers a fun and enriching experience with image manipulation, drag and drop and decision making activities. While the user design experience is expected to be preferable to standard survey forms and questionnaires for large numbers of customers of mass-market products for which customer motivation to participate is generally low, it can also be seen as a compliment to these traditional methods. This would likely result in an increase of customer input and improved customer satisfaction,
and a much-improved understanding of customer needs by providing product designers a better understanding of the tradeoffs that customers make in their purchase decisions. Also, it provides timely customer information at different stages in the product development process to improve vehicle development time. As mentioned earlier, an expedient and thorough understanding of the needs of each customer is a key enabler for supporting Mass Customization. It should be clear that proceeding on a Mass Customization program without this knowledge is likely to lead to less than satisfactory results and may, in fact, be detrimental to the organization.

Aside from the frequently discussed issues associated with web-based user design due to the inherent limitations of existing technology, there are other weaknesses that should be understood.

- Solutions are limited to the choices presented.
- This method does not test the complete possible design space. – Design space already constrained.
- Sense of proportion is difficult to convey spatially.
- Representations may not reveal product imperfections (i.e. might make the product look/perform better than it actually does.)
- Sensory experiences can not be translated well across the web
- Organizations are required to expose intellectual property to individuals beyond their direct control. This requires careful management of data access.
- Bandwidth limitations constrain the effectiveness of data intensive data files (such as high resolution images and videos).
Implementing User Design Concepts

In order to help the reader understand the power of User Design methods, a couple of examples are presented. They are not intended to encompass the full capability of this method, but merely assist in framing the material in the previous discussion.

User Design Example 1:
The user is asked to select a module or attribute from one of many as their 'preferred choice'. A draw back of this is that this method does not adequately measure the importance of the attribute with respect to the other attributes of the product and therefore would have to be conducted after an appropriate preference test. This type of testing will be discussed in more detail in the following chapter. In fact, when coupled with a more formalized experimental approach such as Conjoint Analysis, this type of exercise begins to answer the question regarding how many levels of an attribute to offer.

In the example below, the user selects from a set choice of possible steering wheels. Presumably, these choices have been screened by engineering and manufacturing for feasibility and compliance with affordable targets. In effect the question is, "Given that this attribute is important, which do you prefer?" A simple 'mouse-over' each object might present the user with more detail on the attribute (i.e. leather wrapped, remote stereo controls, remote phone controls, etc.). Additionally, prices could be attached to allow the user to trade-off the perceived benefits of their preferred choice with its cost.
An enhancement to this example would be to incorporate some level of user manipulation to allow the user to design his/her own steering wheel. This type of testing might reveal levels of attributes previously not thought of or quickly dismissed during feasibility and cost analysis. This information can potentially lead to the uncovering of product 'Surprise and Delights' thereby significantly increasing overall customer satisfaction.

**User Design Example 2:**
Another example of user design that is more engaging requires the selection of several different attributes into an overall product design. In the following example, users actively manipulate the design space, choosing attributes and levels to their preference. Again, as in the example above, it is important to understand the levels of importance on various attributes before engaging in this type of testing so that trivial and unimportant attributes/elements are not tested. While testing incidental features is not in and of itself harmful, it does dilute resources that could be utilized on more important studies and fundamentally it provides very little benefit to the engineering and manufacturing activities because even though the customer may have a clear preference, these features will likely be dropped when product tradeoffs are made by the development team.

In this example, the user is asked to design their preferred seating configuration. They must choose seats for the front, 2nd and 3rd rows. Simply clicking on the attribute level of their choice makes this selection appear in the seating design.
space on the left. Clicking on the elements within the seating design space will remove the feature and place it back in the choice palette on the right. An added feature incorporates a 'Price' field that is automatically updated with each add/delete. As mentioned before, this allows the user to make the appropriate tradeoffs so that they do not create an unrealistic offering that they prefer but cannot afford.

Figure 9 – User Design Example #2

User Design Example 3:
Using the same concept, but with a slight twist – another example would be to use the same layout as in Example 2. However, in this example all of the features are added to the offering at the onset, and the user must remove those that he/she does not desire (or in other words, whose perceived utility is not in line with the feature's added cost). While this is seemingly a trivial detail, Park, Jun and
Macinnis\(^{16}\) conducted studies that demonstrated that in fact, such presentation can influence customer decisions.

**Why does User Design Work?**

User design works for a number of fundamental reasons. Using easy to understand intuitive interfaces allows for the implementation of interactive simulations that make participation in the design task more realistic, interesting and less fatiguing. Also, the use of graphics provides a common language that aids in the correct interpretation of certain attributes and their corresponding levels by unsticking "sticky" information. By engaging the customer in this process, he 'learns' what the best solution should be for himself as an individual. Additional benefits are derived by linking this testing method with the capability of the Internet thereby providing a relatively inexpensive customer interface tool that is very quick with automatic data collection and entry that can be utilized to feed the upstream Product Development Process more effectively. Another important feature that should not be overlooked is the ability to customize the screens on a real time basis based upon customer information and prior responses. I believe that this intimate involvement of customers in the design process links them to the products (and the company) and will tend to make them more loyal customers by crossing the bridge from traditional customer-product relationships to Pine's 'learning relationships' which is a fundamental step in moving towards collaborative customization.

TESTING THE USER DESIGN METHODOLOGY WITH CONJOINT ANALYSIS

The first step during the development of the product is to accurately define the product so that it satisfies the Voice Of the Customer (VOC). In general, mass produced products are defined so that a single product will satisfy enough customers to be 'competitive'. Mass Customized products, on the other hand, need to be defined so that a planned range of variations can be provided to satisfy many individual customers -- 'segments of one', in an efficient manner.

Care must be taken to accurately determine what product attributes should even be considered for Mass Customization. As stated previously, these attributes are perhaps best identified as 'points of common uniqueness'. Therefore, the fundamental question this test hopes to answer is: Which attributes should be customized based on customer wants and needs? And conversely, which should not? This data must then be correlated with the data from the previous discussion on cost. There will likely emerge situations where the customer wants/prefers a particular attribute, yet is unable/unwilling to pay for it. In a very competitive market this may not even be a concern. The manufacturer provides the feature because it is the price of playing in a market or a particular product category. An even better strategy is to figure out how to get the cost down to a sustainable level that allows for a profitable offering without customer sacrifice.

**Experiment Setup**
In order to begin to understand which attributes an organization should offer as customizable, an experiment was designed utilizing 3 different methods for determining customer preferences. These methods are:
To make the experiment more meaningful, a real world product was chosen to frame this example. The product selected to serve this purpose is the cross-over vehicle product category. Cross-over vehicles are best defined as vehicles that 'cross-over' two or more traditional vehicle segments. The graph on the following page illustrates how the various vehicles in this segment are associated to the more established segments of SUV, Pickup Truck, MPV and Car/Wagon. As a class, crossover vehicles embody the best attributes of these associated segments taking the large interior space and exterior versatility of a minivan (MPV), the safety and convenience of an SUV and a minivan and the comfort, quiet and agility of a car/wagon. The target customers for this segment are primarily current car/wagon, minivan and SUV owners whose current vehicle does not satisfy some of their dominant needs. Some of the vehicles included in this product category are as follows:

- Acura MD-X
- Audi Allroad Quattro
- BMW X5
- Buick Rendezvous
- Lexus RX-300
- Mercedes ML-320 and 430
- Pontiac Aztec
- Toyota Highlander
Conjoint Analysis Overview

Conjoint Analysis was chosen for its ability to accurately determine a product attribute’s importance and desired level for each individual respondent. Additionally, using concepts based on Experimental Design, it can test hundreds of potential product designs in a much smaller number. The fundamental premise behind conjoint analysis is that it can uniquely solve each person’s utility for any particular attribute and develop an overall utility function for any given product. (This is a very valuable tool because most consumers are unable to accurately translate their utility by themselves.) This information can then be used to understand a respondent’s willingness to trade-off one attribute for another and group them into smaller market segments – perhaps even into ‘segments of one’! Understanding this information, product development teams can begin plotting customer value against the costs of complexity for each attribute and each level within that attribute, as discussed earlier. This would then allow them to optimize the design of the final product to maximize profits and customer value. This
'Value', of course, means different things to different people. Therefore, by getting the user to identify their own value system, the product development team can more effectively cluster product attributes, options, and related services.

There are several necessary elements required in order to establish an effective conjoint study. These are:

1. Determine relevant product attributes
2. Determine relevant levels of those attributes
3. Determine potential offerings within an orthogonal array
4. Design and implement the study
5. Determine method of data analysis
6. Calculate Utilities for each participant
7. Calculate the Weighting of each attribute
8. Calculate Utilities for specific products

The relevant attributes and their levels for this conjoint study were determined through literature review of various automotive magazines coupled with an analysis of features that might readily lend themselves to customization because of either their inherent modular design or a hypothesis of anticipated varied customer preference coupled with high importance. These attributes then were chosen to understand those vehicle features where customers are likely not to be in agreement ("Points of Common Uniqueness" - ala Pine vs. points of common commonness). Characteristics of Points of Common Uniqueness are:

- Customers universally care about the attribute
- Customers tend to be in disagreement about what the attribute should be.

---
17 Adapted from "Notes on Conjoint Analysis" Drazen Prelec, Fall 1999.
Identifying, understanding, and focusing customization on product dimensions that have a high importance (high utility) and high variability (high standard deviation) around customer preference will help ensure customers actually value the customization provided. Conversely, this same technique can be used to verify attributes for which variety has no customer value at all. The attributes chosen for this experiment are shown in the following table:

<table>
<thead>
<tr>
<th>Attribute</th>
<th># of Levels</th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery Delay</td>
<td>2</td>
<td>1 week after order</td>
<td>6 weeks after order</td>
</tr>
<tr>
<td>Seating Capacity</td>
<td>2</td>
<td>5 passenger</td>
<td>7 passenger</td>
</tr>
<tr>
<td>Telematics</td>
<td>2</td>
<td>Navigation only</td>
<td>Internet/E-mail only</td>
</tr>
<tr>
<td>Price</td>
<td>2</td>
<td>$29,000</td>
<td>$37,000</td>
</tr>
<tr>
<td>Ride Height</td>
<td>2</td>
<td>Low (car-like)</td>
<td>High (SUV-like)</td>
</tr>
<tr>
<td>Drivetrain</td>
<td>2</td>
<td>All Wheel Drive (Auto)</td>
<td>Rear wheel Drive w/ selectable 4WD</td>
</tr>
</tbody>
</table>

Figure 11 – Table of Proposed Attributes and Levels for Cross-Over Study

**Kano Model Overview**

The Kano model was chosen for its ability to assess the relationship between customer needs and customer expectations and for its simplicity. This relationship is determined based on customer responses to pairs of questions and classifies customer needs into one of three categories:

- **Basic Requirements** – these are needs which must be met as a basic requirement to market entry. As an example, a car sold in the US must have power steering as a basic requirement.

- **Revealed Requirements** – these are needs that have increasing value with increasing levels and must be traded-off for price and performance. Fuel economy would clearly fall into this category of customer needs.
• *Surprise and Delights* – these are needs that the customers themselves are unaware of or do not expect to be fulfilled within a particular product class. These needs are potential differentiators that provide strong motivation for purchase. Providing 4 doors on a minivan is a good example of a Surprise and Delight.

Both the Basic and Surprise and Delight requirements are customer wants and needs that are usually unspoken because they are either assumed or unknown.

![Kano Model](image)

**Figure 12 – Kano Model**

Finally, a trade-off analysis was chosen to understand the value of a particular attribute, by ‘trading-off’ the degree of an attribute against cost. This analysis is useful for understanding each respondent's exact 'value' for a given attribute.

**Conjoint Study Design**

Given the attributes and levels shown in Figure 11, a Full Factorial would require \((2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2) = 128\) potential product combinations. Because this
number is so large, a fractional factorial of 12 product profiles was designed on individual cards to conduct this study. Appendix B illustrates the textual representation of an 18-card test. Appendix C illustrates the concept design for a graphical representation of the same 18-cards. Appendix D illustrates the alpha level prototype of a graphical representation for the final 12-card design. An example of each is shown below:

Card 1
Delivery 6 wks after order
7 passenger seating
Internet-Email only
$37,000
Low Ride Height (like a car)
64 Cubic Feet Cargo Cap.
Front-wheel Drive

Textual Concept

Figure 13 – Prototype Conjoint Cards

Through this intuitive interface the respondent is able to sort the different product variations which are represented by the cards. The respondent would be asked to pre-sort the 12 unique product cards into 2 separate piles: “Would Consider Buying” and “Would not Consider Buying”. Those not chosen for either pile would automatically be sorted into an intermediate grouping for 'Might Consider Buying'.
While presorting allows the respondents to "break" the pool of cards into smaller groups, thereby taking into consideration the manageability of large data sets by those taking the survey, it also simplifies web implementation for large experiments where the number of available design cards would not be able to be displayed easily on a standard computer monitor set to 1024 x 768.

After the cards are pre-sorted into the three groups, the participants would then be instructed to rank order the cards in each grouping from 'most likely to purchase' to 'least likely to purchase' as 1 thru N (where N is the number of cards in that grouping). This process would continue for each group until every card is sorted by preference. A final step would verify the boundary conditions between the three presorted goups. This can done by selecting the first and last cards from each group.
adjacent ‘pile’ and allowing the participant to confirm the ordering of each card in that boundary pair. The participant could accept the order as it was originally sorted or swap the two cards around. This verification sort can be done once for the last card of the "Would Consider Buying" pile and the first card of the "Might Consider Buying" pile and again for the last card of the "Might Consider Buying" pile and the first card in the "Would not Consider Buying" pile. Customers' card rankings can then be analyzed using regression analysis or least squares techniques to identify the value the customer places on each attribute.

<table>
<thead>
<tr>
<th>Delivery Delay</th>
<th># of Passengers</th>
<th>Telematics</th>
<th>Price</th>
<th>Ride Height</th>
<th>Cargo Capacity (cu. Ft.)</th>
<th>Drivetrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card 1</td>
<td>1</td>
<td>7</td>
<td>Internet-Email</td>
<td>37000</td>
<td>Low</td>
<td>90</td>
</tr>
<tr>
<td>Card 2</td>
<td>1</td>
<td>7</td>
<td>Navigation only</td>
<td>29000</td>
<td>High</td>
<td>50</td>
</tr>
<tr>
<td>Card 3</td>
<td>6</td>
<td>5</td>
<td>Navigation only</td>
<td>37000</td>
<td>High</td>
<td>90</td>
</tr>
<tr>
<td>Card 4</td>
<td>6</td>
<td>7</td>
<td>Navigation only</td>
<td>37000</td>
<td>Low</td>
<td>90</td>
</tr>
<tr>
<td>Card 5</td>
<td>1</td>
<td>5</td>
<td>Internet-Email</td>
<td>37000</td>
<td>Low</td>
<td>50</td>
</tr>
<tr>
<td>Card 6</td>
<td>1</td>
<td>7</td>
<td>Internet-Email</td>
<td>29000</td>
<td>High</td>
<td>90</td>
</tr>
<tr>
<td>Card 7</td>
<td>6</td>
<td>7</td>
<td>Internet-Email</td>
<td>37000</td>
<td>High</td>
<td>50</td>
</tr>
<tr>
<td>Card 8</td>
<td>6</td>
<td>7</td>
<td>Navigation only</td>
<td>29000</td>
<td>Low</td>
<td>50</td>
</tr>
<tr>
<td>Card 9</td>
<td>6</td>
<td>5</td>
<td>Internet-Email</td>
<td>29000</td>
<td>High</td>
<td>90</td>
</tr>
<tr>
<td>Card 10</td>
<td>1</td>
<td>5</td>
<td>Navigation only</td>
<td>29000</td>
<td>Low</td>
<td>90</td>
</tr>
<tr>
<td>Card 11</td>
<td>6</td>
<td>5</td>
<td>Internet-Email</td>
<td>29000</td>
<td>Low</td>
<td>50</td>
</tr>
<tr>
<td>Card 12</td>
<td>1</td>
<td>5</td>
<td>Navigation only</td>
<td>37000</td>
<td>High</td>
<td>50</td>
</tr>
</tbody>
</table>

Figure 15 - Listing of Conjoint Product Cards with Product Attributes
Kano Test Design

Since a primary focus of this research project is on Mass Customization (or Build to Order), the effect of Delay on customer satisfaction is important to understand. For this reason, Delivery Delay was included in the attributes list in the conjoint product cards. To further understand the significance of this attribute, the following Kano questions could be posed:

<table>
<thead>
<tr>
<th>How satisfied would you be with your vehicle purchase if it was delivered within 1 week of your custom order?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Very Pleased</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How dissatisfied would you be with your vehicle purchase if it was delivered 5-6 weeks after your custom order?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

Figure 16 – Kano Question on Delay

The purpose of the question above then, is to determine the user’s satisfaction and associated dissatisfaction of having to wait for the delivery of their custom ordered vehicle. A rating of Neutral for having the vehicle delivered within 1 week of ordering and Unacceptable or Tolerate for having the vehicle delivered within 5-6 weeks of ordering would indicate a Basic requirement. A rating of Very Pleased for having the vehicle delivered within 1 week and a strong negative response for not having the vehicle delivered within that period, would point to the requirement being Revealed. Finally, a rating of Very Satisfied for having the vehicle delivered within 1 week and Neutral for having the vehicle delivered several weeks later would mean the need is a Surprise and Delight because it is unexpected. It should be pointed out that over time, needs tend to migrate from Surprise and Delight to Revealed then to Basic.
Delay/Price Trade-off Design

A final test was designed to assign an actual dollar amount to the cost associated with not immediately satisfying a custom order from a consumer. It is likely that this cost/attribute relationship will vary across products (some products such as computers become obsolete at such a rapid rate, that any delay may be viewed as too costly). It is equally likely that this relationship varies across products in different customer segments. In either case, a reasonable hypothesis is that customization gradually loses its added value proportionally to the length of the delivery delay period.

<table>
<thead>
<tr>
<th>Delay - Price Trade Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typically it takes 5-6 weeks to receive a custom ordered vehicle.</td>
</tr>
</tbody>
</table>

If you custom ordered your vehicle, how much more would you be willing to pay if the vehicle was delivered to you

4 weeks after ordering? $ 

Same day as your order? $ 

Figure 17 – Delay/Price Trade Off Question

Data Analysis

It is not necessarily obvious how this data, especially the preference data collected from the conjoint test, might be analyzed to help in understanding the question

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18 At the same time, the National Bicycle Industrial Company in Japan had to delay the delivery of its customized bicycles to its customers because their delivery was "too quick". Customers were more satisfied with the slower delivery product because their paradigms said that customized products can not be made in a couple of days.

19 GM has recently come out suggesting that their research indicates that more important to consumers than the length of the delivery delay is that the vehicle shows up on the date promised. This may be an indication of a credibility issue with consumers more than an actual difference in customer utility.
around what attributes and which levels to allow for and design in customization. In order to better frame this discussion, data was created to illustrate four distinct regions of interest. These regions are:

- High Mean Utility/Low Standard Deviation
- High Mean Utility/High Standard Deviation
- Low Mean Utility/Low Standard Deviation
- Low Mean Utility/High Standard Deviation

It is important for the reader to understand that this segmentation technique is only part of the overall picture as will be explained throughout this discussion.

Based on the previous discussion of 'Points of Common Uniqueness', a good starting point would be to assume that those attributes that have a high mean utility/high standard deviation would tend to be candidates requiring further investigation on cost and other competitive/strategic issues as outlined in previous chapters. While this is correct, it is not the only region of interest in trying to understand which features may support a Mass Customization strategy. The attributes falling into the low mean utility/high standard deviation should also be investigated for possible Mass Customization requirements. This is true because of data aggregation, which presents a simplified collective view of the data, also works to mask the necessary details that are useful for understanding the market's underlying fundamental requirements.

This subtlety is perhaps best explained with the aid of Figure 18, which depicts the distributions of data within each of the four previously discussed regions. (It should be noted that for the sake of argument normal or binominal distributions were assumed for the data.) The 1st Quadrant represents data whose mean utility is high which complies with our first requirement for establishing 'Points of
Common Uniqueness' that the attribute is something that the customer's care about. However the standard deviation is low which suggests that the population tested, largely agrees with what the attribute should be. This apparent consensus greatly reduces the advantages of implementing a Mass Customization strategy. Fundamentally, if everyone agrees with what a given attribute should be, there is very little incentive to provide anything else.

![Chart Depicting Mean Utilities vs. Standard Deviations for Various Populations](image)

Figure 18 – Chart Depicting Mean Utilities vs. Standard Deviations for Various Populations

The data represented in Quadrant 2 Has both a low mean utility and a low standard deviation. Therefore it is neither important to the customer nor does it represent significant conflict over the levels of the attribute in question. Quadrant 3 is a more interesting case. The mean utility is high - so we know this is an important attribute, also the standard deviation is high as well - so we know that the customer's do not agree with what level of the attribute should be offered. As mentioned earlier, this Quadrant is key to an organization's Mass Customization strategy. The data comprising this Quadrant could be shown by either a normal
distribution or a binominal distribution around two distinct means with low individual standard deviations. This implies that there are two very distinct market segments around the attribute in question. The 4th and final Quadrant contains data whose variance is high (indicating heterogeneous needs), but the mean utility is low suggesting that the population has little value for this attribute. This, however, may not be the case given the high divergence of customer utilities related to this attribute. It is possible that the population as a whole carries varying levels of low or negative utility with respect to a given attribute level. In this instance, there would be no reason to offer anything other than the least expensive default level attribute. Conversely, it is also possible that half of the population holds a high utility toward the attribute while the other half of the population holds a negative utility toward the same attribute. The aggregated result may look like a low value attribute, when in fact, it is exactly the type of attribute that an organization should consider for customization.

To better illustrate how this analysis might be done on actual data, the data in Appendix E was created. This data was manufactured using a random number generator in Microsoft Excel and is meant to be representative of a typical data set with the notable exception that it has been designed to encompass each of the 4 Quadrants mentioned above. Four of the seven attributes for the previously detailed conjoint test were chosen: # Of Passengers, Telematics, Cargo Capacity, and Ride Height. A high level summary of this data is in the following Table:

<table>
<thead>
<tr>
<th># Passengers - 7</th>
<th>Navigation</th>
<th>90 cu ft Cargo</th>
<th>High - Ride Height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H Mean/H Std. Dev.</td>
<td>Mean</td>
<td>H Mean/L Std. Dev.</td>
</tr>
<tr>
<td>Mean</td>
<td>3.5</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.35</td>
<td>0.3</td>
<td>0.05</td>
</tr>
<tr>
<td>Attribute Importance</td>
<td>43.8%</td>
<td>37.5%</td>
<td>6.3%</td>
</tr>
</tbody>
</table>

Figure 19 – Summary of Sample Data

This Table shows the mean values of each attribute's utility based on the population. As an example, the attribute level of # Of Passengers = 7 shows a
mean utility of 3.5 in relation to the default attribute level of 5 Passenger Seating. This means that as a population, the 7 Passenger Seating is strongly preferred to 5 Passenger Seating. Also shown is the Standard Deviation. A high standard deviation indicates that the population varies in how it values this attribute level. Finally, the attribute's importance is calculated from the attribute's utility score in relation to the other attributes in the test. Again, using the # Of Passengers, the attribute's importance is 43.8% compared to 37.5%, 12.5% and 6.3% for the other 3 attributes. This suggests that not only do customers prefer the benefits of 7 Passenger Seating over 5 Passenger Seating, but also that it is very important to them (or at least more important than the other three attributes). In fact, it is much more important to them than the 90 cu. ft Cargo Capacity, which they also prefer (43.8% vs. 6.3%). This would indicate that customer's would be more willing to pay for 7 Passenger Seating over 90 cu. ft Cargo Capacity. Another way to look at this is that they would be less likely to buy an offering that did not include 7 Passenger Seating even if included 90 cu. ft. Cargo Capacity. Let's take a closer look at the data and try to analyze it based on the previous discussions.

Charting the data in Appendix E for 7 Passenger Seating produces the following graph:
This graph clearly shows two distinct customer segments — those that strongly prefer the 7 Passenger Seating to the 5 Passenger Seating and those that prefer the 7 Passenger but at a lower utility value. Both segments, in this case, indicate a low preference for the 5 Passenger Seating which might indicate that there is no value to offering the 5 Passenger level at all. An interesting discussion involves how to price this feature for optimal profitability given that one segment has a much higher value as is therefore much more inclined to pay extra for the 7 Passenger level than the other segment. This discussion, however, is beyond the scope of this thesis, but will be touched upon towards the end of this chapter.

Using the same data chart in Appendix E but for Telematics – Navigation, yields the following graph:
This data clearly depicts a very homogeneous customer preference. Everyone, more or less, prefers the Navigation to the Internet/E-mail and the preference is rather strong. This data indicates that there is little need, in fact little benefit, to offering the Internet/E-Mail attribute level at all. And therefore one could easily conclude that there is no need to design in modularity or other customization friendly design capabilities into this feature that would allow for easy integration of either level at any point in the supply chain.

A word of caution is offered – especially when it comes to radically new features or existing features that may never have been applied to a given product before. Customers do not know what they do not know, or conversely, Customers only know what they know. Fundamentally customers have a very difficult time assessing their value for these types of features because they have either never used them before or never used them in a particular application and are therefore unfamiliar with the benefit these features might provide them. There are many popular examples of such products from overnight mail delivery, fax machines,
microwave ovens and even radios in cars. If you talked to the customers prior to the introduction of these products you would have gotten a very consistent message, "We do not want or need these products." Yet each one of them now is considered an essential or basic product. To better understand these types of products and to aid you in successfully introducing new products, the interested reader should research some of the work from Eric von Hippel related to Lead Users.20

Graphing the data from Appendix E related to Cargo Capacity generates to following chart:

![Normal Distribution of Preferences Representing Low Preference with Low Std Dev.](image)

Figure 22 - Graph of Sample Data for Normal Distribution Illustrating Low Mean with Low Std. Dev.

The information depicted in the previous graph represents an attribute with a low customer preference with strong homogeneity. The population as a whole does not value this attribute significantly and would be equally satisfied with either level.

20 A good start is Mr. Von Hippel's Harvard Business School case on the topic, Note on lead User Research, 9-699-014, October 16, 1998.
As in the previous example, the organization utilizing this information should likely proceed without consideration for Mass Customization around this attribute. The final offering to go with 50 cu. ft. Cargo Capacity - or 90 cu. ft. Cargo Capacity would have to be consider with respect to cost, competition and process capabilities. It is not any more obvious that the 90 cu. ft. Cargo Capacity would not be offered as the standard product than it is that the 50 cu. ft. Cargo Capacity would be.

The final data analysis example is again taken from the data in Appendix E and is shown below:

![Graph of Normal Distribution](image)

*Figure 23 - Graph of Sample Data for Normal Distribution Illustrating Low Mean with High Std. Dev.*

The chart depicting the data for Ride Height presents a more interesting case than that of the previous data set for a number of reasons. The overall customer preference in not very high and the population is not so neatly polarized as those of the previous examples that have been analyzed. Yet there is clear and significant customer heterogeneity regarding the value of this attribute that can be
seen by the large deviation of the data from the mean. This should be considered an important attribute for many of the customers and therefore an opportunity to capture customers outside of an organization's traditional customer base. In this instance, an organization would do well to consider implementing some of the Mass Customization techniques discussed in earlier chapters. The uniqueness of the data distribution for this attribute shows a varying preference throughout the population which may suggest that allowing for an adaptable design with a reasonable degree of variability in the range of the attribute (in this case – ride height), might serve best to satisfy the largest range of the population. This could entail having several set selections for ride height or allowing the customer to enter their own value from an essentially infinite selection and having the system adjust accordingly.

The examples presented in this discussion should enlighten the reader on why customer data is useful to the question of Mass Customization and illustrate one potential method to begin to analyze this data in order to make the most appropriate decisions regarding the actual implementation of Mass Customization. As stated before, there is usually no clear-cut answer to this question as several other organizational and competitive factors (including Price and Cost) must be considered to make the most appropriate decisions. It is certainly possible that attributes may be offered based on the customer requirements (divergent need) as the price for market participation rather than on profitability alone.

**Introduction to Defining the Ideal Stock Product**

There are four fundamental methods that can be employed to grow one’s existing business:

1. Steal customers from competitors
2. Cultivate new customers
3. Develop new uses for your product

4. Expand to foreign markets

Because mass customized products exactly match customer needs, it can be hypothesized that an increase in sales would be driven by customers who were not satisfied with the stock product but are satisfied with the unique made to order offering. The following analysis focuses only on the first two methods of market expansion (Stealing Customers from Competitors and Cultivating new Customers). Additionally, it presumes that customers can be categorized in one of four categories:

- Loyalists – these are customers whose surplus for the made to stock offering is positive. These customers will not switch to a competitive product because their utility is higher for the standard offering. (This loyalty might be associated with a given brand or individual offering.)

- Switchers – these are customers whose surplus for the made to order offering (mass customized) is greater than their surplus for the made to stock offering. These customers, while already loyal to the product, will switch from the standard stock offering to the customized offering. It should be noted that this might not be a desirable consequence unless the customized offering can generate a significantly higher price without equally significant cost penalties. This is principally due to the higher efforts required to support multiple unique product offerings and the potential cannibalization of the existing offerings.

- Converts - these are customers who would not consider the stock product, but will convert to the made to order offering because it has a higher utility

---

Surplus is defined as the reservation price (the price the customer is willing to pay) minus the actual price. A positive surplus then is an indication that the customer would purchase. A (+) surplus indicates that the price could be raised; a (-) surplus indicates that the price is too high for this customer, and a (0) surplus indicates that the price is perfect for this customer.
then any of the other standard or customized offerings provided by competitors.

- Detractors – these are customers who have a negative made to stock surplus, as well as, a negative made to order surplus such that they will not consider buying the standard product, let alone the customized offering. They may be loyal to a competitor or non-players in the product segment.\(^{22}\)

The following graph illustrates how these customers would map onto a Stock Surplus vs. Order Surplus graph, where the Stock Surplus is the surplus the customer realizes with the stock offering and the Order Surplus is the surplus the customer realizes with the customized offering.

\(^{22}\) This analysis was proposed by Cattyani, Dahan, and Schmidt, *Using a Dual Strategy of Make to Stock and Make to Order to Manage Demand Uncertainty*, Working Paper, 2001.
It is not necessarily evident that the best Make-To-Stock offering would simply be defined by the product offering providing the highest utility. One reason for this is that the strong preference of a minority customer segment could significantly influence the data representing the larger general population who might in fact have a weak preference and therefore an unwillingness to pay for a particular level of an attribute. A stock offering should try to appeal to the largest customer segment so as to minimize the amount of customization required by the operational side of the business. Additionally, it should do so in such a way as to maximize the derived profit. Needs based segmentation is perhaps one approach to addressing this issue by segmenting the population into similar groups who are likely to have similar purchasing behaviors. This can be accomplished using an individual's utility function based on their conjoint card ranking. A technique called Cluster Analysis then finds segments whose members are similar on several attribute dimensions. (A popular statistical software package from SAS called JUMP can prove invaluable to performing such a hierarchical-cluster analysis.) Once this information is compiled, one would have to understand the most profitable segment overall based on segment size and profit per product. This may or may not be the largest segment defined and has everything to do with how much the customer's in a given segment are willing to pay and how much it will cost the organization to provide the desired feature levels. This analysis is as significant as it is complex. The following equation begins to frame how this might be analyzed:

Maximize Profit

Where: Profit = S * MS (Price – VC) – FC
S = size of market (function of Price)
MS = size of market share (function of Price)
Price = Price of Offering
VC = Variable Cost to provide offering (function of S and MS)
FC = Fixed Cost to provide offering

Subject to: 0 < MS < 100%
S > = 0
Price > = 0
Profit Maximization Example

Analyzing the sample data shown in Appendix F can create an interesting exercise of this concept. This data set was developed from test results taken from approximately 30 MIT students utilizing many of the techniques discussed in this chapter. The preferences provided by the respondents were converted into dollar amounts to allow for a more straightforward analysis of profit maximization. The following table details the cost assumptions that were made in order to derive a profit picture for each attribute:

<table>
<thead>
<tr>
<th>Delivery (6 -&gt; 1 weeks)</th>
<th>Seats (5 -&gt; 7)</th>
<th>Email -&gt;</th>
<th>Ride Height (50 -&gt; 90)</th>
<th>Cargo (50 -&gt; 8 cu ft)</th>
<th>2/4 -&gt; AWD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute Cost</td>
<td>$500</td>
<td>$1,500</td>
<td>$1,500</td>
<td>$500</td>
<td>$2,000</td>
</tr>
</tbody>
</table>

Figure 25 - Profit Maximization Example Cost Assumptions

Examining the overall statistics of the data yields some rather interesting results. These statistics are shown in the following table:

<table>
<thead>
<tr>
<th>Delivery (6 -&gt; 1 weeks)</th>
<th>Seats (5 -&gt; 7)</th>
<th>Email -&gt;</th>
<th>Ride Height (5 -&gt; 8)</th>
<th>Cargo (50 -&gt; 8 cu ft)</th>
<th>2/4 -&gt; AWD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of Preferences</td>
<td>147,907</td>
<td>262,527</td>
<td>84,705</td>
<td>(38,329)</td>
<td>360,172</td>
</tr>
<tr>
<td>Mean of Preferences</td>
<td>5,100</td>
<td>9,053</td>
<td>2,921</td>
<td>(1,322)</td>
<td>12,420</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>10,787</td>
<td>14,245</td>
<td>14,196</td>
<td>12,477</td>
<td>15,216</td>
</tr>
<tr>
<td>Coefficient of Variance</td>
<td>2.12</td>
<td>1.57</td>
<td>4.86</td>
<td>9.44</td>
<td>1.23</td>
</tr>
<tr>
<td>Attribute Weight</td>
<td>14.75%</td>
<td>26.18%</td>
<td>8.45%</td>
<td>3.82%</td>
<td>35.92%</td>
</tr>
<tr>
<td>Attribute Ranking</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 26 - Attribute Statistics Including Importance Rankings
Several useful conclusions can be pulled from this information. For instance, the customer value-maximizing offering (without including pricing) would be: 1 week Delivery – 7 Passenger Seating – Navigation – 5 inch Ride Height – 90 cubic feet Cargo Capacity and All Wheel Drive with a total value for this data sample of $964,353; while the customer value-minimizing offering (without including pricing) would be: 6 weeks Delivery – 5 Passenger Seating – E-mail – 8 Inch Ride Height – 50 cubic feet Cargo Capacity and Selectable 2 Wheel/4Wheel Drive with a total value for this data sample of -$38,329. Another interesting observation shows that the overall customer preference of Ride Height favors the lower value of 5 inches over the higher value of 8 inches. This could easily lead a development team to design a product offering only capable of accommodating the low value of 5 inches. However, a quick look at the Coefficient of Variance (Standard Deviation/Mean) indicates that the spread on this attribute is very high with respect to the mean. Examining the data closer shows that in fact, there are a significant number of customers who would value the higher ride height. Along the same lines of analysis, 90 cubic feet Cargo Capacity has the highest customer value and the lowest Coefficient of Variance indicating that only the 90 cubic feet level should be offered. The actual data (Appendix F) confirms that none of the customers in this sample would prefer the 50 cubic feet capacity to the 90 cubic feet capacity.

The fundamental objective of most firms is to maximize profit. Therefore, it is a useful exercise to manipulate the data to better understand how to price each attribute level in order to achieve the highest total profit. In order to accomplish this task it is necessary to simplify the profit maximization equation presented earlier to the following:

Maximize Profit
Where: Profit = SUM_{i} (Price_{i} – Cost)
Subject To: Price_{i} \leq Customer Value_{i}
Price_{i} \geq Cost

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The constraints are necessary in that they recognize that a profit maximizing firm would not price below the actual cost as this would only erode profitability and that customers would not pay more than their value of the attribute as this would undermine their own desire to maximize their value equation. One can quickly see that optimizing across all 6 attributes simultaneously is an arduous, if not an impossible task. A more manageable approach is to investigate each attribute independently. This implies that a customer's willingness to pay for one attribute is not tied to their willingness to pay for another – a reasonable assumption. Fundamentally, this analysis boils down to the question of providing a product to a large number of people for a small profit per customer or providing the feature to a couple of people for a large profit per customer. Dissecting the data in this manner produces the following results:

<table>
<thead>
<tr>
<th>Delivery (6 &gt; 1 weeks)</th>
<th>Seats (5 -&gt; 7)</th>
<th>E-mail&gt;</th>
<th>Ride Height (5 &gt; 8 in)</th>
<th>Cargo (50 -&gt; 90 cu ft)</th>
<th>2/4 -&gt; AWD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Price</td>
<td>$23,852</td>
<td>$28,381</td>
<td>$28,195</td>
<td>$14,244</td>
<td>$15,918</td>
</tr>
<tr>
<td>Maximum Profit</td>
<td>$70,056</td>
<td>$107,523</td>
<td>$80,086</td>
<td>$68,722</td>
<td>$111,347</td>
</tr>
<tr>
<td>Number of Respondents</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Percentage of Respondents Choosing to Pay</td>
<td>10.3%</td>
<td>13.8%</td>
<td>10.3%</td>
<td>17.2%</td>
<td>27.6%</td>
</tr>
<tr>
<td>Percentage of Respondents Preferring</td>
<td>16.7%</td>
<td>21.1%</td>
<td>18.8%</td>
<td>41.7%</td>
<td>30.8%</td>
</tr>
</tbody>
</table>

Figure 27 – Optimal Attribute Pricing to Maximize Profit

Given the optimal prices that were determined, the attribute level of 90 cubic feet Cargo Capacity produces the highest overall profit. Additionally, it captures a higher share of the total respondents and equally important, it captures a higher share of the respondents who preferred this attribute level in the first place. On the other hand, the pricing for improving the delivery time from 6 weeks to 1 week captured only 10.3% of the total market and only 16.7% of those that preferred this
attribute. This could indicate that the price established does not support the overall market's value even though it resulted in the maximum profit based on the value pricing exercise.

This leads to some of the weaknesses in this analysis. Firstly, the accuracy of the customer values must be questioned. Certainly it is possible, but rather difficult to rationalize that any customer would be willing to pay $55,849 for the benefit of 2 additional seats or $68,480 for an added 40 cubic feet of cargo capacity, as the test data in Appendix F suggests. This analysis then becomes very susceptible to how accurately respondents capture their own price sensitivity. Another significant issue involves the overall number of respondents that chose anything other than the base level offering (this was determined by their own value given the established pricing). From this data set, only 13 of the 29 respondents would actually purchase any of the upgraded levels. The presumption that the remaining 66.7% of the respondents would simply buy the base offering may not be valid. Equally plausible is that they would choose to buy nothing at all or switch to a competitor.
Chapter 7

CONCLUSION

Summary
Implementing Mass Customization is not a trivial endeavor – especially from within a traditional mass production system. There are several questions that are key to defining an organization's implementation of Mass Customization.

1. Should Mass Customization be pursued by the organization?
2. If so, which attributes should be customizable?
3. How many levels should be offered for each attribute that is customizable?
4. What methods should be used for designing in Mass Customization?
5. Should a Stock product be made and if so, what should it be?
6. How should an organization price each level of an attribute in order to maximize profit?

This thesis has started to lay the groundwork for how some of these questions might be answered. Arguments and supporting evidence have been offered to help organizations convince themselves that established customer trends are racing towards more uniqueness and even greater choice - not less. Techniques were presented for using customer preference and selection data to point to attributes the organization should investigate for customization. It was additionally suggested that this information be reconciled with what the organization can effectively and efficiently provide. Understanding how many levels and which
levels to provide was addressed in the section on User Design. Allowing customers to essentially design their own product can illustrate what levels are most important, as well as, how many. These tools are most valuable when used in conjunction with conjoint analysis techniques discussed in the previous chapter. The method to be used to design a customizable offering was addressed in detail and varies whether the organization is customer focused or product focused (for instance - the customer focused collaborative view vs. the product focused modular view). It is suggested that true Mass Customization opportunities occur at the intersections of these perspectives. Modularity was discussed at some length as a principle method for designing in customization and providing for easy late point personalization (postponement) of a vehicle. Understanding the boundary and interface requirements for an effective modularity strategy was addressed with a proposal to make use of associative tools such as Design Structure Matrices (DSM) to guide the architectural decisions of the product design teams. A method was proposed to help define a potential stock product offering through needs based segmentation and a focus on capturing the largest profit generating segment of the population. Finally, the question of how to price each level of an attribute in order to maximize profit has not been addressed and will not be covered within the confines of this thesis. One can begin thinking about this in more detail, however, through the last example in the previous chapter and with the following discussion.

The fundamental idea behind a solid Mass Customization approach is to commonize where appropriate (economy of scale) and reuse modules across multiple product lines (economy of scope), while still meeting the specific heterogeneous needs of each customer. This, as well as, flexible manufacturing techniques that drive the EOQ (Economic Order Quantity) to zero can effectively reduce the fixed costs and variable costs of standardized components and reduce the fixed costs and variable costs of cross product components. Understanding these costs and how they relate to multiple level attribute offerings is a fairly
difficult analysis that must be performed uniquely based on each attribute and its levels on any particular product. In other words, not all attributes are created equal – nor do they cost the same. A reasonable hypothesis might be to conclude that offering 1 level of an attribute is always less expensive from both a variable cost and fixed cost perspective than offering 2 levels or even 3 levels. A graph of this might look as follows:

![Fixed and Variable Cost of Multiple Level Attributes](image)

Figure 28 – Hypothesis of Fixed and Variable Cost Relative to Multilevel Attributes

In this scenario, the cost of offering a singular level of A Only, B Only or C Only are the same and lower than the costs involved for offering multiple levels regardless of the combination. While this scenario is quite valid in the world of mass production, it holds little truth in the paradigm of Mass Customization. An illuminating example provided during an interview with the Executive Director of Engineering from one of the automotive OEMs illustrates this point with razor sharp clarity.

Over the course of the last year, several progressive automotive suppliers have recently begun to come forward with innovative products designed with Mass
Customization in mind for their OEM partners. One particular supplier has designed an instrument panel\textsuperscript{23} that can be used across multiple applications with only minor modifications to trim inserts and control face panels. The underlying structure is exactly the same and the trim/control interfaces are standardized so that any number of trim pieces and control interfaces can be swapped in and out of the instrument panel structure to effectively create an all new instrument panel (or IP). The benefits of this approach are numerous and cover many of the same costs that were identified in earlier chapters. Because the underlying structure is exactly the same, engineering costs are incurred only once, as are tooling costs, expensive testing and certification costs (the IP is a safety critical component and must adhere to stringent safety requirements), as well as process design costs and prove out. In fact, in this scenario, the more unique uses found for this IP, the lower the variable cost! (Quite simply, as volume goes up, variable costs come down as overhead burden and setups are spread across a larger number of pieces, and economies of scale drive down the cost of materials.) Additionally, because of the design, fixed costs remain fairly constant (it turns out that these trim pieces are relatively inexpensive to design and tool). This rather lucid example punctures the way we have traditionally understood manufacturing – the paradigm of mass production is shifting.

**Future for Mass Customization**

If the reader comes away with nothing more than this, they should understand that Mass Customization requires a mental shift from a view that perceives product variety and manufacturing flexibility as detriments to an organization’s ability to perform efficiently towards a view that understands that consumer driven customization is a tremendous opportunity that can provide a significant avenue to growth for those that learn to harness its power. Creating the ability to cost-effectively treat customers as individuals is an enormous competitive advantage.

\textsuperscript{23} 'Instrument Panel' in an industry term for the module containing the driver information gauges and controls. It is more commonly referred to as the 'dashboard'.

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The ‘new’ enterprise understands that Mass Customization is not about adding complexity. Rather it is about managing complexity in a customer-focused manner. Exploiting, where possible, an organization's inherent competencies.

Many companies in different industries have successfully implemented build-to-order/mass customization systems on various scales. These include Dell Computers, Mattel’s My Design Barbie and individually assembled investment portfolios with Charles Schwab. What these pioneers have demonstrated is that Mass Customized products can be produced at the same or lower cost than mass-produced offerings through reductions in inventory, obsolescence, working capital and quality defects, as well as, design and testing. Additionally, Mass Customization can lower marketing costs because the offering more closely matches the customer’s actual needs, which directly translates into a higher utility, and therefore creates a more satisfied consumer who is less likely to turn to a competitor or require incentives to purchase.

According to Joseph Pine, in order to effectively manufacture, market and distribute customized offerings involving decreased life cycles and shrinking individual product market share – companies must also invest in general purpose processes. These processes by definition are more flexible, more responsive, and easily reused across products and product families. This, in fact, represents a significant paradigm shift where companies are no longer defined by their products (i.e. GM is an automobile manufacture), but by their processes (i.e. Corning is a glass and ceramic process company). Though not discussed in this thesis, there are two other enablers that contribute to the effective implementation of Mass Customization:

1. Modular Process Design - allows flexibility to make adjustments to accommodate different process designs.
2. Agile Supply networks – provides the flexibility to quickly respond to varying customer demand through the supply network.

Both of these principles are clearly centered on product fulfillment.

At the end of the day, it is not expected that all industries can or should migrate to an all Mass Customization operation. Rather, it is more likely that an approach integrating elements of build to stock and build to order will be more sustainable. Particularly in industries where the cost of the capital resources employed by operations is high, such is the case in the automotive industry. A good bit of advice from Stan Davis (author of Future Perfect) "Be selective: Mass Customize as much as necessary and as little as possible."

**Future of User Design**
Understanding the wants and needs of customers is critical to an organization’s ability to produce successful products, yet customers are often unable to articulate their needs in a format that the design community can readily translate. User Design can help transfer this 'sticky' information. Additionally, it can also aid customers in discovering their own unmet needs by exploring and manipulating the available design space. This medium of connecting with consumers will only increase as technology continually presses forward and as consumers become more accustomed to this new found voice within the product design community.

**Proposed Next Steps for Future Study**
This thesis provides an open door to several areas of future research including:

- Studying User Manipulation to actually engage the customer fully in the design process by letting respondents design a cross over vehicle from scratch or design their own seating configurations.

- Additionally, the question relating to maximizing profit through pricing strategies remains largely unanswered.
## Complexity Reduction Actions and Their Effects

<table>
<thead>
<tr>
<th>Complexity Action</th>
<th>Plant Complexity</th>
<th>Engineering Complexity</th>
<th>Customer Viewpoint</th>
<th>Buildable Combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combine options or use Preferred Equipment Packages</td>
<td>Limited Effect. Reduced number of options in the system; all parts are still on site.</td>
<td>Limited to No Effect Engineering still required for same number of parts.</td>
<td>Reduced Choice</td>
<td>Significant Reduction</td>
</tr>
<tr>
<td>Eliminate Option</td>
<td>Reduced Complexity No longer need to stack, track, handle or install inventory.</td>
<td>Reduced Complexity Fewer Parts/Systems required to be engineered or tested</td>
<td>Reduced Choice</td>
<td>Significant Reduction</td>
</tr>
<tr>
<td>Make option LPO rather than RPO</td>
<td>No Effect Plant must still stock, track, and handle and install parts.</td>
<td>No Effect Engineering still required for same number of parts.</td>
<td>No Effect</td>
<td>Reduction LPOs are not counted in buildable combinations.</td>
</tr>
<tr>
<td>Standardize Option</td>
<td>Reduced Complexity No longer need to stack, track, handle or install inventory.</td>
<td>Reduced Complexity Fewer Parts/Systems required to be engineered or tested</td>
<td>Reduced Choice</td>
<td>Significant Reduction</td>
</tr>
<tr>
<td>Complexity Action</td>
<td>Plant Complexity</td>
<td>Engineering Complexity</td>
<td>Customer Viewpoint</td>
<td>Buildable Combinations</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------</td>
<td>------------------------</td>
<td>--------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Limit option availability by series (similar to Japanese manufactures)</td>
<td>No Effect Plant must still stock, track, and handle and install parts. Possibly improved Quality.</td>
<td>Limited to No Effect Engineering still required for same number of parts.</td>
<td>Reduced Choice</td>
<td>Significant Reduction</td>
</tr>
<tr>
<td>Postpone installation of the option to the dealership (similar to Japanese manufactures)</td>
<td>Reduced Complexity No longer need to stack, track, handle or install inventory.</td>
<td>Limited to No Effect Engineering still required for same number of parts if Ford maintains D&amp;R responsibility.</td>
<td>Immediate Delivery. Pricing may be affected. Quality may be affected.</td>
<td>Significant Reduction</td>
</tr>
<tr>
<td>Reduce interior/exterior color combinations</td>
<td>Limited to Moderate Effect Same number of parts in the same number of colors may still be required.</td>
<td>No Effect</td>
<td>Reduced Choice</td>
<td>No effect Color Combinations are not counted.</td>
</tr>
<tr>
<td>Reduce number of Interior Colors</td>
<td>Reduced Complexity Better than eliminating exterior colors or combinations</td>
<td>No Effect</td>
<td>Reduced Choice</td>
<td>No effect Color Combinations are not counted.</td>
</tr>
<tr>
<td>Complexity Action</td>
<td>Plant Complexity</td>
<td>Engineering Complexity</td>
<td>Customer Viewpoint</td>
<td>Buildable Combinations</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>---------------------------------------</td>
<td>------------------------</td>
<td>-----------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Limit interior color availability by series</td>
<td>No Effect</td>
<td>No Effect</td>
<td>Reduced Choice</td>
<td>No effect Color Combinations are not counted.</td>
</tr>
<tr>
<td></td>
<td>Plant must still stock, track, and handle and install parts – unless parts are not shared between series.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce number of Exterior Colors</td>
<td>Reduced Complexity</td>
<td>No Effect</td>
<td>Reduced Choice</td>
<td>No effect Color Combinations are not counted.</td>
</tr>
<tr>
<td></td>
<td>Depends on number of color keyed exterior parts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Karin Dean – Ford Motor Company
APPENDIX B

Sample Conjoint Cards with Textual Product Description
Card 0

Delivery
Seating
Telematics
Price
Ride Height
Cargo Volume
Drivetrain

Card 1

Delivery 6 wks after order
7 passenger seating
Internet-Email only
$37,000
Low Ride Height (like a car)
54 Cubic Feet Cargo Cap.
Front-wheel Drive

Card 2

Delivery 1 wk after order
5 passenger seating
Satellite Digital Radio only
$37,000
High Ride Height (like an SUV)
94 Cubic Feet Cargo Cap.
Front-wheel Drive

Card 3

Delivery 6 wks after order
7 passenger seating
Navigation only
$29,000
Low Ride Height (like a car)
54 Cubic Feet Cargo Cap.
Front-wheel Drive

Card 4

Delivery 1 wk after order
5 passenger seating
Navigation only
$29,000
Low Ride Height (like a car)
54 Cubic Feet Cargo Cap.
Rear-wheel drive w/ selectable 4-wheel drive

Card 5

Delivery 6 wks after order
7 passenger seating
Internet-Email only
$37,000
High Ride Height (like an SUV)
94 Cubic Feet Cargo Cap.
Rear-wheel drive w/ selectable 4-wheel drive
<table>
<thead>
<tr>
<th>Card 6</th>
<th>Card 7</th>
</tr>
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<tbody>
<tr>
<td><strong>Delivery</strong>: 6 wks after order</td>
<td><strong>Delivery</strong>: 6 wks after order</td>
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<tr>
<td><strong>7 passenger seating</strong></td>
<td><strong>5 passenger seating</strong></td>
</tr>
<tr>
<td><strong>Satellite Digital Radio only</strong></td>
<td><strong>Internet-Email only</strong></td>
</tr>
<tr>
<td><strong>$37,000</strong></td>
<td><strong>$37,000</strong></td>
</tr>
<tr>
<td>Low Ride Height (like a car)</td>
<td>Low Ride Height (like a car)</td>
</tr>
<tr>
<td><strong>54 Cubic Feet Cargo Cap.</strong></td>
<td><strong>54 Cubic Feet Cargo Cap.</strong></td>
</tr>
<tr>
<td>Rear-wheel drive w/ selectable 4-wheel drive</td>
<td>All-wheel drive (automatically distributes power)</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Card 9</th>
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<td><strong>Delivery</strong>: 1 wk after order</td>
</tr>
<tr>
<td><strong>7 passenger seating</strong></td>
<td><strong>7 passenger seating</strong></td>
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<td><strong>$37,000</strong></td>
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<tr>
<td>High Ride Height (like an SUV)</td>
<td>Low Ride Height (like a car)</td>
</tr>
<tr>
<td><strong>54 Cubic Feet Cargo Cap.</strong></td>
<td><strong>94 Cubic Feet Cargo Cap.</strong></td>
</tr>
<tr>
<td>All-wheel drive (automatically distributes power)</td>
<td>All-wheel drive (automatically distributes power)</td>
</tr>
</tbody>
</table>

<table>
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<tr>
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</thead>
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<td><strong>Delivery</strong>: 6 wks after order</td>
</tr>
<tr>
<td><strong>7 passenger seating</strong></td>
<td><strong>5 passenger seating</strong></td>
</tr>
<tr>
<td><strong>Satellite Digital Radio only</strong></td>
<td><strong>Navigation only</strong></td>
</tr>
<tr>
<td><strong>$29,000</strong></td>
<td><strong>$37,000</strong></td>
</tr>
<tr>
<td>Low Ride Height (like a car)</td>
<td>High Ride Height (like an SUV)</td>
</tr>
<tr>
<td><strong>94 Cubic Feet Cargo Cap.</strong></td>
<td><strong>54 Cubic Feet Cargo Cap.</strong></td>
</tr>
<tr>
<td>Front-wheel drive</td>
<td>Front-wheel drive</td>
</tr>
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</table>
Card 12
Delivery 1 wk after order
7 passenger seating
Internet-Email only
$37,000
Low Ride Height (like a car)
54 Cubic Feet Cargo Cap.
Front-wheel drive

Card 13
Delivery 6 wks after order
7 passenger seating
Navigation only
$37,000
Low Ride Height (like a car)
94 Cubic Feet Cargo Cap.
Rear-wheel drive w/ selectable 4-wheel drive

Card 14
Delivery 1 wk after order
7 passenger seating
Internet-Email only
$29,000
High Ride Height (like an SUV)
54 Cubic Feet Cargo Cap.
Rear-wheel drive w/ selectable 4-wheel drive

Card 15
Delivery 6 wks after order
5 passenger seating
Satellite Digital Radio only
$37,000
Low Ride Height (like a car)
54 Cubic Feet Cargo Cap.
Rear-wheel drive w/ selectable 4-wheel drive

Card 16
Delivery 1 wk after order
7 passenger seating
Satellite Digital Radio only
$37,000
Low Ride Height (like a car)
54 Cubic Feet Cargo Cap.
All-wheel drive (automatically distributes power)

Card 17
Delivery 6 wks after order
7 passenger seating
Navigation only
$37,000
High Ride Height (like an SUV)
54 Cubic Feet Cargo Cap.
All-wheel drive (automatically distributes power)
Card 18
Delivery 6 wks after order
5 passenger seating
Internet-Email only
$29,000
Low Ride Height (like a car)
94 Cubic Feet Cargo Cap.
All-wheel drive
(automatically distributes power)
APPENDIX C

Sample Conjoint Cards with Graphical Product Description

Legend

Cargo Capacity

90 cu ft.  50 cu ft.

Ride Height

H
High  (SUVlike)  Low  (carlike)

Drivetrain

All Wheel Drive
Rear wheel w/ 4WD
Front Wheel Drive

Delivery Delay

1 Week
1-Week Delay

6 Weeks
6-Week Delay

Telematics

Satellite Digital Radio
Navigation
Internet / E-mail

Seating Capacity

5 Pass. Seating

7 Pass. Seating

Price

$37,000

$29,000
Alpha Prototype Conjoint Cards with Graphical Product Descriptions -
Created by Limor Weisburg

1 Week Deliv. $29,000
6 Week Deliv. $29,000

Internet/Email
High (SUV)
All Wheel Dr (auto)

7 Seats
Large Cargo
(90 cu. ft.)

1 Week Deliv. $37,000
6 Week Deliv. $37,000

Navigation
High (SUV)
2/4 Wheel Dr (manual)

5 Seats
Medium Cargo
(50 cu. ft.)

1 Week Deliv. $37,000
1 Week Deliv. $29,000

Internet/Email
Low (Car)
All Wheel Dr (auto)

5 Seats
Medium Cargo
(50 cu. ft.)

Navigation
High (SUV)
2/4 Wheel Dr (manual)
1 Week Deliv. $37,000
7 Seats
Large Cargo (90 cu. ft.)
Internet/Email
Low (Car)
2/4 Wheel Dr (manual)

6 Week Deliv. $37,000
7 Seats
Medium Cargo (50 cu. ft.)
Internet/Email
High (SUV)
All Wheel Dr (auto)

6 Week Deliv. $29,000
5 Seats
Large Cargo (90 cu. ft.)
Internet/Email
High (SUV)
2/4 Wheel Dr (manual)

6 Week Deliv. $37,000
5 Seats
Large Cargo (90 cu. ft.)
Internet/Email
High (SUV)
All Wheel Dr (auto)

1 Week Deliv. $29,000
5 Seats
Navigation
Large Cargo (90 cu. ft.)
Low (Car)
All Wheel Dr (auto)

6 Week Deliv. $29,000
7 Seats
Medium Cargo (50 cu. ft.)
Navigation
Low (Car)
All Wheel Dr (auto)
### Data Tables for Customer Importance and Hetero/Homogeneity

<table>
<thead>
<tr>
<th># Passengers - 7</th>
<th>Navigation</th>
<th>80 cu ft Cargo</th>
<th>High - Ride Height</th>
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<tbody>
<tr>
<td></td>
<td>H Mean/H Std. Dev.</td>
<td>H Mean/L Std. Dev.</td>
<td>L Mean/L Std. Dev.</td>
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<tr>
<td></td>
<td>Mean 3.5</td>
<td>3</td>
<td>0.5</td>
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<tr>
<td></td>
<td>Standard Deviation 0.35</td>
<td>0.3</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Attribute importance 43.8%</td>
<td>37.5%</td>
<td>0.3</td>
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</table>

- 1. 5.2118808 3.569576514 0.507956628 -3.360544518
- 2. 4.91237865 3.11862155 0.525003715 -3.000533095
- 3. 5.044638568 3.10628999 0.47832085 -2.646210749
- 4. 4.95591647 2.796332986 0.57440307 1.483383838
- 5. 4.224526154 2.759606591 0.49748836 1.76552341
- 6. 4.65329483 3.137255711 0.463810296 -1.82930614
- 7. 5.60801254 3.60491075 0.529555286 -1.634533303
- 8. 5.109359917 2.79624643 0.51881224 1.564042916
- 9. 5.19036041 3.173867875 0.512959309 -1.564042916
- 10. 4.751781843 2.75091586 0.462124491 -1.529286576
- 11. 4.36404681 2.86646412 0.42386014 1.448641681
- 12. 5.79646518 3.18908361 0.490189622 -1.329061317
- 13. 5.23687603 3.13596814 0.52855819 -1.214733286
- 14. 4.88287553 2.88221441 0.46303018 1.205997589
- 15. 5.25355348 2.68316584 0.4976859 1.173956001
- 16. 4.23460672 3.57041143 0.53816488 1.02451575
- 17. 5.74205328 2.80132933 0.519016852 -1.009149443
- 18. 4.04956204 2.893388917 0.503684818 -0.940511538
- 19. 4.78556249 3.55218785 0.470486262 -0.819860788
- 20. 6.71363353 2.991381401 0.50841312 -0.869934538
- 21. 4.964072117 2.46991049 0.50101807 0.689448264
- 22. 5.019059411 2.60758562 0.302288717 -0.819860788
- 23. 3.663261067 3.18351443 0.503512241 -0.819860788
- 24. 4.74365835 2.72732762 0.486037494 -0.641615199
- 25. 5.30036773 3.516371074 0.439569534 -0.629218787
- 26. 5.842355803 3.060618049 0.622470282 -0.607224358
- 27. 5.64608912 2.86510988 0.537251652 -0.548251021
- 28. 4.772513775 2.84960971 0.60805491 -0.538156533
- 29. 4.697273552 3.129453269 0.539920337 -0.519711077
- 30. 4.638966452 3.010616532 0.49862542 -0.493094715
- 31. 4.239944373 2.74490624 0.597383699 -0.399382463
- 32. 5.020679636 2.66719085 0.484811881 -0.357082222
- 33. 5.064273979 3.35986925 0.457506899 -0.291100486
- 34. 3.90458524 3.43685504 0.497445741 -0.180842339
- 35. 5.670380587 3.0450456 0.488402059 -0.080945698
- 36. 5.66631757 3.465360699 0.548561787 -0.049345428
- 37. 4.51713347 3.150320359 0.54384303 0.006642484
- 38. 4.56521264 2.54382065 0.584784955 0.031801963
- 39. 5.029717739 3.06386964 0.475863833 0.193232725
- 40. 4.852282411 2.474296146 0.475958303 0.261813173
- 41. 5.013637035 2.9537464 0.453676748 0.286775056
- 42. 5.243814497 2.29934421 0.457325144 0.359000066
- 43. 5.80816798 2.8451673 0.4634814 0.374840627
- 44. 5.74608748 3.58522164 0.514208433 0.393930281
- 45. 5.40638294 2.57616546 0.4747361 0.428214643
- 46. 5.12578946 3.07031439 0.45921621 0.502667967
- 47. 4.678659022 3.02019309 0.50826912 0.521094196
- 48. 5.03283735 3.43373059 0.53820309 0.69055807
- 49. 5.71926807 3.17596186 0.49068433 0.696265013
- 50. 4.3623484 2.407695213 0.523504656 0.763758751

**APPENDIX E**
<table>
<thead>
<tr>
<th># Passengers - 7</th>
<th>Navigation</th>
<th>90 cu ft Cargo</th>
<th>High - Ride Height</th>
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### APPENDIX F

**Data Table for Conjoint Analysis Test Results with Pricing Translation**

<table>
<thead>
<tr>
<th>Delivery (6 -&gt; 1 weeks)</th>
<th>Seats (5 -&gt; 7)</th>
<th>Email -&gt;</th>
<th>Cargo (50 -&gt; 90 cu ft)</th>
<th>Ride (5 -&gt; 8)</th>
<th>2/4 -&gt; AWD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondent 1</td>
<td>0</td>
<td>13,465</td>
<td>(7,155)</td>
<td>3,155</td>
<td>7,576</td>
</tr>
<tr>
<td>Respondent 2</td>
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<td>1,869</td>
<td>1,420</td>
<td>15,028</td>
<td>2,585</td>
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<tr>
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<td>4,000</td>
<td>0</td>
<td>3,184</td>
<td>372</td>
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<td>Respondent 5</td>
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<td>37,994</td>
<td>(3,665)</td>
<td>(1,833)</td>
<td>18,988</td>
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<td>Respondent 6</td>
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<td>0</td>
<td>(4,203)</td>
<td>(7,998)</td>
<td>19,782</td>
</tr>
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<td>Respondent 7</td>
<td>23,852</td>
<td>55,849</td>
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<td>(77)</td>
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<td>(122)</td>
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<td>(754)</td>
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<td>13,641</td>
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<td>(802)</td>
<td>(371)</td>
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<td>4,311</td>
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BIBLIOGRAPHY


