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Implementation of a mass customization strategy

Requirements to product and process design

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Management summary

This paper is a descriptive literature research to investigate the requirements to product and process design related to the implementation of a mass customization strategy. Mass customization is a strategy that makes it possible for a firm to customize products to individual customer requirements and producing those with the standards of mass production. Feitzinger and Lee (1997) pointed out that the critical point of implementing a mass customization strategy is in designing the products and processes.

The findings of this research are that mass customization requires *modular product design*. With modularity companies are able to provide more variety, economies of scope, low cost production and decrease their order lead times. Therefore, Duray, Ward, Milligan and Berry (2000) stated that "the successful implementation of mass customization is enhanced by the effective use of modular product designs". Another effect of modularity is the standardization of modules. The extra benefits of standardization are that products can be produced at a constant quality and it lowers the complexity of product development.

Related to the process design of a mass customization strategy, firms should implement a *leagile* process design. The effect of the order decoupling point is important for the design of the processes. Through leagile process design a company makes it possible to produce standard product modules in a mass production way, while after the order decoupling point the product can be specified to the specific customer requirements. According to Partranen and Haapasalo (2004) the fundamental belief behind mass customization and modularization is that the order penetration point is delayed as late as possible. This can be realized through the process of postponement.

Specific for process design can be concluded that the focus must be on designing flexible processes to achieve customization. Efficiency will be provided through the production of modular components. Finally, Feitzinger and Lee (1997) determined in their practical investigating that it is possible for companies to deliver customized products quickly and at a low cost if they follow their organizational design principles. These principles consists of modular product design, flexible process design and the design of the supply network to provide efficiency and responsiveness.

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Chapter 1: Introduction

1.1 Problem indication

Markets have moved from a business environment where the supplier held the power to a situation where the customer is in charge. This situation forces organizations to be more flexible to changing customer requirements (Christopher, 2005). Related to this development concepts like agile manufacturing, focused factories, customer relationship management and mass customization have enjoyed increasing attention in the literature during the last decade (Piller, Moeslein and Stotko, 2004). These new concepts of industrial value creation share a common objective; to provide ways of enabling companies to increase cost efficiency while simultaneously increasing the ability to react to changing customers' needs. For companies it becomes more and more important to develop customer value into their products. Therefore companies should listen more carefully to their customers (Fournier, Dobscha and Mick, 1998).

This study will focus on the strategy of mass customization. Mass customization is becoming an important topic in industry and academia (Tseng and Jiao, 1998). Despite of the increased attention mass customization has received in the literature; it is still a novel concept lacking more extensive development (Silveira, Borenstein and Fogliatto, 2001). This statement is confirmed by Duray, Ward, Milligan and Berry (2000) by saying that mass customization is known to exist in practice, but academic research has not adequately investigated this new form of competition. In the literature is little contention on theoretical aspects such as the mass customization concept, objectives and justification, the debate over more specific and often practical questions remains somewhat inconclusive (Silveira et al., 2001). Also McCarthy (2004) states that there is a relative shortage of research on how to design and operate a manufacturing system capable of mass customizing.

According to Silveira et al. (2001) the implementation part of mass customization is in the literature still at a starting point. The problem of how to implement and operate new manufacturing strategies like mass customization is a recurring and important theme in operations management (McCarthy, 2004). Despite of this importance, the adoption rate of mass customization in practice is low. The reason for this is the need for significant change to existing business models (Broekhuizen and Alsem, 2002). For achieving a mass customization strategy standardized methods and modularized product structure must be utilized. This requires changes inside of the company (Partanen and Haapasalo, 2004). The problem of the implementation part is not about understanding what constitutes the strategy, but determining how to design and transform an organizational system from its current form into one capable of achieving its new goals. This is certainly the case for mass customization

(Skinner, 1996). More specific, the critical point of implementing a mass customization strategy is in designing the products and processes (Feitzinger and Lee, 1997).

1.2 Problem statement

From the problem indication, the following problem statement is formulated:

- *What are the requirements to product and process design related to the implementation of a mass customization strategy?*

1.3 Research questions

The problem statement will be divided in the following research questions:

1. What are the levels of mass customization?

The first research question will give an insight in the definition and levels of mass customization. It is important to have a clear definition about the concept mass customization to avoid confusion and misunderstanding. Furthermore the different levels of mass customization will be described because the level of mass customization is an important indicator for the degree of customization.

2. What are the requirements of mass customization to product design?

For answering research question two, the requirements to product design will be investigated. In the problem indication the importance of product design is described in order to successfully implement a mass customization strategy.

3. What are the requirements of mass customization to process design?

Research question three, will focus on the requirements to process design. The aim of this question is the same as for question two. In the problem indication the importance of process design is described in order to successfully implement a mass customization strategy.

4. How is product and process design related to the implementation of a mass customization strategy?

The last research question will combine research question two and three. A practical investigation will be analyzed to examine the requirements of the mass customization concept.

1.4 Relevance

The academic relevance of this study is that in the literature the implementation part of a mass customization strategy is still incipient and there is a need for more specific and practical approaches related to mass customization (Silveira et al. 2001). Also Piller et al. (2004) argued that empirical research in the field of mass customization is dominated by very broad approaches. Feitzinger and Lee (1997) pointed out that the critical point of implementing a mass customization strategy is in designing the products and processes. The aim of this study is to go more in detail about the requirements to product and process design to get a more detailed view about what is necessary to implement a mass customization strategy.

The practical relevance of this paper is best explained by Feitzinger and Lee (1997). They refer to the fact that mass customization will be a success if "firms rethink and integrate the designs of their products, the processes used to make and deliver those products, and the configuration of the entire supply network. By adopting such a comprehensive approach, firms can operate at maximum efficiency and quickly meet customers' orders with a minimum amount of inventory". From this statement can also be concluded that product and process design are important factors to make the implementation of mass customization a success. Piller et al. (2004) noticed that the concept of mass customization has been described in the literature for decades, however the increased implementation of mass customization principles can only be found in the last few years. This could be a reason that the adoption rate of mass customization in practice is low (Broekhuizen and Alsem, 2002). To get more insight in the requirements to product and process design, strategic or logistics and operations management can improve their knowledge concerning the implementation of mass customization. More specific related to product design, Ulrich (1995) argued that "the architecture of the product can be a key driver of the performance of the manufacturing firm, that firms have substantial latitude in choosing a product architecture, and that the design of the product is therefore important in managerial decision making".

1.5 Research design and data collection

For carrying out this study, a descriptive literature review will be used to identify the requirements to product and process design related to the implementation of a mass customization strategy. According to Sekaran and Bougie (2010) "this type of research is undertaken in order to establish and be able to describe the characteristics of the variables of interest in a situation". They also pointed

out the purpose of a descriptive study, which is to describe the relevant aspects of the phenomenon of interest from an individual, organizational, industry-oriented, or other perspective.

The main goal of this research is to investigate what the product and process requirements are for implementing a mass customization strategy. This will be worked out with collecting empirical and theoretical data available from secondary sources.

For collecting secondary data, search engines like: JSTOR, Science Direct, ABI/INFORM, Catalogue Tilburg University and Google Scholar have been used. To find useful articles, among others the following main key words were used:

- Mass customization.
- Product design;
    - Modularity.
- Process design;
    - Agile.
    - Lean.
    - Postponement.

1.6 Structure of the thesis

The first chapter of this paper describes the problem indication, problem statement and the academic and managerial relevance. Chapter one will end with describing the research design and data collection. Chapter two will give an overview of the definitions of mass customization and describe the different levels of mass customization. Chapter three is related to product design and will discuss the requirements to product design in order to implement a mass customization strategy. The same will be done in chapter four, only in this chapter the requirements to process design will be described. Chapter five combines the requirements to product and process design by analyzing a practical investigation related to these requirements. Finally in chapter six the overall conclusions, discussion and recommendations will be presented.

Chapter 2: Mass customization

2.1 Introduction

The strategy of mass customization has emerged in the late 1980s and can be seen as a logical development to processes that have become increasingly flexible and optimized regarding quality and costs. In addition, mass customization makes it possible to differentiate companies in a highly competitive and segmented market (Silveira, Borenstein and Fogliatto, 2001). This chapter will give an overview of the definitions and levels of mass customization.

2.2 Definition of mass customization

Duray, Ward, Milligan and Berry (2000) stated that "the practice of mass customization does not fit with the conventional paradigm of the manufacturing management". In the past, production companies chose processes that supported the production of either customized produced products or standardized mass produced products. This means that customized products with high variety and a high degree of customer involvement are made using low volume production processes. This is the opposite with mass production processes for making standardized products where the focus is on efficiency and scale economies. In contrast to this traditional paradigm, mass customization has appeared.

The definition of mass customization was first described by Davis (1987) in his book *Future Perfect*. Davis described mass customization as "the ability to provide individually designed products and services to every customer through high process agility, flexibility and integration without sacrificing scale economies". This definition is confirmed by Kotha (1995) who described mass customization as a system by which companies apply technology and management methods to provide product variety and customization through flexibility and quick responsiveness. In addition to Davis and Kotha, Broekhuizen and Alsem (2002) defined mass customization as the ability to provide customized products and services to individual customers using technology at optimal production efficiency and cost levels.

Silveira et al., (2001) stated that "in any case, mass customization is seen as a systematic idea involving all aspects of product sale, development, production, and delivery, full-circle from the customer option up to receiving the finished product.

The development of a mass customization strategy is based on three main changes (Silveira et al., 2001):

1. New flexible manufacturing and information technologies enable production systems to deliver higher variety at lower costs;
2. Increasing demand for product variety and customization;
3. Shortening product life cycles and expanding industrial competition.

These three aspects have lead to the breakdown of many mass industries and the increasing need for production strategies focused on individual customers. This breakdown has lead to several levels of mass customization that can be adopted in practice (Silveira et al., 2001).

2.3 Levels of mass customization

There are many ways to achieve mass customization (Broekhuizen and Alsem, 2002). Each level of mass customization can be categorized by:

- *The degree of organizational transformation that is required:* this refers to the initial point in the manufacturing process where customers can alter their products, also known as the point of customer involvement or decoupling point (Duray et al., 2000, Lampel and Mintzberg, 1996).
- *The mass customization approach*: this is related to the nature of the customization.

The initial point of customer involvement relates to the internal transformation required and the mass customization approaches are related to *how* customer value can be created. First the degree of organizational transformation that is required will be described.

Lampel and Mintzberg (1996) developed the idea that the level of customer involvement in the production cycle can play a critical role in determining the degree of customization. Also McCutcheon, Raturi and Meredith (1994) argued that the production stage where a product is differentiated is a key variable in process choice decisions. This means that the point of customer involvement in specifying the product is related to choices about the customization process (Duray et al., 2000). Duray et al. stated that “the point of customer involvement is a key indicator of the degree or type of customization provided”.

For defining the level of mass customization, the four points in the production cycle are important. These four points are: *design*, *fabrication*, *assembly* and *use*. The earlier customers are involved in

the production cycle, the higher products could be customized. If the point of customer involvement is at the assembly or use stages, the degree of customization will be not that great. This reasoning by Duray et al. is supported by the typology of Lampel and Mintzberg (1996). Lampel and Mintzberg view customization as taking one of three forms:

1. *Pure*: customers are involved in the entire production cycle, from design through fabrication, assembly and delivery and it provides a highly customized product.
2. *Tailored*: the customer enters the production cycle at the point of fabrication where standard products are modified.
3. *Standardized*: the customer enters the assembly and delivery processes through selection of the desired features form a list of standard options.

The initial point of customer involvement relates to the internal transformation required. For answering the question *how* customer value can be created, Broekhuizen and Alsem (2002) identified four approaches that can be used to customize the products. These four approaches are:

1. *Collaborative*: designers dialogue with customers on product and packaging.
2. *Transparent*: products are adapted to individual needs.
3. *Cosmetic*: standard products are packaged specially for each customer.
4. *Adaptive*: standard products can be altered by customers during use.

In table 2.1 the above described typologies of mass customization are combined.

Level of mass customization	Type of mass customization	Approaches of mass customization
Design	Pure	Collaborative, Transparent
Fabrication	Tailored	Collaborative, Transparent
Assembly	Standardized	Collaborative, Transparent
Use	Standardized	Adaptive

Table 2.1 – Source: Lampel and Mintzberg (1996) and Broekhuizen and Alsem (2004).

The cosmetic approach can be placed between the assembly and use level. Broekhuizen and Alsem (2004) described this level as *additional services*.

2.4 Conclusion

It can be concluded that the point of customer involvement plays an important role in determining the level of mass customization. The categorization of Lampel and Mintzberg (1996) shows that the

type of customization implies different levels of customer involvement in product design and different points at which that involvement begins. These different types of customization also define the degree of customization. Pure customization provides the highest degree of customization with all of the products designed specifically for the customer. Standard customization includes the lowest degree of customization with only an arrangement of components for determining the customized configuration (Duray et al., 2000).

Chapter 3: Requirements to product design

3.1 Introduction

Product design is one of the critical points in developing a mass customization strategy (Feitzinger and Lee, 1997). The aim of this chapter is to investigate the requirements to product design in order to achieve mass customization. According to Duray, Ward, Milligan and Berry (2000) mass customization requires that unique products must be provided in a cost-effective way by achieving volume-related economies. They suggest that *modularity* is the key to achieve customization at or near mass production costs. Also Piller, Moeslein and Stotko (2004) argued that mass customization is only possible due to the capabilities of flexible manufacturing systems and *modular product structures*. Therefore, this chapter will focus on *modular product design*. The role of flexible manufacturing systems will be investigated in chapter four.

3.2 Modular product design

van Hoek, Commandeur and Vos (1998) defined some methods for achieving mass customization. Two of these methods are related to product design. Firstly, a company must create products that are customizable by customers and secondly, companies must design modularize components to customize end-products. To investigate the aspects of modular product design it is important to know more about the boundaries of mass customization. These boundaries can be more clearly established by delineating two issues (Duray et al., 2000):

1. *The basic nature of customization*: this part is related to the distinction between customization and variety. Ulrich (1995) argued that product variety has emerged as an important element of manufacturing competitiveness. He added that variety is only meaningful to customers if the functionality of the product varies in some way.

   Durey et al. (2000) pointed out that variety provides choice for customers, but not the ability to specify the product. To improve variety a company must design their products specifically to meet the needs of a customer. He described further that customization and variety are distinct. This distinction is important because it implies that customers must be involved in specifying the product.
2. *Achieving customization at or near mass production costs*: this part addresses the *mass* in mass customization. Pine (1993) argues that for developing and manufacturing unique products in a mass production way, modularity is a key to achieve mass customization. Through modularity a part of the product can be made in volume as standard modules, while

product distinctiveness will be achieved through the combination or modification of modules. Duray et al. (2000) concluded that modularity can be viewed as the critical aspect of gaining scale in mass customization.

Pine (1993) argued that mass customization requires product modularity. Through utilizing modularity a firm can also provide variety and speed (McCutcheon, Raturi and Meredith, 1994). This is confirmed by Ulrich (1995) who stated that "modularity can provide an increase in product variety, shorten delivery lead times and economies of scope". Durey et al. (2000) concluded in their research that "the literature suggests that modularity can facilitate an increasing number of product features available while also decreasing costs. Therefore, it follows that the successful implementation of mass customization is enhanced by effective use of modular product designs". This statement is confirmed by Feitzinger and Lee (1997) by arguing that to achieve an effective mass customization program, "a product should be designed so it consists of independent modules that can be assembled into different forms of the product easily and inexpensively".

3.2.1 Types of product modularity

Pine (1993) described different types of modularity. These types of modularity are presented in figure 3.1 on the next page. From this figure can be seen that six different types of modularity can be determined. These six types are declared by Pine:

1. *Component sharing modularity*: the same component is used across multiple products to provide economies of scope. Durey et al. (2000) defined this type of modularity as products that are uniquely designed around a base unit of common components.
2. *Component swapping modularity*: this type of modularity is a complement of component sharing modularity. With component swapping modularity the different components are paired with the same basic product in order to create as many products as there are components to swap.
3. *Cut-to-fit modularity*: this type is similar to the previous two types, except that in cut-to-fit modularity one or more of the components is always variable within planned or practical limits such as length, width, or height.

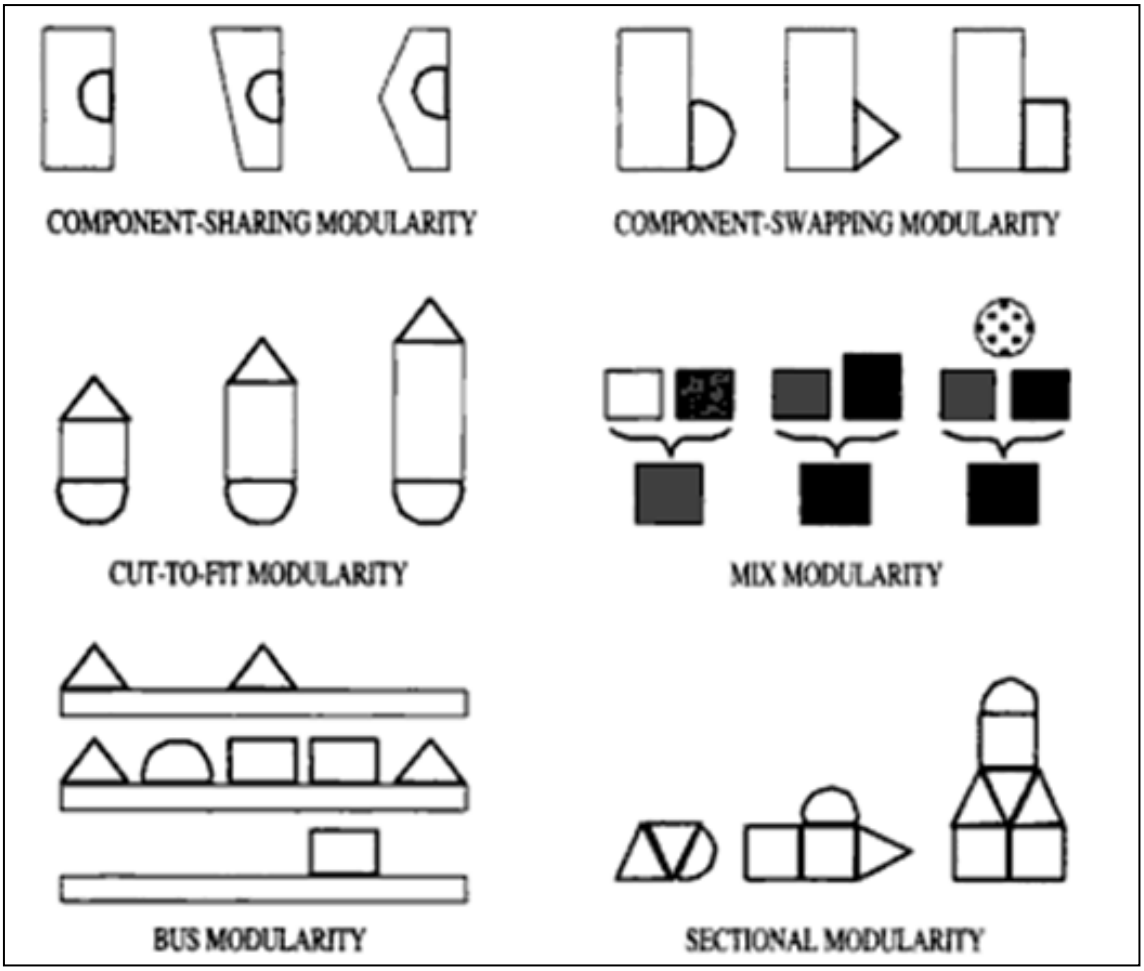

Figure 3.1 – Source: Pine (1993).

4. *Mix modularity*: this type of modularity can use any of the above types, with the clear distinction that the components are so mixed together that the end product become something different.
5. *Bus modularity*: this type of modularity uses a standard structure that can attach one or more different kinds of modules.
6. *Sectional modularity*: the structure or architecture of the product itself can change, providing a lot of possibilities for variety and customization.

These different types of modularity can be combined with the different stages of the production cycle. Duray et al. (2000) integrated these two aspects in a framework. Also the point of customer involvement is added to the framework, which gives an indication of the degree of customization. This framework is presented in figure 3.2 on the next page.

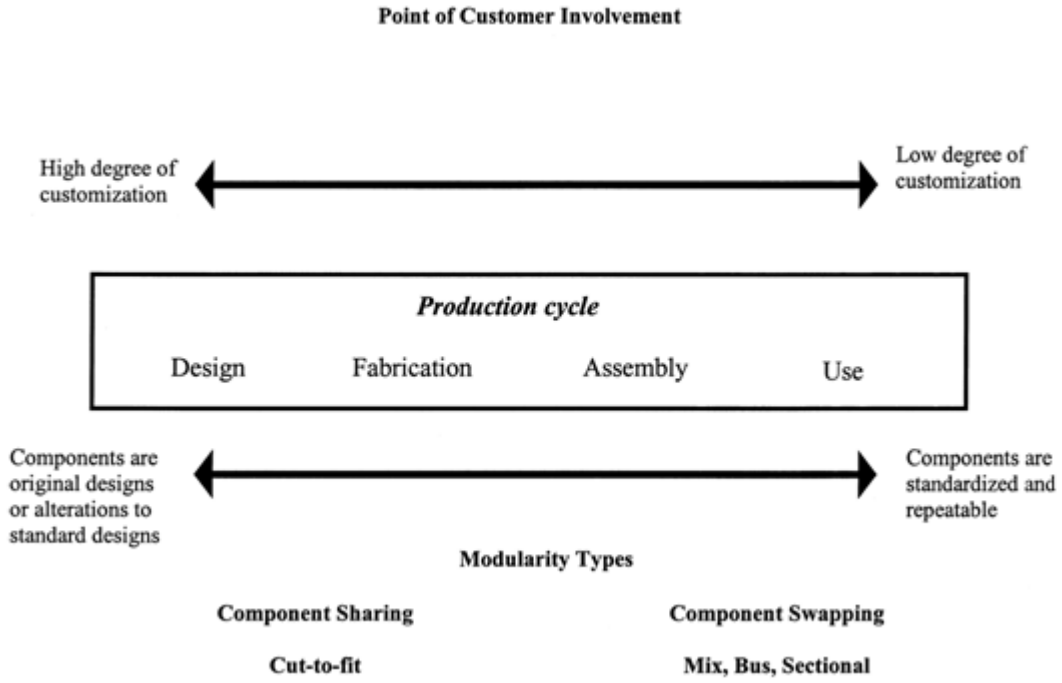

Figure 3.2 – Source: Duray, Ward, Milligan and Berry (2000).

If the customer is involved during the early stages in the production cycle, the degree of customization is high. In the design and fabrication stages modules can be altered or components can be fabricated to provide the unique requirements of the customer (Duray et al., 2000). Modularity types like *component sharing* and *cut-to-fit* must take place during the design and fabrication stages because these modules are newly designed or changed.

If the point of customer involvement is in the assembly or use stages, modules can only be arranged or combined according to customer specification. Components cannot be manufactured or modules cannot be transformed. In this situation modularity types like *component swapping* or *mix*, *bus* and *sectional* are suitable. These modularity types use standard modules without modification. These types of modules can only be combined for providing an end-product that satisfies the customer needs.

During the design of the products customer involvement and modularity are important factors for achieving mass customization. Customer involvement provides the customization while modularity restricts the range of choice to decrease the variety of components (Duray et al., 2000). Durey et al. stated further that "if modularity is integrated in mass customized products, product distinctiveness is a result of either the combination of standard modules into a finite number of permutations or the alteration of prescribed modules into a limited range of products". This is in contrast with purely customized products. Modularity bounds the degree of customization of the product and separates

mass customization from pure customized products. Also the fact that modules are standardized makes it possible to produce mass customized products at low costs and consistent quality (Duray et al.). Another benefit of modularity is that through modular product design, standardization of the components is possible (Ulrich, 1995).

3.2.2 Standardization of modular product design

Component standardization is the use of the same component in multiple products and is closely linked to product variety. According to Ulrich (1995) standardization can arise only when:

- A component implements commonly useful functions.
- The interface to the component is identical across more than one different product.

Otherwise, a component would not be useful in more than one application or would not physically fit in more than one application. Through modular product design the likelihood increases that a component will be commonly useful (Ulrich, 1995). Ulrich noticed also two benefits of standardization:

- Standard components expose higher performance (for a given cost) than unique designs.
- The use of standard components can lower the complexity, costs and lead time of product development.

For declaring the importance of standard modular product design a more practical research was carried out by Patranen and Haapasalo (2004). They investigated the role of mass customization in the electronics industry from a manufacturing approach. They achieved their theoretical findings and experiences during the Pro Electronica project. During this project eight companies were studied, where the theory of mass customization was utilized. From this project some practical points for the implementation of mass customization were gained. Related to product development the following aspects should be carried out in order to implement a mass customization strategy:

- The usage of standard product modules in order to reduce the cycle times.
- Using component-based standard modules to speed up the product development.
- Using modules and components in order to combine products to match the customer needs.
- The combination of product modules must happen effectively for the creation of new products by varying one or several modules against the customers' needs.

From the Pro Electronica project can be concluded that for the implementation of mass customization, modular product design is essential to realize mass customization in practice.

3.3 Conclusion

Product design and in specific modular product design is a very important design practice to achieve mass customization. To achieve mass customization a company must focus on developing products that satisfy customers needs. Mass customization can only be reachable if the firm is able to produce the unique products in a mass production way. This is possible through modular product design. Through modularity a part of the product can be made in volume as standard modules and product distinctiveness will be achieved through combination or modification of the modules.

The six different types of product modularity described by Pine (1993), can be integrated in the production cycle stages. If the customer is involved in the design and fabrication stage modules can be altered or components can be fabricated to provide the unique requirements of the customer. If the point of customer involvement is in the assembly or use stages, modules can only be arranged or combined according to customer specification.

Customer involvement and modularity are important factors for achieving mass customization. Customer involvement provides the customization while modularity restricts the range of choice to decrease the variety of components (Duray et al., 2000). The use of modular product design makes standardization possible. The use of standard components in product design can lower the complexity, costs and lead time of product development (Ulrich, 1995).

Chapter 4: Requirements to process design

4.1 Introduction

According to Silveira, Borenstein and Fogliatto (2001) processes and methodologies are important enablers of a mass customization implementation. Their analysis of the literature pointed out that *agile manufacturing, lean manufacturing* and *supply chain management* are one of the main business practices relating to the mass customization concept. In order to investigate the requirements to process design the processes of agile and lean will be investigated. If it is possible, the connection will be made with supply chain management.

4.2 Difference between agile and lean

According to Christopher (2000) companies must become more responsive to be able to meet the demands of customers for ever-shorter delivery times and to be highly flexible. This has lead to the emergence of the agile paradigm. *Flexibility* is the key characteristic of an agile organization. Christopher and Towill (2001) suggest that the origins of agility as a business concept lie partially in flexible manufacturing systems. Through manufacturing flexibility, firms could enable rapid changeovers (reduced set-up times) and thus permit a greater responsiveness to changes in product mix or volume.

The essential of lean is about the elimination of waste (Christopher and Towill, 2001). Stratton and Warburton (2003) argues that lean manufacturing and lean thinking have showed the broad potential of the elimination of waste in improving business performance. The elimination of waste is closely connected with reduced inventory or 'zero inventory' and just-in-time management. The key characteristic of lean is *efficiency*.

The lean approach is focusing on eliminating waste and achieving low cost manufacturing of a standard and stable product, the agile paradigm is more focusing on the need to deliver a variety of products with uncertain demand (Stratton and Warburton, 2003). This is confirmed by Christopher (2000) who stated that the lean approach makes sense in a situation where the demand is predictable and the requirement for variety is low and volume is high. He also argued that the agility approach should be implemented in a situation where the demand is less predictable, the requirement for variety is high and the volume at the individual stock keeping unit level is low.

Figure 4.1 shows in which situation lean or agile must be utilized based on the dimensions; variety, variability (or predictability) and volume. Stratton and Warburton (2003) and Christopher and Towill (2001) compared lean and agile on more distinguishing attributes. This comparison is presented in table 4.2.

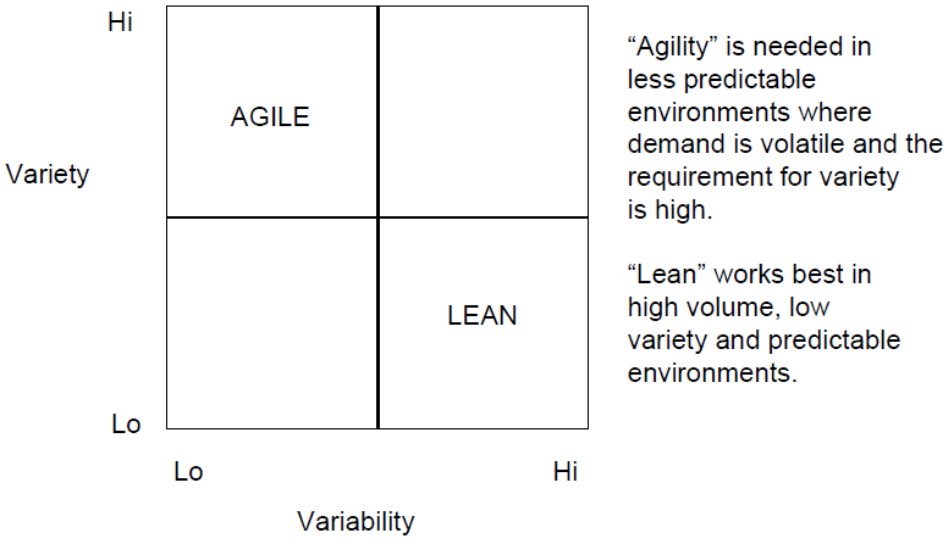

Figure 4.1 – Source: Christopher (2000).

Distinguishing attributes	Lean	Agile
Typical product	Commodities	Fashion goods
Market placed demand	Stable	Unstable
Product variety	Low	High
Product life cycle	Long	Short
Customer drivers	Costs	Availability
Profit margin	Low	High
Management task	Low costs	Delivery speed
Delivery penalties	Long term contractual	Loss of order
Purchasing policy	Product specific	Assign capacity
Information enrichment	Desirable	Important

Table 4.2 – Source: Stratton and Warburton (2003) and Christopher and Towill (2001).

The two product types defined in table 4.2, are critical attributes in distinguishing lean and agile. Therefore, the two product types will be further explained (Naylor, Mason-Jones and Towill, 2000):

- *Fashion products* are characterized by short life cycles and high demand uncertainty, therefore the company or supply chain is exposing the risk of both stock outs and obsolescence.
- *Commodities* are basic products, which have relatively long life cycles and have low demand uncertainty due to the fact that these products have a known consumption pattern.

These two products types respond differently to marketplace pressures and require a different production and supply chain approach to address their specific characteristics (Naylor et al., 2000). Naylor et al. stated that "only through understanding the particular characteristics of the product type, marketplace requirements and management challenges can the correct strategy be designed to ensure optimal performance and to establish competitive advantage". For choosing the right strategy it is important for a company to decide what their *order qualifiers* and *order winners* are.

- *Order qualifiers* are the baseline for entering into a competitive market.
- *Order winners* are specific capabilities to win the order.

According to Naylor et al. the market winner for fashion products is availability (service level), whereas the market winner for commodities is price (costs). The market qualifiers are for both products quality and lead-time. Naylor et al. combined the two product types with their order qualifiers and order winners, presented in figure 4.3. Christopher and Towill (2001) made the connection between order qualifiers and order winners and lean and agile (figure 4.4).

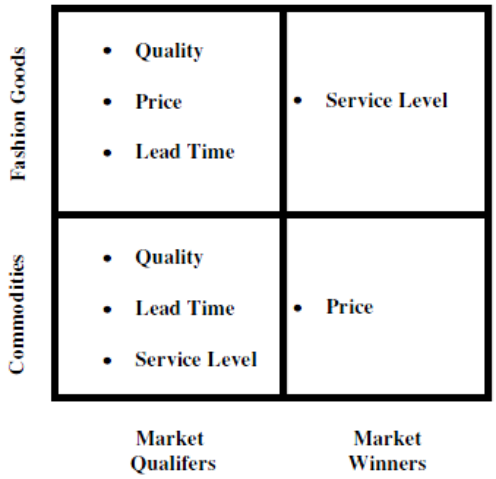

Figure 4.3 – Source: Naylor, Mason-Jones and Towill (2000).

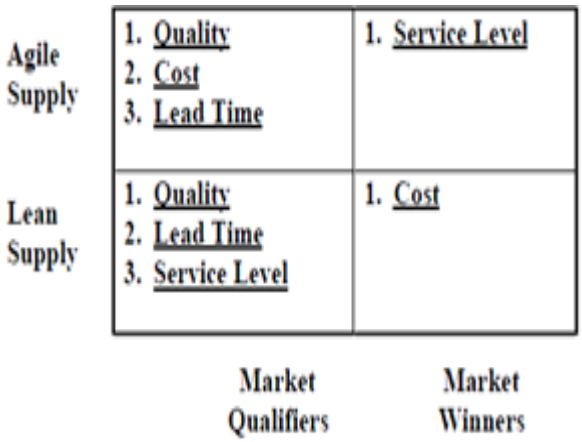

Figure 4.4 – Source: Christopher and Towill (2001).

From these two figures can be concluded that the lean paradigm is most powerful when the winning criteria is cost. Agility becomes the critical dimension if service and customer value improvement are the top requirements for market winning (Christopher and Towill, 2001). Within an organization the standard modules can be seen as commodities and the customized end-products can be seen as fashion products.

To implement a mass customization strategy a company should be able to provide a high service level to meet the specific requirements of the customer, while the production costs are as low as possible.

The differences between agile and lean are examined in this section. There will be situations when either a 'pure' agile or lean approach might be appropriate for a company or supply chain. It is also possible that a combination of agile and lean may be appropriate (Christopher, 2000). This combination will be explained in section 4.2.

4.3 Leagility

In situations where a 'pure' agile or lean approach across the whole supply chain may not be appropriate, the combination of the agile and lean approaches can be a solution. These two approaches can sometimes be combined with the strategic use of a *decoupling point (*Naylor et al., 2000). This is presented in figure 4.5 where the benefits of both paradigms are combined.

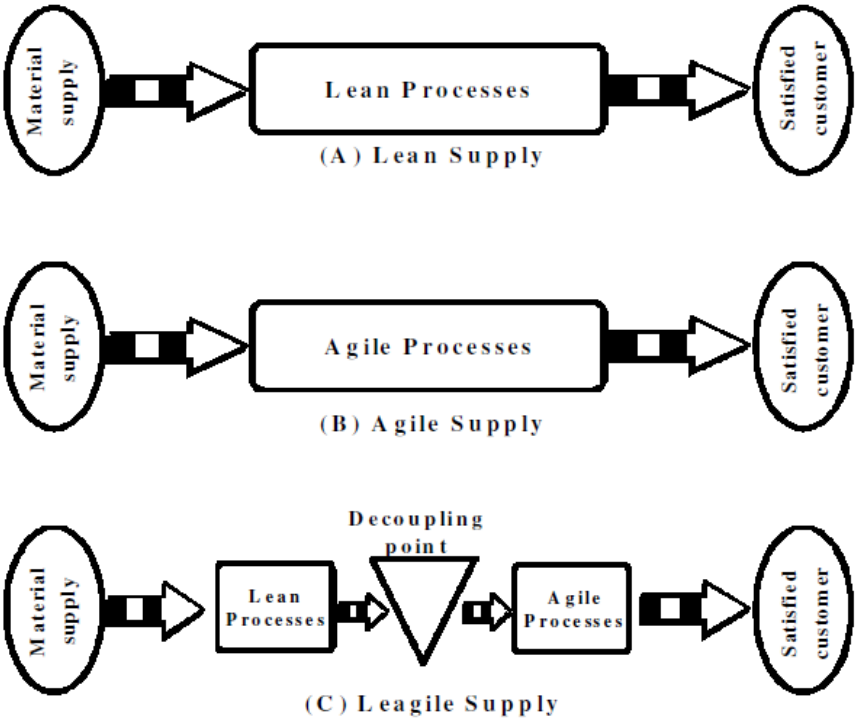

Figure 4.5 – Source: Naylor, Mason-Jones and Towill (2000).

According to Naylor et al. the combination of lean and agile is known as *leagility*. This combined approach is also known as a *hybrid strategy* (Christopher, 2000).

In chapter three (product design) the role of the decoupling point by was very significant. The importance of the decoupling point is also noticeable in the design of the processes. Therefore, in the next subparagraph the role of the decoupling point will be further investigated.

4.3.1 The role of the decoupling point

According to Christopher (2000) most supply chains facing major problems in their limited visibility of real demand. He stated that "because supply chains tend to be extended with multiple levels of inventory between the point of production and the final marketplace, they tend to forecast driven rather than demand driven". The decoupling point is the point at which real demand penetrates upstream in a production cycle or supply chain. Christopher and Towill (2001) termed the decoupling point as *strategic inventory*. The idea is to hold inventory in some generic or modular form and only complete the final assembly or configuration when the precise customer requirement is known.
Stratton and Warburton (2003) stated that "the concept of a decoupling or order penetration point within the supply chain, utilizes the opportunity to postpone the design configuration and therefore reduce the impact of variation further upstream". According to Partranen and Haapasalo (2004) the fundamental belief behind mass customization and modularization is that the order penetration point is delayed as late as possible. This can be realized through the process of postponement.

Postponement means that companies delay production, assembly or even design until the customer order has been received. This makes it possible for companies to increase their ability to fine tune products to specific customer requirements (van Hoek, Commandeur and Vos, 1998). This is confirmed by Christopher (2000), who stated that "postponement or delayed configuration, is based on the principle of seeking to design products using common platforms, components or modules but where the final assembly or customization does not take place until the final market destination and/or customer requirement is known". By using the concept of postponement, companies may utilize lean methods up to the decoupling point and agile methods beyond it (Christopher and Towill, 2001). The advantages of postponement are further declared by Christopher (2000). He argued that the advantages of postponement are several:

- Inventory can be held at a generic level. This means that there will be fewer stock-keeping variants and this results in less total inventory.
- Because the inventory is generic, its flexibility is greater. This means that the same components, modules or platforms can be represented in a variety of end products.
- Forecasting is easier at the generic level than at the level of finished products.
- The last point is that postponement creates the ability to offer a higher level of customization at lower total costs. This enables that a strategy like mass customization can be pursued.

By using generic or modular inventory to postpone the final specification it should be possible to achieve volume-oriented economies of scale through product standardization. The product flow up to the decoupling point may well be forecast driven and after the decoupling point the product flow should be demand driven (Christopher and Towill, 2001). This is visualized in figure 4.6.

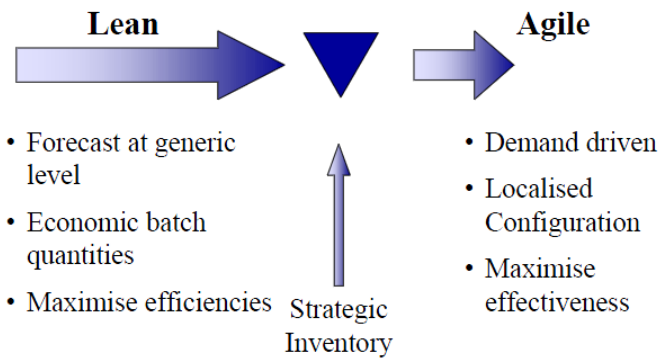

Figure 4.6 – Source: Christopher and Towill (2001).

4.4 Conclusion

Mass customization provides organizations the ability to provide customized products or services through flexible processes in high volumes and at reasonably low costs (Silveira et al., 2001). To implement a mass customization strategy the role of the order decoupling point is significant. For implementing mass customization, the process design in the production cycle stages before the order decoupling point must be related to the lean approach. The lean approach is focusing on eliminating waste and achieving low cost manufacturing of a standard and stable product. After the order decoupling point the design of the processes must be related to the agile process design for achieving customization. The agile approach is more focusing on the need to deliver a variety of products with uncertain demand (Stratton and Warburton, 2003). Thus, to successfully implement a mass customization strategy related to process design a combination of lean and agile processes must be utilized. This combination is known as *leagility*. Through leagile process design a company makes it possible to produce standard product modules in a mass production way, while after the order decoupling point the product can be specified to the specific customer requirements.

By postponing the order decoupling point a company reduce the impact of variation further upstream and can respond rapidly to customer demand, market change and market opportunities (Yang and Li, 2002).

Chapter 5: The combination of product and process design

5.1 Introduction

This chapter will combine product and process design to provide an answer how to implement a mass customization strategy. This will be investigated by the research of Duray, Ward, Milligan, and Berry (2000) who defined four types of mass customizers and tested in practice the effect on the design of the processes.

5.2 Practical investigation of mass customization

Duray et al. (2000) defined four mass customization configurations. These configurations are determined by the point of customer involvement in de production cycle and the type of modularity.

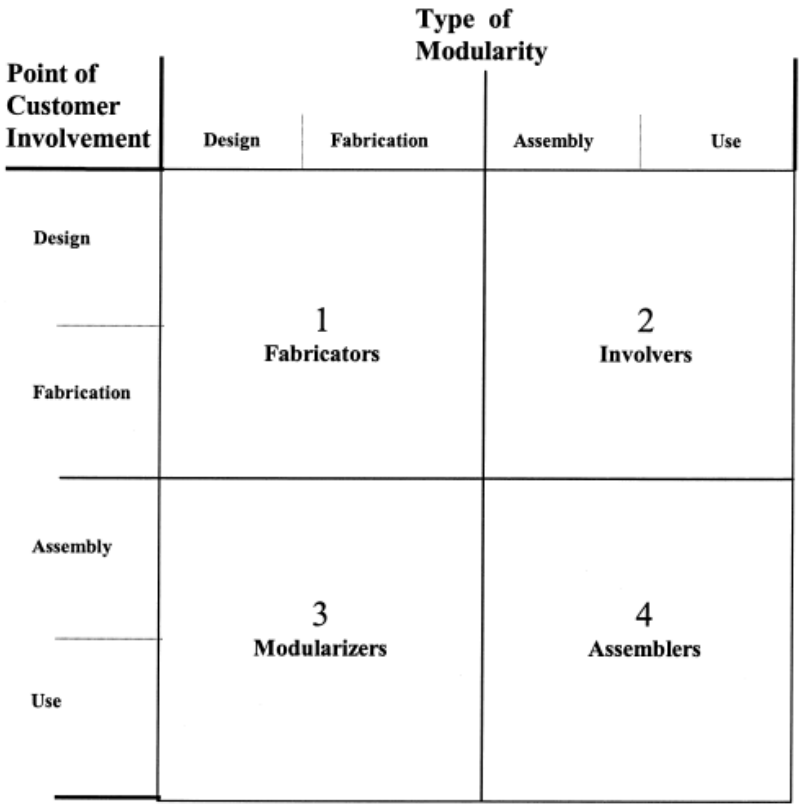

Figure 5.1 – Source: Duray, Ward, Milligan, and Berry (2000).

From figure 5.1 can be seen that within the first group both customer involvement and modularity taking place during the design and fabrication stages. Duray et al. named this group the *fabricators*. This group involves the customers early in the process when unique designs can be produced or major transformations can be made in the products. Duray et al. stated that “the fabricators closely

resemble a pure customization strategy, but employs modularity to gain standardization of the components".

The second group integrates customer involvement during the design and fabrication stages but modularity is used during the assembly and use stages. This group is named by Duray et al. as *involvers*, because customer involvement precedes the use of modularity. This means that customers are involved early in the process but no new modules are produced for this customer. In this case customization will be achieved by combining standard modules to meet the specific requirement of the customer. Comparing this group of mass customizers with the first group (fabricators), Duray et al. determined that involvers capture greater economies of scale than the fabricators while maintaining a high level of customer involvement.

The third group creates a modular approach in the design and fabrication stages, but the customer can just specify their unique requirements in the assembly or use stages. Duray et al. named this group the *modularizers*. This configuration of mass customization does not gain maximum customization advantages from modularity (Duray et al.).

In the fourth group customer involvement and modularity take place at the assembly and use stages. Duray et al. called this group the *assemblers*. Assemblers offer mass customization by using modular components to present a wide range of choices to the customer. Comparing this group with the other groups, the assemblers are the most related to mass production. However, this group differs from mass producers in the way that the customer is involved in specifying the product and the range of choice that assemblers made possible is large related to mass producers.

Duray et al. tested their theoretical classification of mass customizers in practice. They carried out an empirical analysis and classification of 126 mass customizers for exploring manufacturing systems and performance implications of the various mass customization configurations.

The mass customization configurations use different processes to achieve their mass customization capabilities. Duray et al. investigated the usage of line manufacturing processes and flexible manufacturing processes in order to achieve mass customization. The outcome of their research, related to the process choice of companies, can be summarized as follows.

The fabricators are most closely related to pure customization. Therefore, the limited use of line processes for component manufacturing is not surprising. If a company qualifies itself as a fabricator, the company needs more *flexible* manufacturing methods to be able to produce products given specific customer requirements.

The opposite of the fabricators are the assemblers. This group of mass customizers is most closely related to mass producers. This means that assemblers have the highest usage of line processes.

Modularizers utilize modularity in the early stages of the production cycle. Duray et al. stated that "Modularizers may use modules to provide component standardization without providing customization until the customer is involved in the later stages". This means that a part of the production processes exist of line processes and that the flexible manufacturing processes are necessary for achieving customization in the assembly part.
Involvers have the customer involvement early in the production cycle and modularity later in the production cycle. For this group no new modules will be produced, so the standard modules can be produced with the use of line processes. After the customer specification is known more flexible manufacturing processes are necessary to combine these standard modules to the customer specification.

Combining these outcomes of the practical investigation of Duray et al. with the process design approaches defined by Christopher (2000), Christopher and Towill (2001) and Naylor, Mason-Jones and Towill (2000) the following can be concluded:

- All the four mass customization groups have a leagility process design.
- The point of customer involvement determines the intensity of lean and agile in the processes. If the point of customer involvement is in the design or fabrication stages the main focus is on flexible production processes. If the point of customer involvement is in the assembly or use stages the focus is in the beginning more on efficiency and after the decoupling point agility is needed.
- For the design of the processes the focus must be on designing flexible processes to provide customization and responsiveness. Efficiency must be achieved through the production of standard modular components.

Also Feitzinger and Lee (1997) investigated mass customization in practice by the Hewlett-Packard Company. They proved that it is possible for companies to deliver customized products quickly and at a low cost. Feitzinger and Lee defined three organizational-design principles that form together the basic building blocks of an effective mass customization strategy:

- A product should be designed so it consists of independent modules. This makes it possible for a companies to assemble their products into different forms easily and inexpensively.
- Also the manufacturing processes should be designed that it consist of independent modules to provide flexibility.

- The positioning of inventory and the location, number and structure of manufacturing and distribution facilities in the supply network, should be designed to provide two capabilities:
    1. Supply the basic product to the facilities providing the customization in a cost-effective way.
    2. It must have the flexibility and responsiveness to take individual customers' orders and deliver the finished, customized products quickly.

Finally, Feitzinger and Lee stated that "the key to mass customization is postponing the task of differentiating a product for a specific customer until the latest possible point in the supply network".

5.3 Conclusion

Related to the point of customer involvement in de production cycle and the type of modularity, four different mass customization configurations can be determined. These configurations are: *fabricators, involvers, modularizers* and *assemblers*. Duray et al. (2000) tested the implications of these configurations in practice. All the four configurations have a mix of flexible and efficient process design, which implicates the utilization of a leagility process design. The point of customer involvement determines the intensity of lean and agile within the processes. But for the design of the processes the focus must be on designing flexible processes to achieve customization. Efficiency will be provided through the production of modular components.

Feitzinger and Lee (1997) investigated also mass customization in practice. Their findings at the Hewlett-Packard Company contains the fact that it is possible for companies to deliver customized products quickly and at a low cost if they follow the organizational design principles defined by Feitzinger and Lee. These principles consists of modular product design, flexible process design and the design of the supply network to provide efficiency and responsiveness.

Chapter 6: Concluding

6.1 Introduction

This chapter gives the overall conclusion of the research. The requirements to product and process design will be summarized and the overall conclusions will be provided to answer the problem statement. Finally, the limitations of this research will be presented and recommendations for future research will be made.

6.2 Conclusions

The main problem statement of this research was:

- *What are the requirements to product and process design related to the implementation of a mass customization strategy?*

Mass customization can be divided in different levels. These levels are related to the stages of the production cycle; *fabrication*, *design*, *assembly* and *use*. The point of customer involvement or decoupling point in the production cycle determines the level of mass customization. The earlier customers are involved in the production cycle, the higher products could be customized. If the point of customer involvement is at the assembly or use stages, the degree of customization will be not that great.

For the implementation of mass customization a company should focus on developing products that satisfy customer needs and that the unique products can be produced in a mass production way (Duray, Ward, Milligan and Berry, 2000). This is possible through *modular product design*. Through modularity a part of the product can be made in volume as standard modules and product distinctiveness will be achieved through combination or modification of the modules. According to Pine (1993) and Duray et al. (2000) modular product design is a key to achieve mass customization and can be viewed as the critical point for gaining scale or 'mass' in mass customization.

The design of the processes is also important to successfully implement mass customization. Companies should produce customized and affordable products through the use of *leagile* process design. This means that the design of the processes should be a mix of efficiency and flexibility.

The role of the order decoupling point is significant for design of the processes. The processes before the order decoupling point should be related to the lean approach (efficiency). After the order decoupling point the design of the processes must be related to the agile approach (flexibility).

Mass customization can be optimized through the process of postponement. Postponement provide a reduction of variety upstream and respond more quickly to customer demand (Yang and Li, 2002). For implementing mass customization it is important that a company should postpone the point of customer involvement as far as possible downstream in the production cycle. In this way a company can produce the different modules on a stable and efficient way, while the distance with the end customer is short. This means that a company can respond quickly to customer requirements. Thus through postponement a firm can optimize their mass customization strategy. Feitzinger and Lee (1997) describes the process of postponement as the key to mass customization.

6.3 Discussion

A limitation of this research is the fact that it is based on secondary data. If primary data were used, this paper would have been more reliable. This research used different kinds of information from different years and authors. For this literature research a lot of conclusions were drawn from the papers of Silveira, Borenstein and Fogliatto (2001) and Duray, Ward, Milligan and Berry (2000). It is important to notice that the information used from these articles are published from around the year 2000. This might be considered as outdated, because in the years till now developments related to production or information technologies, changing customer requirements and new product materials could have a positive or negative influence on implementing mass customization. Also the articles of Christopher (2000), Christopher and Towill (2001) and Naylor, Mason-Jones and Towill (2000) who are frequently used for explaining the requirements to process design, are published around the year 2000.

It should be noted that mass customization has been studied extensively around the year 2000. Most of these investigations are based on theoretical findings. However, for improving the mass customization concept more practical research should be carried out. This means that more primary data should be gathered in order to indentify the specific requirements of implementing mass customization in different industries. But such investigations are very time-consuming.

6.4 Recommendations

Several recommendations for future research can be made. First, most of the literature is dominated by researches that are purely focused on the manufacturer perspective of mass customization. The service part related to mass customization is still ignored in the literature.

Second, most investigations are related to a single firm perspective or more specific to the manufacturing department inside the company. It is necessary that more researchers investigate the implications of mass customization in a supply chain context. But also the implications within a company can be further examined. For example, the collaboration between production and marketing departments or between production and the research and development department.

Third, more practical investigation must be carried out to get more detailed information about implementing mass customization in practice. This means that more primary data must be gathered from different kind of industries to get more specific and reliable information about mass customization.

Based on the theoretical aspects related to the mass customization concept and objectives, there is little contention in the literature. Important is that more exhaustive research should be carried out in practice to obtain more information about the requirements of implementing a mass customization strategy.

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