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Mass Customization in Supply Chain: Development of a Conceptual Framework to Manage and Asses Performance

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Abstract

Mass customization is one of the buzzwords of the markets according to Pillar (2004). With increasing coverage in the literature, it is a growing area of research with new opportunities as well as gaps.

This thesis aims to address the gap which exists in literature about implementation of mass customization in supply chain level. Inspired by extensive literature review, it has been recognized that implementation of mass customization in supply chain has been studied fragmented and still it is not clear how it would be possible to manage a supply chain in a turbulent environment. The purpose of the framework is to help companies, which want to start doing mass customization, to understand main aspects of the supply chain, understand which factors impact these aspects and how their performance can be assessed. To reach this goal this study needs to answer to two main questions:

1. Which factors are needed to be considered while implementing mass customization in supply chain level?
2. How these factors can be measured?

Different strategies have been analyzed and understood in relation with the other strategies to create a wholesome frame. Each strategy is presented with different factors which affect the decisions and indicators for assessing these factors. The frame aims to aid the companies by providing these different factors they have to manage to implement for an effective mass customization strategy and indicators which they can use to assess the performance of these factors. At the end of the study, a validation phase has been implemented to evaluate the correctness and completeness of the frame.

1. Introduction

Mass customization, is a almost new rising subject, is now follows an increasing trend both in literature and in industry with customization of products which reach the customers.

Before starting, it is appropriate to define mass customization. Davis first coined the term in 1987 and from that they the literature has been growing (Pillar, 2004). Over the literature, it can be seen that mass customization definition is constantly evolving, so rather than a single definition an explanation is more necessary.

Piller (2004) defines as

"Customer co-design process of products and services, which meet the needs of each individual customer with regard to certain product features. All operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes. As a result, the costs associated with customization allow for a price level that does not imply a switch in an upper market segment".

It is a strategy, not a manufacturing but a business one, which create these customized products in high volume and high efficiency within an acceptable price range for the customers. Three distinctive elements are identified which creates the system: customer co-design, modular product design and finite solution space (Kumar et al, 2008)

By being a market pull system it responds to market demands by enabling the customers to co-design the products. The customer is integrated in the design of the product the make the customization possible. Within the system, the co-design can happen at different steps of the product design cycle, engineering, production, assembly or distribution. These strategies with different levels of involvement are defined as pure customization, tailored standardization, customized standardization, segmented standardization and pure standardization. In pure customization the customer starts the coordination at the engineering phase, involving in the design of product making it fully customized for them. At the other extreme, in pure standardization, the process is fully standardized without customer involvement and the production is made-to-stock, no customization is done.

Another important aspect of mass customization strategy is the mass production efficiency. This efficiency enables the prices to be kept low, meaning that the cost changes created by customization is minimally reflected on the customer, by decreasing costs of the supply chain and manufacturing.

Based on the overview of the mass customization strategy, the aim of this work is to create a framework for companies who want to start mass customization activities on their supply chain or manage better their existing systems. The frame aims to aid the companies by providing different factors they have to manage to implement an effective mass customization strategy and indicators which they can use to assess the performance of these factors.

The organization of this thesis is as follows. First a literature review is presented followed by a critical analysis. As the third chapter the research objective and methodology is given, explaining the steps of the work. The methodology is followed by the explanation of the

conceptual framework. The fifth chapter is dedicated to the validation of the created framework and the work is finished with discussion of the findings.

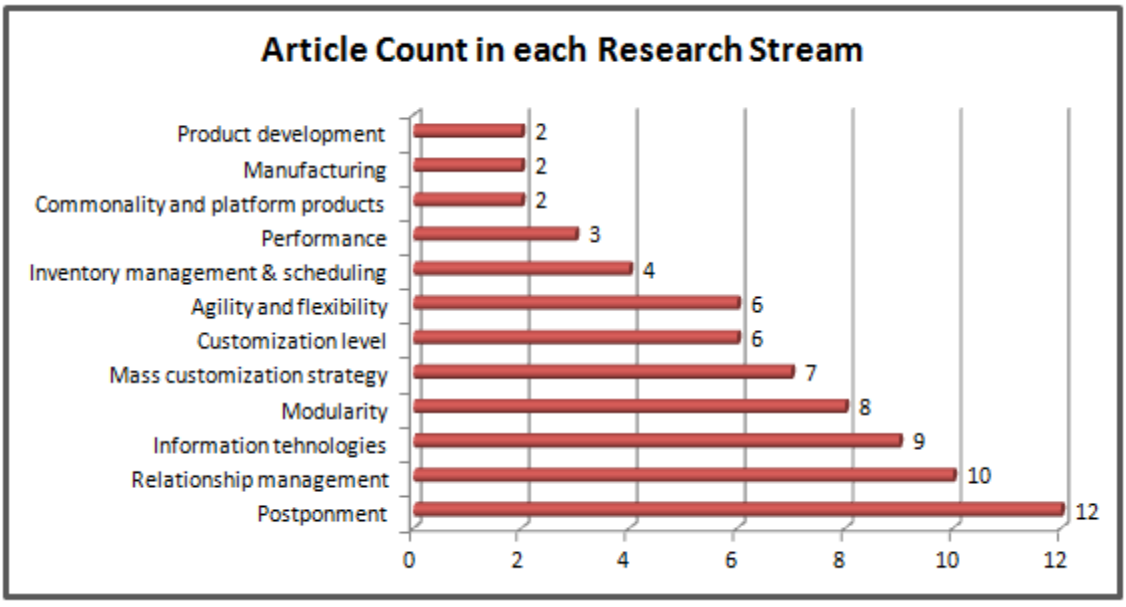
2. Literature Review of Mass Customization on Supply Chain Level

From now on the literature review will focus on the only the supply chain in the mass customization context, which is the scope of this thesis.

The literature review consists of two steps. First the related studies were searched. As the second step, the found studies were grouped in different research streams to analyze for the beginning of the framework.

As the first step of this thesis, an extensive literature review was done on the subject of supply chain management and mass customization strategies. In order to do so, searches was done for studies with the keywords “mass customization” and “supply chain” in their keywords, abstracts or titles.

As the second step of the work, all the publications found were clustered into different groups based on the main idea or strategy that is investigated in them. The 12 research streams created are given below with the corresponding article counts (Graph 1).



Graph 1 - Research Stream Composition

In the following parts of this chapter, first the contents of each research stream will be explained in detail, with the relevant definitions and extractions from the literature. In the second part, the critical analysis of each stream is given to better understand the strengths and weaknesses of topic.

2.1. Postponement Strategy Research Stream

This group of literature is dedicated to the postponement strategy which is one of the enablers of a mass customization system. To ensure the application and the efficiency of mass customization on the supply chain different types of postponement strategies can be used. There are different partial definitions associated with postponement strategy. Graman (2010) defines postponement as "the capability of a supply chain to delay product differentiation, or customization, until closer to the time that demand for the product is known". Baozhuang, et al. (2008); Hoek (1999) and Qin (2011) defines postponement only on postponement of manufacturing until the receiving of customer orders while Su (2005) emphasizes on the delaying distribution until the arrival of customer orders and also delaying differentiation in the supply chain. Ji & Sun (2011) adds to the definition with the conflict between product variety and quick response time and Qin (2011) defines it as a supply chain strategy which is used to achieve mass customization and can deal with product growth while keeping costs at certain levels**.**

Different companies adapt different types of postponement strategies which are best fit for their operations and market. The literature agrees on three different categories of postponement strategy is present: time, form and place postponement. With the integration of these different categories a full postponement strategy is created**.**

2.1.1. Postponement types: Time, Form and Place Postponement

Time postponement (TP) denotes the delaying type created by the holdup of delivery of the product until the orders are received from the customer. This holdup can occur at different stages of the supply chain, mainly manufacturing and logistics. In manufacturing, the production of the final good is started after the receiving of the customer order also known as the make-to-order approach. In logistics the handling and the shipping of the product can be postponed to a later time. This postponement strategy results in lower inventory levels while it increases service by fulfilling the customized demand (Hoek 1999; Su 2005; Kisperska-Moron et al 2011).

In the case of form postponement, production of the product is completed to a certain point, (Hoek 1999; Su 2005; Graman 2010; Trentin and Forza 2010; Kisperska-Moron et al. 2011). The semi-finished products are in generic form when they are shipped out of the manufacturing process and customized further on the downstream supply chain after the customer order is received. The final form and function of the product is given by differentiation after the exact demand is known so that the resources to be used at the end product are hold as long as possible in the supply chain and product variety is compensated. This kind of postponement is aimed to have shorter lead times on customer orders by manufacturing the generic part of the product beforehand

The last type of postponement is the place or location postponement. This category is based on moving of the inventories in the upstream supply chain in selected centralized locations where manufacturing or distribution activities occur. In these inventory-keeping points downstream shipment is delayed until the customer order is received, resulting in postponement of the progress of the products towards the customer. This is usually a part of

the logistics process of the supply chain and can result in spatial reconfiguration of the supply chain by repositioning inventory points and sometimes also final manufacturing activities. (Hoek 1999; Artur et al 2011).

With the combination of these three different postponement types a postponement strategy can be put forward in a company. A supply chain with postponement and mass customization is a market pull strategy; it is initiated by a customer order, rather than a traditional push strategy of mass production. According to Artur et al. (2011) different categories like product type, consumer demand and supply chain approach are used to determine the different strategies. Product type is important in two different aspects. The first one is the current place in the product lifecycle and the second product design. The product lifecycle is important because at different stages of the lifecycle different postponement strategies can be used for increasing customer satisfaction (during introduction and growth) or reducing costs (during decline). Product design is another aspect affecting postponement strategy. Based on how the product is designed, for example its modularity, different strategies can be adapted.

The consumer demand is an important influencer alongside with the market's effects. The requirements of the consumer influence the type and extent of the postponement strategy, which can be described under customer satisfaction. Factors influencing the customer satisfaction, like the delivery times should be balanced in the supply chain based on the different customer types to ensure satisfaction.

The last category is the supply chain approach which denotes the production and logistics activities and their characteristics in the supply chain. Kisperska-Moron et al. (2011) sees two factors as most important, the availability of economies of scale and the need of special knowledge. When there is lack of both, a postponement strategy can be more effectively implemented.

Studies Su (2005) and Ji et al. (2011) take look at the system in a strategic point of view. In Ji and Sun (2011) they use different decision drivers of a supply chain, namely correlative coefficient, customization ratio of the products, expected waiting time's coefficient on total cost and product variety in the production system to perform a sensitivity analysis over the total cost of the supply chain. These different decision drivers drag the optimal differentiation point of the system at different points of the supply chain which raises the question of how different drivers affect the structure of the postponement strategy.

The study of Su (2005) follows a similar way to assess the two different postponement strategies, time and form postponement. The strategies are evaluated under two performance measures, costs, which include both fixed and operational costs, and customer waiting time. Experiments conducted by the authors try to understand the effects of arrival and process time variations, generic component coverage percentage, number of products and interest rates on the supply chain under the two different strategies. Results show that higher variations both in arrival and process time are compensated in form postponement systems; there was no evidence of waiting time increase. Also generic component coverage increases are favorable in form postponement because they result in waiting time decreases. The other two drivers, number of products and interest rates, both favor time postponement.

In the light of these results Su (2005) explains that for companies with high variations it is significant to apply some type of form postponement to compensate the effects of the variation. The affects of variations are not projected upon the customer on the waiting times by the mass produced and stored generic components of the products. On the other hand, number of products favors time postponement because, usually, more products might indicate the need of different generic components or more customization work after receiving of the order on form postponement but does not have such effects on time postponement. Similarly interest rate increases also favor time postponement due to amount of inventories at hand. Although it increases costs in both cases, because there are less inventories in time postponement when compared with form postponement and interest rate increases the cost of inventories, the increase in interest rates have higher impact on form postponement strategy.

Within the literature there are studies which are industry specific. The food industry is examined in Hoek (1997) via a case study of a wine producer. Different decision making models for postponement are created to show the role of product differentiation, process, technological and market characteristics. The final decisions considered are manufacturing, assembly time and packaging and labeling postponements, which denote the level of customization as done by Ji & Sun (2011).

Hoek (1999) sets to examine food, electronics, automotive and clothing companies to understand the effects of postponement strategy, outsourcing and special reconfiguration across these industries and mainly understand the food industry. An important characteristic of the study is that it defines some processes (i.e. sourcing, primary and secondary production, inventory, distribution and sales) and their spatial structure (global, continental, international and local) for the given industries. Even though the research focuses on only companies from Netherlands, Belgium and Germany and especially emphasizes the food industry, it can function as a stepping stone to understand how processes differ over industries and how these differences effect the postponement and outsourcing decisions of companies. Based on the survey conducted on selected companies of these industries the results show that postponement amount increases on activities closer to the customer in the supply chain, mainly packaging, labeling and adding the user manuals. However, it is also found that food industry is the industry where postponement levels are lower than the others. The study also finds the important efficiency levers (costs, inventory and manufacturing efficiency etc.) and customer satisfaction factors based on industry. Another important contribution is the insight on outsourced activities and the factors that affect the outsourcing decision.

Apart from papers which take and compare different postponement strategies some studies focus on only one aspect of postponement, mainly form postponement. Trentin and Forza (2010) focus on designing, or rather redesigning, for form postponement. The analysis on the five case studies on machinery industry aims to reveal different approaches in product architecture, supply chain and production processes and organizational design by understanding the enablers of postponement. The enablers to be considered are “simple production planning environment”, “self containment of the production planning tasks”, “production planning frequency” and “lateral relations in the production planning process”. On all enablers it is found that higher degrees facilitate the form postponement son production family.

Other studies about form postponement focus on the variables which have an effect on the selection of a postponement strategy (Kisperska-Moron et al. 2011). These determinants are consolidated in three categories which according to the author determine the production strategy, which are product type, consumer demand and supply chain approach. The variables, 15 in total, are merged into five different factors based on their characteristics like compare company performance, quality of forecasting etc. to use in a multiple regression analysis with postponement strategy in general and also three subgroups, full (engineer-to-order), production (make-to-order) and assembly (assemble-to-order) postponement.

2.1.2. Advantages and Disadvantages

Implementation of a postponement strategy as explained by Hoek (2000), Graman (2010) Hoek (1997) and Qin (2011) has different advantages over the supply chain. The first one is increased value to the customer which is achieved by customization of the product, which is general for a mass customization strategy. However as mentioned before strategies like form postponement can decrease lead times which also reflects positively on customer service levels. Another benefit gained by postponement is lowered inventory costs by pushing the inventories towards upstream and reducing downstream inventories by the market pull method and different postponement strategies.

However, there are also some disadvantages associated with postponement strategy which requires attention during implementation. An important point is that manufacturing costs are higher due to small lot sizes and additional handling, moving and storage activities (Graman, 2010). Qin (2011) shares this view of increasing costs and attract attention to the tradeoff between finished goods inventories and inventories upstream created by the postponement strategies. They also consider costs incurred by lost sales or customer dissatisfaction due to high lead times after ordering.

2.1.3. Inventory management for postponement

When the research done on the subject it can be seen that one of the topics most emphasized is the effect of postponement on inventory levels and costs in the supply chain. All Baozhuang et al. (2008), Ma et al. (2002), Graman (2010) and Qin (2011b) create mathematical models to optimize the inventory levels in the supply chain. While doing this and set the optimal stock amounts, they also create models which find the optimal level of postponement for the companies. At the heart of the objective functions of these studies lie different costs. Ma et al. (2002) uses component and product inventory costs as well as cost of holding of goods in work in progress to find the optimal inventory levels of the system. Graman (2010) uses cost categories of assembly labor and material, postponement, packaging, finished goods inventory, postponed inventory and shortage costs to find inventory levels and capacity for the optimal postponement strategy. Two papers (Qin, 2011b; Qin 2011a) take the study conducted by Graman (2010) and create new models with added value. Qin (2011b) creates a new model with penalty costs while Qin (2011a) aims to understand and model the benefit and costs of the strategies based on the work of Graman (2010).

These studies show that, theoretical studies costs of the supply chain are used as a performance indicator to evaluate the benefit of the postponement strategies against systems without postponement strategies. Also minimization of the costs is considered the pillar to find the optimal level of postponement and commonality in the systems.

The literature, even though only in one study (Hoek, 2000), talks about the logistic processes and its possible importance for a mass customization strategy. With the outsourcing option of some of the logistics processes to third parties some of the steps of final manufacturing and postponement can be outsourced to the third parties (Hoek, 2000). The article gives an overview of the activities that can be overtaken by the third party which gives a clear picture of the logistic services provided. It also presents empirical data about the importance and positive effect of information sharing and advanced partnerships on the ability to outsource the postponement actions. However the study lacks the understanding of why, under which circumstances and which type of companies prefer to outsource certain actions to third parties.

Year	Author	Focus
1997	Hoek	Food industry decision model
1999	Hoek	Postponement, outsourcing and spatial reconfiguration
2000	Hoek	Third party logistics
2002	Ma, Wang, Liu	Inventory management
2005	Su	Form and time postponement
2008	Baozhuang, Shouping, Zhiyong, Xinghua	Inventory management
2010	Graman	Inventory management
2010	Trentin, Forza	Postponement enablers
2011	Ji and Sun	Postponement level and performance
2011	Qin (a)	Inventory management
2011	Kisperska-Moron, Swierczek	Postponement determinants
2011	Qin (b)	Inventory management

Table 2-1 - Postponement Research Stream

2.2. Information Technologies Research Stream

The focus of this research stream is information technologies (IT) and e-commerce and their interaction between them the mass customization supply chain. In the following sections it will be explained how the literature portrays IT as an enabler of MC, the place of e-commerce on MC supply chains and especially agent systems, Enterprise resource planning (ERP) and Electronic Data Exchange (EDI) which are present in the literature.

2.2.1. Information Technologies as an enabler of MC

According to Peng et al. (2011) information technologies are computers, software and telecommunication devices which offer different capabilities to the user. These can be in different forms like ERP systems discussed by Akkermans et al. (2008) or the different computer aided tools listed by Romero et al. (2011).

For a mass customization practicing company the information technologies can be used to enhance information sharing and processing capacities (Peng et al. 2011; Ruohonen et al. 2006) which is vital for understanding customers and their needs. It also helps the efficient and effective proceeding of operations while automating and integrating processes (Peng et al,

2011). It decreases time to market and increases flexibility and reliability which facilitates mass customization (Ghiassi et al. 2003) which emphasizes the role of the IT as an enabler in the mass customization system.

However there are also some disadvantages to be considered. Even it decreases the cost of information processing (Peng et al. 2011), it is a costly, capital intensive option (Dietrich et al. 2006). However, internet based systems like internet based software can present different options which are scalable, more compatible and easy to implement which can result in lower investments (Jiao et al. (2006)).

The study conducted in Peng et al. (2011), conducts an analysis based on a large scale survey to understand the impact of IT on mass customization capability. According to their results new product development information technologies (NPD IT) has a positive correlation with modular product design, while modular product design has a positive correlation with MC capability. Also, they found support to their hypothesis that modular product design encourages the use of configuratior IT in companies. As a last point they indicate that IT which helps supplier collaboration with the manufacturer has a positive influence over MC capability. The hypothesis based on positive affect of manufacturing IT/ MC capability and configurator IT/MC capability pairs were not supported by the data collected.

An example to an enabling IT is given in the article Jiao et al. (2006). In Jiao et al. (2006) an electronic configure-to-order platform was created and explained by the authors as a result of their research. This platform, gives the ability to the company which manufactures and sells injection-molded products to customize its products over the internet. By this the design and engineering activities can be organized within the company and effectively communicated to the outside actors and the customers.

2.2.2. E-commerce

In the research of Turowski (2002) e-commerce is defined as businesses in any form which take place electronically over computer networks between supply chain actors. These interactions between actors resulted in four different types of e-commerce activities: business to business, business to consumer, business to administration, and consumer to administration (Turowski, 2002). Ghiassi et al. (2003) also attracts the attention to the new opportunities created for business-to-business operations constructed by e-commerce.

The study of Helander et al. (2002) focuses on e-commerce and its use as an enabler of mass customization in the new product development phase (in other words e-product development (ePD) and present a research program. According to the authors, mass customization is one of the pillars of ePD along with supply chain management and integrated product lifecycle along design, engineering, manufacturing, assembly, distribution, sales and marketing. The fundamental issues to be considered are identified as human-computer interaction in customization, customer decision making process especially based on internet and mass customization, product platforms, electronic catalogs, product family modeling, virtual teaming of supply chain actors, web-based workflow management and architecture of the system.

Ruohonen et al. (2006) aims to understand the relationship between e-business and mass customization using metal and electronics industries. Four different types of different mass customization strategies were identified based on change in product and change in presentation: transparent, collaborative, adaptive and cosmetic. After this identification, the authors tried to understand the different phases of mass customization implementation in these companies. The four phases discovered were ERP-phase, SCM-phase, Customer relationship management (CRM) -phase and Knowledge Networks (KN)-phase. Shortly, the ERP phase denotes the beginning which aims to create the integration within the company. the second phase, SCM implementation, ensures the fluency of the supply chain. CRM-phase focuses on customer relations and knowledge while the last phase based on KNs try to use business intelligence systems to handle different actors and systems within the supply chain.

2.2.3. Agent based systems

Multiagent systems are artificial intelligence systems which are composed of intelligent agents (Dietrich et al. (2006)). The agents are autonomous units within the system which can perform different tasks without the need of human interaction (Turowski, 2002; Ghiassi et al. 2003; Dietrich et al. 2006). These agents have the ability to choose the tasks to work on (Dietrich et al. 2006) and they can use data from different environments. This capability results in agents using different resources and know how within a network (Ghiassi et al. 2003). They also can detect changes in the environment (Dietrich et al. 2006). Apart from these another important characteristic of these systems is the cooperative nature of the agents. Different agents communicate, interact and share information to complete tasks and solve problems (Ghiassi et al. 2003; Dietrich et al. 2006).

In the mass customization context the agents can be used for communication and coordination of activities within the supply chain. They can efficiently and effectively handle data exchanges between actors, as an example supplier and manufacturers. This can be a cost efficient and flexible way to ensure these processes are working effectively (Turowski, 2002)

In the study of Dietrich et al. (2006), the aim is to understand mass customizations effect on business information systems using agent technology. After giving background information, the authors explain the DAISY (Deliberative Agents for Intelligent Simulation Systems) framework. The framework is a methodology to help researchers analyze and implement agent based simulation systems for different scenarios.

The focus on Turowski (2002) is in a different aspect of multiagent systems; the e-commerce and electronic data interchange (EDI) applications connected with agent technologies. For a mass customization supply chain they propose to implement an agent system based on contract net paradigm where all actors (manufacturer and suppliers) are represented by different agents. These agents negotiate on the offer until an acceptable offer is reached and the ERP system creates an offer. In the case of failure again agents negotiate to create suitable conditions like shipment times or amounts. As a result of these systems Turowski (2002) argues that the mass customizing company would be more flexible, efficient and more responsive to the needs of the customers.

A part of the research done on the subject doesn't point to the technology directly. These researches rather integrate and explain different technologies and strategies to use them in the mass customization supply chain. The following papers show integrated solutions (Ghiassi et al. 2003), state of the art software systems (Romero et al. 2011) and ERP systems (Akkermans et al. 2008).

Ghiassi et al. (2003) studies a software system that satisfies the needs resulting from the changing supply chain and the environment it is in due to mass customization. It explains IT enablers for mass customization, especially object oriented (Java), intelligent agents and e-marketplaces and using these technologies to create a synchronized supply chain model. The proposed software for this model is LEAP, software which integrates all the technologies given in the research. The authors provide information about the characteristics, architecture of the software and benefits.

The research conducted by Romero et al. (2011) aims to present state of the art computer aided tools and their characteristics which help the mass customization process. The tools presented are computer aided engineering and manufacturing, production and planning, supply chain management and sustainable support tools.

Akkermans et al. (2008) focuses on the relations between Enterprise Resource Planning (ERP) systems and supply chain management. For the research a survey was conducted to understand the current SCM trends. Five of these trends, integration, customization, driver seat, information exchange and transparency, were selected for a deeper analysis to identify the shortcomings of current ERP systems. The main clusters of shortcomings found are: lack of extended enterprise functionality, flexibility to adapt altering supply chain requirements, lack of supporting functionality and open and modular system architectures.

Year	Author	Focus
2002	Helander and Jiao	Agent based systems
2002	Turowski	E-commerce
2003	Ghiassi, Spera	Software systems to support SCM
2006	Dietrich, Kirn, Timm	Agent based systems
2006	Ruohonen, Riihimaa, Makipaa	IT as an enabler
2006	Jiao, Helander	IT as an enabler
2008	Akkermans, Bogerd, Yücesan, Wassenhove	ERP systems
2011	Peng, Liu, Heim	IT as an enabler
2011	Romero, Osorio, Bentacur, Estrada, Molina	Computer aided tools

Table 2-2 - Information Technologies Research Stream

2.3. Relationship Management Research Stream

This research stream in the literature review is dedicated to the works on the relationship between actors in the supply chain. Apart from the material and monetary flow in the supply chain there is another very important flow to be considered: the information flow. It is becoming more and more important these information and knowledge flows and their effect on the other flows of the supply chain (Warkentin et al. 2000).

Physical supply chains created by suppliers, manufacturers, customers and other third party players, of which in the globalized world are not bounded by geographical, time or space constraints also help create a second very important network which is part of the supply chain created by the aforementioned information and knowledge, the value network (Warkentin et al. 2000). These networks, acting together and harmoniously, create modern networks which Monroy and Arto (2010) believes defined by globalization as well as strategic alliances, flexibility and mass customization. The advantage of these value webs is the increased efficiency and profitability of the actors of the system. The network has the ability to provide customized solutions to the customers in an inexpensive and fast manner (Warkentin et al. 2000).

These networks, which are based on the information and knowledge, are used to create environments which are characterized by information exchange based on the relationships between different actors (Warkentin et al. 2000). These free or easy information flows and the carefully managed relationships result in more efficient decision making which is beneficial and desirable by all the actors, mentioned by Warkentin et al. (2000) and Jitpaiboon et al. (2009), can have many benefits on quality, product variety, flexibility and many others (Liao et al. 2011).

It is believed to be appropriate to start with Warkentin et al. (2000), which provides an overviewed look over the subject. Warkentin et al. (2000) investigates the altered information flows between the actors on a traditional supply chain caused by the new web-based e-commerce activities. The authors describe how the linear information flow of supply chains turned into value webs, where all actors become connected with the removal of time, space and location constraints. Due to these webs, customer specific solutions can be created for mass customization. The paper also highlights new marketplace models which alter both internal and external relationships (industrial organizational effects) and macro and micro economic indicators.

The other article related to networks is Monroy and Arto (2010). In the study a data analysis was done for the modeling of Global Manufacturing Virtual Networks and gain understanding of the organizations that employ these networks. They proposed a network analyzing framework in four main categories network strategy, structure, communication systems and culture and knowledge sharing. Especially the third level, communication systems relate directly to the aim of this literature group because it tried to analyze the real time information flows, synchronized supply chain management and interactive product development. They used this network analysis on Rolls-Royce's global network case study.

In the literature these relationships are considered in two different levels between three different actors. The two different levels are cooperation and integration considered supplier-manufacturer, manufacturer-customer and internal of manufacturer categories. (Moser and Piller 2006; Wang et al. 2007; Jitpaiboon et al. 2009; Zhanga and Huangb 2010; Liao et al. 2011; Qin 2012). However before defining these concepts the relationship between mass customization and actor relationships are defined based on the literature.

2.3.1. Relationship management for mass customization

At different levels of mass customization involves customers in the system at different degrees (Pan and Holland 2006). Regardless of the point of involvement, mass customization transforms the traditional supply chain, the push strategy, into a pull strategy which is based on the relationship between the customer, the supplier and the manufacturer, which emphasizes the importance of relationship management.

Wang et al. (2007) states that, parallel to mass customization definition, customer information should be well accumulated and understood by manufacturer and provider of the good. However, this is not enough. This understanding should be also communicated and understood by the suppliers to ensure flexibility and smooth flows in the supply chain. This is provided by the information exchanged between customer, manufacturer and supplier, emphasizing the information flows and the importance of relationships.

There are different advantages of relationship management and managing information flows on the mass customization supply chain, like increased customer satisfaction and quality. For Liao et al. (2011) along with environmental uncertainty and enablers, inter-organizational relationships like trust and commitment affect information sharing and mass customization quality of a company.

2.3.2. Cooperation & Integration

Before advancing with the literature review it is important to understand the different types of relationships used, mainly the difference between cooperation and integration with different actors of the supply chain. Although both are used under and sometimes a synonym for relationships they usually denote to different types of associations between actors.

Cooperation is the mutually beneficial relationship between the actors of the supply chain. This relationship can be used to improve important outcomes like customer satisfaction, time to market or resource usage (Pan and Holland (2006)). In coordinative and cooperative situations the actors are centered on common objectives reducing duplicate activities for increasing value added activities (Zhanga and Huangb 2010). This is created through information sharing across the supply chain (Zhanga and Huangb 2010).

Integration is a more rigorous concept which aims to integrate the actors in both ends (downstream and upstream) with the internal functions to achieve an optimal supply chain process. This includes integrating processes, activities, locations etc. to optimize the performance of all actors as a whole (Jitpaiboon et al. 2009; Lau et al. 2010). Lau et al. (2010) argues that with integration decreases uncertainties increasing flexibility and the ability to response.

As seen from the above definitions cooperation (or coordination) results from information sharing along the supply chain based on common objectives of the actors however it does not require the integration of activities, just the presence of a relationship. However, in integration the actors are functioning as a whole rather than smaller, individual companies collaborating, optimizing as a single entity. This can show that there is cooperation in the integration strategy, but the vice versa is not true, cooperation does not signal integration.

After making the distinction, the different approaches of these strategies can be defined on the selected actors (mainly supplier, customer and manufacturer itself) of the supply chain.

2.3.3. Supplier and Customer Cooperation

Supplier cooperation is the activity of communicating and coordinating activities between the supplier and manufacturer for better serving the customer needs. This is done by the quick response capability created by the cooperation (Jitpaiboon et al. 2009). This within the supply chain can be done by building an information platform to manage and maintain the information flows, enhancing the participation of the suppliers and evaluating them to build better supplier relationships and enhance supplier management (Wang et al. 2007).

Similar to supplier cooperation, customer cooperation is based on enhancing customer relationship through information flow and using this information to better understand customers and their needs.

The four articles Pan and Holland (2006), Zhanga and Huangb (2010), Liao et al. (2011) and Qin (2012) focus on coordination of supply chain actors. The first three Pan and Holland (2006),Zhanga and Huangb (2010) and Liao et al. (2011) focus on the upstream relationships, i.e. relationships with the manufacturer, while only Qin (2012) sets to understand the relationship between the distributor and the manufacturer. No study was done to understand the customer cooperation on the supply chain; rather the literature is more concentrated on customer integration as it will be presented later.

The authors of Pan and Holland (2006) focus on the fashion apparel industry to investigate collaborative mass customization upstream, between the manufacturer and the supplier. The focused actor couples are textile suppliers and fashion apparel designers/brand houses and textile manufacturers and fashion apparel designers/brand houses. For these groups key interfaces are identified, like sales team communication and information transfer. The research shows that garment design processes are transferred from designer/brand house to the manufacturer’s domain which signals leanness and shift to mass customization. With this transfer some of the duplicate work carried out by both actors are eliminated, which is decreasing an important time loss in the process flow and decreasing the time from design to production, thus the cycle time. The work also emphasizes the creation of decision integrations and a continuous feedback chain which increases sharing information on customer preferences.

The study done in Zhanga and Huangb (2010) sets to understand the differences when a supplier and manufacturer moves with (with platforming) and without cooperation (without platforming) in a game theory approach. The performances are measured by the different costs and profits present. The results show that costs decrease and profit increases for both actors. Also it is discovered that for low demand levels the manufacturer’s purchasing costs increase, the manufacturer uses a low sourcing and tends to favor lower customization compared with high demand levels. Also it is found that supplier’s flexibility can affect platform product configurations of the manufacturer.

Like Zhanga and Huangb (2010) and Pan and Holland (2006), Liao et al. (2011) also examines the supplier-manufacturer collaboration. The authors, through an empirical study, research the effect of information sharing on mass customization capabilities. The findings confirm that higher information sharing increases with trust and also higher information sharing leads to a higher mass customization capacity of the manufacturer. The results indicate that companies must implement free information flow and sharing on product design, process, logistics and quality management for higher mass customization which can be created by higher trust.

Qin (2012), unlike the others, focuses on the manufacturer-distributor relationship. In the study a mathematical model, a stackelberg game, was created to find the optimal decisions that can be taken by the actors as in customization service and final product price, promised customization time of distributor and promised delivery time of manufacturer. The performance of the system, the objective function, is based on manufacturing cost of the product, service cost paid to the distributor to finish the final customization activities and penalty cost paid to the customer in case of late delivery. The profit and cost of both players are considered to represent the total cost and profit of the supply chain representing the cooperation between the players rather than maximizing their own profits. The results show that total cost of the supply chain is increased when penalty cost, average customization time and price elasticity of customization demand increase and elasticity of the delivery time of supply chain decreases.

2.3.4. Supplier Integration

The supplier integration, also called upstream integration, is the degree that suppliers are present in the activities of the manufacturing firm directly rather than through a supplier management system (Jitpaiboon et al. 2009). Jitpaiboon et al. (2009) and Liao et al. (2011) argues that this is a long time relationship based on trust, reliability and openness which will facilitate the information flow across the players of the upstream supply chain. This information and trust is not contained within the information on production or activities directly relating to the supplier, but as Moser and Piller (2006) states the data coming from customers and forecasting can also be an important input for a supplier. Integration facilitates this information to be shared across parties resulting in a more efficient supply chain.

Similar to the cooperation case the information systems are important to provide a platform for the integration which will help optimizing the supply chain (Wang et al. 2007). Also involving the suppliers in the early production activities, such as design, facilitate optimization by better communicating the requirements of the products from both ends which also helps the manufacturer to understand the supplier technology and benefit from it (Wang et al. 2007; Jitpaiboon et al. 2009). Lau et al. (2010) states that integration with suppliers reduces uncertainties, can promote integrated inventory systems and adding to these advantages can increase customer satisfaction and flexibility of the system (an enabler of mass customization).

2.3.5. Customer Integration

The second type of integration is downstream integration meaning integration with customers and in some cases retailers. The retailers can be part of this integration if the manufacturer is dependent on external partners to achieve distribution and connection with customers (Moser and Piller 2006).

Customer integration is making customers a part of the early product lifecycle, similar to the case with the suppliers, integrating them in design or engineering stages which help the customization aspect of mass customization (Pan and Holland 2006).

In the case of retailers Wang et al. (2007) lists many advantages of an integrated relation between an enterprise and its retailers. Understanding and mutual support, sharing of the risk and information exchange for better understanding the customers or issues about quality are a few of these which are coinciding with mass customization and its implications from the supply chain. Similar to upstream integration, downstream integration reduces uncertainties, increases customer satisfaction and supply chain flexibility (Lau et al. 2010).

2.3.6. Internal integration

Internal integration is the third pillar of integration available in the literature. This integration type deals with employees and information flow systems within the enterprise (Moser and Piller 2006; Wang et al. 2007; Lau et al. 2010). Cross functional teams across companies along with functional coordination to improve their performances as a company by bringing different departments together and enhancing their understanding of each other (Lau et al. 2010). The increased information flows result in a more efficient working enterprise in a mass customization environment.

The papers Moser and Piller (2006), Jitpaiboon et al. (2009), Lau et al. (2010) and Wang et al. (2007) center their attention on integration. Not focusing on a single aspect, all these papers look at integration from different perspectives which include supplier, seller, internal integration and also the role of information within the integration activities.

Moser and Piller (2006) are talking about a single German bicycle producer, Steppenwolf, which is practicing mass customization to provide its customers with customized bicycles. The study first focuses on the customer integration actions taken in the company and secondly on challenges which presented itself on all integration fronts, supplier, customer and internal. The authors emphasize the importance of the sales person in Steppenwolf's case, the customization is done in the store, and the assistance given to him by IT systems which aids them. Also the data collected from the customer is significant. This data is stored, up to 10 years and including bicycle configurations done per customer, and used not for only understanding customers and market trends, but also shared internally to create forecasts for all supply chain.

The second part of the work of Moser and Piller (2006), the problems related to the different integration types are considered. On upstream integration, the problem is based on suppliers' unwillingness to create faster replenishment systems resulting on high inventory costs for Steppenwolf. To solve this problem the manufacturer started to share the forecast data with

the suppliers to both help them plan their activities and demand a more flexible supply structure. When downstream is investigated, the problem arises from the lack of experience of retailers on selling customized bikes, many are mechanics, which effects the customer elicitation. To compensate for this fact, they invested in both shop design and creating sales guidelines and trainings for the sales personnel. The last point is the integral integration. In these activities the problem arises in the transition of employees from a traditional structure to mass customization which is not something they are very comfortable with. To counter with this, they are trying to make mass customization the focus point of the supply chain. Steppenwolf is trying to implement a scalable organizational model with flexible processes for future growth.

In the study of Jitpaiboon et al. (2009), both customer and supplier integration is investigated by obtaining survey information. Different indicators like participation levels of customer or suppliers in internal activities are asked to the 220 companies. The results show that a higher level of customer integration will result in higher level of mass customization. However, the same hypothesis for supplier integration was not supported which means the effect of supplier integration on mass customization is not known. The last hypothesis of the authors was also supported which signals that a high level of mass customization leads to a high level of organizational performance. The authors also point out that the inconclusive nature of the second hypothesis can be due to different levels and types of relationships that firms have with suppliers.

The next research (Lau et al. 2010) focuses on supply chain management as a combination of information sharing, product co-development and organizational coordination and their effect on product design and performance. The authors, based on a survey and two pilot studies on electronic, toy and plastics industries, tested some hypothesis regarding the points mentioned. The hypotheses did not support the positive relationship between information sharing-product performance and organizational coordination-product performance. The data supports the positive relationship between product co-development in supply chain integration and product performance. Also information sharing, product co-development, organizational coordination in a supply chain integration concept has positive relationship with product modularity individually. Finally it is also concluded that product modularity is positively correlated with product performance. Additional results show the positive relationship between product co-development with organizational coordination and information sharing. Also the positive effects exist between organizational coordination and information sharing.

The last research on integration literature (Wang et al. 2007) is a research on the how to harmonize and optimize different actors of the supply chain under mass customization. The research is focused on two pillars: suppliers and sellers. The authors suggest the usage of ERP for decreasing market reaction time, stock levels and waste within the system, synchronization of demand, production plans and material inventories and sharing information. They also suggest the usage of advanced technology and business process reengineering. For the other side of the supply chain, the sale link, the research focuses on an information exchange and an urging mechanism while as a system aiming to increase customer satisfaction.

Year	Author	Focus
2000	Warkentin, Bapna & Sugumaran (2000)	Supply Chain Relationship
2006	Pan & Holland (2006)	Supplier, customer and internal integration
2006	Moser & Piller (2006)	Supplier-manufacturer coordination
2007	Wang, Fan & Li (2007)	Supplier-seller integration
2009	Jitpaiboon, Dangols & Walters (2009)	Supplier-customer integration
2010	Zhanga & Huangb (2010)	Supplier-manufacturer coordination
2010	Lau, Yam & Tang (2010)	Global manufacturing virtual networks
2010	Monroy & Arto (2010)	Integration, product performance and modularity
2011	Liao, Ma, Lee & Ke (2011)	Supplier-manufacturer coordination
2012	Qin (2012)	Manufacturer-distributor coordination

Table 2-3 - Relationship Management Research Stream

2.4. Modularity Research Stream

The research stream focuses on the modularity research done on mass customization supply chains. The main areas of focus are coordination and integration with supply chain actors (Howard & Squire 2007; Lin et al. 2009; Lau et al. 2010), explanation of characteristics of modularity as a mass customization supply chain strategy (Wang 2007; Ro et al. 2007; Lau 2011) and optimization of modularity on the supply chain (Cunha et al. 2007).

Modularity refers to the concept of where the final product is the made up of smaller parts and components, which are called modules, which can be independent in design and production. With mixing and combining of these independent modules, the final product gets different characteristics and functionalities. Within this concept, with a finite number of modules a high number of final products can be realized (Howard & Squire 2007; Ro et al. 2007; Cunha et al. 2007; Lin et al. 2009, Lau 2011). This can be done best on product families, which share similarities in function, structure and technology (Wang 2007).

Lau et al. (2010) defines that a modular product design must have three characteristics: separateness, specificity and transferability. Separateness is the ability to separate the product into modules and reassemble a different configuration without suffering from a decrease in the functionality. Specificity refers to every module having a specific and clear function on the product system. Finally, transferability shows the degree of which the same module can be used by different items within the system. As the level of these characteristics increase the modularity can be used more efficiently within the supply chain.

There are two different kinds of modularity which can be realized within the supply chain, the product and process modularity (Wang 2007). Product modularity refers to, as explained before, structuring the product with modules which have different purposes on the product architecture and corresponds to different functions on the end product. These different modules can be used within different products within the product family, limiting the number of total modules and increasing the transferability. Process modularity concept has the base idea similar to the product modularity, but on a larger, process scale. In process modularity the supply chain processes are divided into modules which are cells performing similar activities. These process modules are independent from each other so can be easily rearranged to enable different network designs, working in parallel or in different sequences.

As in any situation there are different advantage and disadvantages related with the modularity concept. One of the few advantages are modularity can increase product variety, decrease lead times of the products and can result benefiting from economies of scale due to high volumes of shared modules even if the end products are not the same (Ro et al. 2007; Lau 2011). Adding to these reused modules can increase speed of product development, quality problems are treated easily due to localization, experience curve is exploited due to high volume module production, and postponement and mass customization enabling are given as advantages in the literature (Lau 2011). However, mass customization can also decrease product differentiation resulting from increased product similarities, the end product cannot be optimized in terms of mass, size and performance and competitors can copy designs easier.

One of the examples to understand the concept better is the Smart car project done together by Mercedes-Benz and Swatch. The Smart car, unlike traditional car architectures, is based on five principal modules. The low number of modules decreases the number of suppliers (from around 300 to 25) who are integrated into manufacturing and assembly facilities. This leads to sharing of risk, decreasing costs, increasing distribution speed, flexibility and higher collaboration between actors (Howard and Squire 2007; Lin et al. 2009).

Three of the researches (Wang 2007; Ro et al. 2007; Lau 2011) in this research stream focus directly on the characteristics of modularity and its place as the enabler of mass customization.

Wang (2007) first aims to understand the modularization and standardization processes in a supply chain, namely component, process, product standardization and product and process standardization. After this introduction the authors focus on mass customization supply chain difficulties due to product varieties and how modularity helps overcome them. One of the main points is modularity helps general components to be completed earlier and independently from each other (as modules) which helps with uncertainties of inventories and capacity requirements of production. As mentioned before modules increases flexibility and facilitates the determination of quality problems. They can also decrease costs of production, inventory and transportation which tend to increase in mass customization supply chains. The modules can be used within product families, general modules even between different markets.

Apart from explaining these advantages the research communicates the characteristics of a product family oriented supply chain. As a conclusion the authors propose a modeling of the supply chain oriented product family supply chain.

Similarly Ro et al. (2007)’s focus is how modularity alters the processes in the supply chain, how it affects supplier buyer relationships, what forces affect modularity and if modularity is a good strategy to achieve mass customization in the automotive industry. They identified different kinds of modularity strategies used throughout automotive industry history to from outsourcing part of the assembly to fully designing modules with suppliers which is based heavily on supplier manufacturer relationships. The authors also explain the move towards modularity and mass customization within the American automotive industry. One of the

important points of the study is how the modularity affects the supplier manufacturer relationships and what are the problems associated with it. The identified problems are conflict of the sourcing power, lack of trust and warranty and liability issues. These issues started to rise as the actors became more integrated due to the modularity context.

In Lau (2011), the six different case studies of companies of who adopted different levels of modularity are analyzed based on product characteristics, pre-defined product advantage, module definition, selectively used design rule, system integration, internal communication, technological newness and supplier and customer coordination. Based on these case studies, different conclusions are received on these analysis groups. It is found that the product variety signals the product advantage in modularity along with customization and standardization. The module definitions tend to be extended by manufacturers to include intangible knowledge. The design rules are substituted by experience in small companies also difficult to implement design rules are not chosen. In system integration, large firms have formal teams which handle integration, in small companies the middle management substitutes for these teams. New module development causes significant increase in balancing the coordination of the supply chain regardless of the size of company. Internal communications tend to be more informal in small companies and more formal in large ones.

Adding to these, Cunha et al. (2007) proposes a mathematical model to optimize the supply chain to find the configurations of modules with lowest cost in an assemble-to-order system. The results show that mean assembly times and transportation costs of the system have important effects on the optimal number of modules; as the mean assembly time increases the optimal number of modules also increases. In the example given it is cost efficient to stock items rather to assembly them in a nearby location due to high transportation costs, so the system yields a lower overall cost when the number of modules are lower. The results also show that make-to-order increases costs 25% when compared to the optimal solution.

2.4.1. Supplier – manufacturer relationships and modularity

As modularity becomes an important concept on mass customization supply chain, the supplier-manufacturer relationships became more collaborative (Lin et al. 2009). Due to this reason part of the research stream focuses on supplier chain integration, especially supplier-manufacturer relationships and how modularity affects these relationships (Howard & Squire 2007; Lin et al. 2009; Lau et al. 2010).

The authors of Lin et al. (2009) set to understand the supply chain and its actors using a 3C (context, capability and configuration) approach on certain case studies. The case studies are chosen from companies which practice different levels of modularity. The results are based on the comparison of two different scenarios of fully integrated and partly integrated modules (FIM and PIM respectively). In FIM both actors (supplier and manufacturer) are practicing modularity, however in the PIM approach the manufacturer is practicing modularity but the suppliers are beginners in this strategy.

Under the first C, context, in FIM the supplier delivers a fully integrated module to the manufacturer, however in PIM the module is not fully integrated when it reaches the manufacturer; the subassembly is finished afterwards. The capability refers to four subgroups

of design, production, inbound logistics and information, in which the FIM supply chain is more directly connected with the supplier. The design is provided to the manufacturer as a complete solution, the production of the integrated module is finished in the supplier site, the integrated module is delivered directly and not reworked by third parties and there is full visibility. However in the PIM modular supply chain all of these characteristics are partly achieved. The last pillar, configuration, is based on three items, role structure, process structure and information structure. In FIM the supply network is two-echelon but in the PIM the echelon count is higher due to other actors which affect the process structure also. Finally on the information structure there is more information flow on the PIM supply network because of the more number of actors.

Howard & Squire (2007) focuses on modularity, and collaboration between supplier and buyer using two regression models. These models use different mediating variables, asset specificity and information sharing, to test the affects. The results show that, first, collaboration between the actors is positively affected by modularity. With the replacement of traditional sourcing with modular ones the processes of design, production and delivery shifts to be joint decisions. With this movement the collaboration and responsibility sharing increases between actors. Adding to the analysis it is found that intermediaries, asset and information sharing, mediate the collaboration in the modularity environment. On asset specificity, the increase in modularization increases the assets based on supplier-buyer relationships (such as data exchange and quality accreditation) which also increases collaboration. Modularization also enhances information sharing due to the integration of the actors, which shows that information sharing leads to better collaboration and increased modularity capability.

The last study, Lau et al. (2010) aims to understand how product modularity and supply chain integration interact with each other and what kind of relationship they have between them. The results of the cross case analysis identify four contingency factors between modularity and integration which are new module/component development, technological knowledge leakage/capture, project team size and supply chain efficiency. The results show that modular design usually relates to loosely coordinated supply chains while integrated design results in tightly coordinated supply chains. It is found that when the modules and components are innovative, rather than standard, the integration increases due to the need of close connections with suppliers and customers. Another result shows that knowledgeable customers are involved in new product development, for both modular and integrated design. The team sizes are important factors to assess the affect of product modularity on internal integration. When the product development groups are small and there are no sub teams the information flows and sharing decreases due to low need of information sharing which ends with almost no effect of modular products on internal integration. The last point found by the authors is regardless of the design type, integrated or modular, production information must be shared with among actors of the supply chain which points to increased integration between all partners.

Year	Author	Focus
2007	Howard and Squire	Modularity strategy
2007	Wang	SC relationships
2007	Ro, Liker and Fixson	SC relationships
2007	Cunha, Agard and Kusiak	Optimization of modularity
2009	Lin, Zhou, Shi and Ma	Modularity strategy
2010	Lau, Yam, Tang and Sun	Modularity strategy
2011	Lau	SC relationships

Table 2-4 - Modularity Research Stream

2.5. Customization Level Research Stream

The research stream on customization level is made up of works of different authors aimed to answer how customization levels affect mass customization capability and supply chain characteristics and how mass customization supply chains can be configured for different mass customization levels.

In mass customization, which aims to provide customized products to the consumer (Wang 2011), the level of customization is an important characteristic. The mass customized supply chain should balance different factors to find a level of customization which they can provide to the customer. These different factors include waiting time for the product, inventory and transportation costs, feature of the products, level of modules and standardization and others (Yu and Jie 2008).

2.5.1. Customer Order Decoupling Point

The customization level or the level of customer involvement within the system is determined by the Customer Order Decoupling Point (CODP). The CODP is the point in the supply chain where the customer input starts making changes on the production activities (Poulin et al. 2006; Yu and Jie 2008). In this turning point the manufacturing turns from based on inventory or stocking, to base on customization. Upstream to the CODP, the system can be considered to be a push system and after the point a pull system based on customer orders (Yu and Jie 2008; Wang 2011). Also it should be noted that as CODP moves closer towards the customer it can ensure shorter delivery times, but this can limit customization options provided to the consumer. The scope of customization increases as the point moves away from the customer (Yu and Jie 2008).

Even though when a CODP is fixed after it is defined (Wang 2011) a system can have more than one CODP. These systems with multiple CODPs are investigated in this research stream by Yu and Jie (2008) and Wang (2011).

The aim of the research of Yu and Jie (2008) is to introduce and explain the mass dynamic customization systems (MDCS). These systems are characterized by having multiple or mobile CODPs within the system. Products or orders can be grouped together to fix certain CODP within the system while other groups can have different CODPs. This can be based on the popularity of the products, which is found from analysis of the demand information. The

authors emphasize that in MDCS when the demand changes, the location of the CODPs can also change rendering the system flexible.

Similarly Wang (2011) investigates multi-CODP systems. They start by explaining the restrictions of single CODP systems based on an electrical bicycle supply chain as a case study. In single CODP systems every customer must wait the same amount of time before delivery, even though some orders are more standard than others. Also when the CODP is fixed, the changes which can come with time cannot be reflected upon the supply chain. Based on customer preferences, like Yu and Jie (2008) also believed, high demand product groups can be clustered together to be considered as a single CODP point and the push part of the system can be forecasted. These movable and multiple CODPs solve the flexibility problem of single CODP systems which can occur over time.

2.5.2. The Four Representative Supply Chains

In the literature the different CODP points are identified by different names based on where they are located. In the following part it will be seen how these different points can be named and defined as well as their characteristics and customization levels (Salvador et al. 2004; Poulin et al. 2006; Stavrulaki and Davis 2010; Yimer and Demirli 2010).

The study of Poulin et al. (2006) focuses on the golf industry and proposes a personalization framework based on different CODPs within the system. They identify eight customization options named popularizing, varietizing, accessorizing, parametering, tailoring, adjusting, monitoring and collaborating. These different options start with popularizing which is the group where off-the-shelf products are found to collaborating, where the customer is seen as a collaborator of the design. The same points can be defined as sale-to-order, deliver-to-order, assemble-to-order, finish-to-order, make-to-order, design-to-order, and supply-to-order options respectively. These titles give the reader a more clear understanding where the CODPs are located within the supply chain. The authors define this framework to optimize the total manufacturing costs, respecting delivery times and providing the customer with the customization they desire. So the best fitting customization offers should be chosen by companies based on these factors.

In a similar way Stavrulaki and Davis (2010) also proposes a framework, but consisting of less decoupling points within the system. They provide four strategic points on the system, which correspond to build-to-order (BTO), assemble-to-order (ATO), make-to-order (MTO) and design-to-order (DTO) supply chains. After giving detailed product, manufacturing and logistic related characteristics and their effects on the supply chain they propose a matrix based on these characteristics and core competitive focus of the companies which practice them. The companies can locate themselves on the framework to align products and their strategy.

They also provide information on how these different supply chains are performing on different aspects like customer relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, supplier relationship management, product development and commercialization and returns management.

The authors of Yimer and Demirli (2010) focus on the build-to-order (BTO) systems and create a model on how to optimize the supply chain based on this strategy. The model is based on two phases, the first one is a dynamic model to plan assembly and distribution of final products and the second phase is to plan the component manufacturing and raw material procurements based on the plans calculated by the first phase. Different costs, lead times, assembly and production times, capacities, customer service requirements and other supply chain factors were considered during the creation of the model.

The last paper which is the part of this research stream (Salvador et al. 2004) presents their findings on six different case studies to give insights on different supply chain configurations which allow companies to be mass customizers. They base their findings on two different strategies, soft and hard mass customization. Soft mass customization is when the customers are not asking for high levels of customization and are not willing to wait, but usually buy off the shelf. On the other hand, hard mass customization happens when the customer is requesting highly customized products and is willing to wait for the customization. These two opposite strategies are compared based on modularity type, distribution network, manufacturing network and supply network and their place in operational performance.

The main findings are on hard MC the distribution network acts as ATO or MTO system when on soft MC it works on a make-to-stock basis. On the suppliers the effects of the hard MC is much higher and require collaboration and information exchange with the manufacturer while on soft MC very small amount of suppliers are affected. On operational performance, which is measured by cost effectiveness, timeliness of delivery and degree of customization, the two different supply chains focus on different measures. Namely soft MC can focus more on cost effectiveness and timeliness while hard MC can make a tradeoff and score better on degree of customization.

Year	Author	Focus
2004	Salvador, Rungtusanatham and Forza	Differeny CODP systems (BTO, ATO, MTO, DTO)
2006	Poulin, Montreuil and Martel	Differeny CODP systems
2008	Yu and Jie	Multiple CODP systems
2010	Stavrulaki and Davis	Differeny CODP systems
2010	Yimer and Demirli	Build to order systems
2011	Wang	Multiple CODP systems

Table 2-5 - Customization Level Research Stream

2.6. Flexibility and Agility Research Stream

The research stream on flexibility and agility focuses on supply chains using these two strategies in a mass customization environment. This chapter will explain these concepts and shows what kind of research was done on the subject.

2.6.1. Agile supply chain

The agile supply chain is described as the dynamic network of supply and demand in the literature. This network consists of all the actors of the supply chain including suppliers, manufacturers and distributors. The agile supply chain is able to respond quickly to the dynamic environment it is situated in, which is defined by cooperation and competition

(Weizhe & Zhihua 2010; Benzheng 2011). The cooperation within the supply chain is enabled by different IT technologies (Song et al. 2007).

Song et al. (2007) believes that agility consists of two sub-groups which gives this dynamicity and the quick response ability. These characteristics are flexibility and reconfigurability. Flexibility, which will be explained in more detail in the second part, is the skill to adjust the systems to fulfill the changing demands. Reconfigurability is the ability to change with the changing needs of the customers.

The study of Benzheng (2011) focuses on how incentives affect the agile supply chains and mass customization capability. The incentive mechanisms introduced are based on cooperation and risk sharing within the system. They group incentives in different groups based on the subject and object (the giver and the receiver). The subject and object can be different supply chain actors, mainly suppliers, manufacturers, customers and logistics providers. A simple model was created to illustrate the subject better. The incentives offered are based on price, order, reputation, information, co-development, organization, trust, enterprise culture, penalty and elimination incentives.

Weizhe & Zhihua (2010) investigates the agile supply chain in the clothing industry. The aim is to optimize the mass customization supply chain by using the agile thinking to create an agile supply chain and integrating the lean production principles. They believe optimization should be done on standardization and modularization of parts, information platforms, delay manufacturing strategy implementation, supplier management and vendor management inventory to be able to benefit from all advantages agility on the supply chain.

The authors Song et al. (2007) present a multi-agent model for agile supply chain practicing mass customization. They explain a system based on two different agent types, functional and mediators. While functional agents control and plan the system the mediators act as coordinators in between. The authors present a model which ensures that the supply chain produces “the right products in the right quantities (at the right location) at the right moment at minimal cost”.

Yu et al. (2008) focuses on the subject of quick response ability. An index system is created to evaluate the quick response ability of a mass customization supply chain. The quick response ability is evaluated on five aspects: timely material supply, quick demand response, quick production design, quick production manufacture and quick production distribution.

2.6.2. Flexibility

Flexibility is the ability to respond to changes in the environment (Yi et al. 2011). The uncertainty resulting from the environment can be because of suppliers due to lead time or quality, market demand, the information flows within the system or the competitors (Yi et al. 2011). To deal with this, different flexibility strategies were proposed by different researches (Salvador et al. 2007; Yi et al. 2011).

In Yi et al. (2011) a framework is presented for companies to understand and implement different flexibility strategies based on their characteristics. Four strategies, conservative, laggard, agile and aggressive, were proposed by observing case studies based on different

dimensions of flexibility. These dimensions are sourcing, operating system, organizational and distribution flexibility. Based on the case studies few propositions are made by the authors. The first one is when the level of uncertainty is low a conservative flexibility strategy is favored. For high level of uncertainties of supply chain, agile flexibility strategies are put in place. The aggressive flexibility strategy is put in practice by restructuring the companies operating systems to decrease the effects of uncertainties resulting from the environment or finding new ways to increase the flexibility of the supply chain.

The work of Salvador et al. (2007) sets to understand two different flexibility strategies of build-to-order supply chains. These flexibility strategies are volume and mix flexibility. Volume flexibility is used to describe the ability respond to environmental changes by changing the volume of production without losing the cost effectiveness while mix flexibility aims to change the mix of items produced. The authors give an example to these strategies using LawnWorks, a manufacturer of lawn tractors as a case study.

Year	Author	Focus
2007	Song, Fu, Zhu and Xin	Agile supply chain
2007	Salvador, Rungtusanatham, Forza and Trentin	Flexibility
2008	Yu, Ma and Li	Quick response ability
2010	Weizhe and Zhihua	Agile supply chain
2011	Benzheng	Agile supply chain
2011	Yi, Ngai and Moon	Flexibility

Table 2-6 - Flexibility and Agility Research Stream

2.7. Mass Customization Strategy Research Stream

The mass customization strategy research stream consists of works which do not deal with a single aspect of mass customization but give a broad overview of the strategy. Because they cannot be grouped together each paper will be explained individually.

Trappey and Wognum (2012) give a short research article collection about mass customization and demand-driven value systems. Based on the literature, the authors mention reproduction decision support systems which help with sale forecasting. They also talk about how transparency is an important characteristic for attracting and interacting with customers in demand-driven environments.

In the study of Buffington (2011), a comparison between mass customization and generative customization is done based on customer's involvement levels and willingness in the system. In generative customization, the customers are not actively involved in the customization process but rather virtually involved using a generative design process. Based on their study they found that customers are willing to pay for the design process, they are unwilling to pay a price premium for mass customization and don't have more than a few days of extra tolerance for a customized product. However, customers are inclined to consider a mass customization product if the proposed value is satisfied. When branding is considered, it is found to be more important the value and buying experience than brand loyalty and customers don't pay much attention to brand messages. Based on these results it is suggested that

generative customization can fulfill customer requirements, aiming to address problems with willingness to wait and pay premium prices.

The aim of MacCarthy et al. (2003) is to give a unifying framework of mass customization strategy for supply chains. They identified six processes which create mass customization. These processes are order taking and re-ordination, product development, product validation and engineering, order fulfillment management, order fulfillment realization and post-order processes. Based on these processes, five different modes of mass customization were created. The first, catalogue MC, the engineering is done before the order comes to the company. In fixed and flexible resource design per order MC, the product is engineered for the customer, however there is one difference. In the latter the order fulfillment is specific for the product, while for the first it is standard. The fourth mode is fixed resource call off MC the item is designed for the customer and the customer can order anytime through a standard order fulfillment process. The last one, flexible resource call off MC, is the same with again a difference in the order fulfillment process, the process is modifiable.

On Dong et al. (2012) a process representation is given for the garment industry mass customization supply chain. The main processes included are a tailored system for collecting and storing of customization information, data analysis system to analyze the data collected, customized design system which designs according to the output generated by the analysis system, an inventory system which manages inventories, distribution management system, which manages the distribution network and CAD/CAM system which provide IT solutions to the supply chain. As an example the Adidas system is presented at the end of the studies.

Liu & Deit (2011) aims to understand how management enables mass customization in a supply chain. Based on their survey, the results show empirical evidence that customer focused product design and supplier lead time reduction are increasing the mass customization capability of a company. Also the hypothesis about supply chain planning positively impacting supplier lead time reduction and customer focused product designs are supported.

Mikkola and Skjøtt-Larsen (2004) focuses on three supply chain strategies, mass customization, postponement and modularity. First they give different characteristics of these supply chains and contrast with the traditional supply chain on interface compatibility effects, component customization, value inputs and supplier-buyer interdependence. After they give more detail about postponement and modularization strategies.

The final research in this stream Barutcu (2007) is based on the concepts customized products, relationship marketing, mass customization and agile manufacturing. For relationship marketing, four main key stages are identified. These are, identifying, differentiating, interacting with the customer and customizing the products. The other concepts are also explained and as a result an integrated strategy has been presented by the authors. According to this framework, personalization starts with relationship marketing strategy and then mass customization IT, flexible processes and organizational structures come into the picture. The companies must have agility, flexibility and responsiveness in their

supply chains to be able to keep up with the changing markets. Finally supply chain management keeps all the supply chain in harmony, enabling information and material flows.

Year	Author	Focus
2003	MacCarthy, Brabazon and Bramham	Unifying framework for MC
2004	Mikkola and Skjøtt-Larsen	MC, postponement and modularity
2007	Barutcu	MC, relationship marketing and agile manufacturing
2011	Buffington	MC vs generative customization
2011	Liu and Deit	MC on supply chain
2012	Trappey, A.J.C., Wognum, P.M.	Literature review on MC
2012	Dong, Jia, Li and Dong	MC on supply chain

Table 2-7 - Mass Customization Strategy Research Stream

2.8. Performance Research Stream

This research stream consists of works which are concentrated on the performance of the mass customization supply chain under different strategies. The strategies considered are modularity (Lau et al. 2007; Cheng 2011), co-development of products (Lau et al. 2007) and elicitation, flexibility in design, advanced manufacturing technologies and just in time practices (Zhang et al. 2011).

The work of Cheng (2011) searches for performance metrics to measure the effects of organizational modularity in the company. Organizational modularity is described as autonomous but interrelated sub-systems in the organization. Four metrics are used to measure the performance of the systems; product, specialization and capacity utilization to measure the efficiency of the system and return on investment (ROI) and return on assets (ROA) to assess profitability. To study concludes that organizational modularity tends to have a decreasing effect on product specialization but increasing on capacity utilization. For the profitability metrics, the regression model shows that higher organizational modularity leads to higher ROI and ROA for the company.

Lau et al. (2007) aim is to understand the relationship between modularity, co-development and performance and also how can supply chain integration improve supply chain performance. To do so, all concepts are considered to be consisting of different sub-strategies for measurement and explanation. For co-development and thus integration, these variables are supplier, internal and customer co-development. In the model performance of the supply chain is described by flexibility and customer service as the literature suggests.

The results of Lau et al. (2007) show that co-development has a positive relationship with product modularity which has a positive relationship with flexibility and customer service. Increased flexibility and customer service causes increased product performance. The results also suggest that market stability has a positive relationship with supply chain integration.

Zhang et al. (2011) researches the mass customization practices and their effects on the company's performances. According to the results achieved by the surveys conducted, the operational performance of a supply chain, both in cost and quality, has positive effect on the

financial performance of the company. Keeping this in mind, it has been proved that elicitation practices and integrated logistics information systems interface (an interface which enables real time collaboration) has a positive force on operational performance. For application flexibility, there is evidence to support the positive effect on cost performance but not quality. The same case is present for advanced manufacturing technologies. According to the study the JIT supply chain hypothesis about operational performance are not supported.

Year	Author	Focus
2007	Lau, Yam and Tang	Modularity, co-development and SC performance
2011	Cheng	Organizational modularity and SC performance
2011	Zhang, Qi and Zhao	Customization pracitecs and SC performance

Table 2-8 - Performance Research Stream

2.9. Inventory Management and Scheduling Research Stream:

The inventory management and scheduling research stream consists of works which are focused on inventory management (Aigbedo 2007; Guohua and Jihong 2010), and scheduling problems (Yaoa & Liub 2009; Fei et al. 2009) of the mass customization systems as the title suggests.

2.9.1. Inventory Management

The focus of the research of Aigbedo (2007) is the inventory management in the just-in-time supply chain. The study was done to understand how the mass customization supply chains' inventory levels are affected in the automotive industry. To study this subject a mathematical model was proposed to act as a basis of a simulation study. As the results of the simulation study it has been found that making supply frequency more frequent results in higher inventory levels for the manufacturer. The results also demonstrate that as customization level increases, the inventory levels also increase to prevent stock outs of the parts in the system.

The other study on inventory management (Guohua and Jihong 2010) focuses on a supply chain with three actors (supplier, manufacturer and distributor) to understand the effects of target inventory and order cycle time of different actors on the system. The simulation study illustrates that the supplier order cycle time can be increased up to an optimal point where the delivery ratio of all the actors also increases. However after this optimal point, the manufacturer and distributor's inventories face problems with satisfying demand. The same effect of increasing all the delivery ratios cannot be done by changing the distributor's order cycle time.

The target inventories of different actors affect the system differently. When the target inventory of the manufacturer is changed, it affects the deliveries of supplier and manufacturer but not the distributor. If the inventory target of the supplier is changed, it affects all three actors in the supply chain. However, as changing suppliers levels the delivery ratios cannot have a positive position for all actors, the solution does not improve the delivery ratios of all actors at the same time, it is local.

2.9.2. Scheduling

The authors Yaoa & Liub (2009) create a dynamic and multi-objective model to optimize the scheduling problem of the mass customization supply chain. As a result of the model several problems are identified which can cause problems in the mass customization scheduling problem. The points which need attention are production congestion at some nodes, timely delivery, dynamic characters and irregularities in the system.

The last study (Fei et al. 2009) focuses on real-time scheduling problem for production and distribution in the mass customization supply chain. The advantages of the model created are listed as follows. It enables coordinate distribution allocation which results in lower costs of inventories and low service levels. It enhances the market pull characteristics of mass customization and takes into account all objectives of the supply chain with realistic decision variables. At the end of the study numerical results are given to demonstrate and validate the model.

Year	Author	Focus
2007	Aigbedo	Inventory management
2009	Yaoa and Liub	Scheduling
2009	Fei, Meng-na, Bao-feng and Hua	Scheduling
2010	Guohua and Jihong	Inventory management

Table 2-9 - Inventory Management and Scheduling Research Stream

2.10. Commonality and Platform Products Research Stream

This research stream focuses on commonality and platform products in a mass customization concept. The main areas focused in the supply chain are performance (Huang et al. 2005) and supplier-manufacturer relationships (Huang et al. 2007) in relation with commonality and platform product practices.

For a mass customizer company a common platform denotes a platform based approach where the different products which similar properties can share. These platforms can be components, structure or production processes. The advantages associated with commonality and platform products are easier scheduling and planning due to common components, lower setup and handling costs, decreased safety stocks, lower lead time uncertainty due to suppliers and ability to benefit from economies of scale (Huang et al. 2005). However, it should be noted that these advantages are achieved by the trade-off between providing the exact customized product wanted from each market segment and the benefits gained by the economies of scale from the usage of common platforms (Huang et al. 2007).

2.10.1. Supply Chain Configuration and Performance

Huang et al. (2005) aims to understand the effects of platform commonality and supply chain performance by constructing a model to optimize the platform product configuration. Three different cases for two products, one together with commonality and two individual cases without common platforms were analyzed to understand the differences. Two decision variables are considered for the optimization: option selection and service time.

As a result of this optimization problem, it has been found that the results of the configurations are dependent on variation of demand rather than the level. When the variation is high, the optimal solutions shift to solutions with lower lead times. The option with commonality provides higher service time allowances by the presence of short service times of assembly and ability to react fast to the changing demands. Also, the option with commonality is affected less by the demand variation. The configuration of the supply chain does not show an excess change in the optimal solution when the coefficients for the demand (variation) changes which is not the case in configurations without commonality.

The costs on all cases increase with demand variability, however the common platform options shows a lower increase which points to the ability to buffer variation. Also quantity discounts have important effects on configuration of the supply chain. It has been observed that quality discounts have a higher impact on the optimal solution than the demand variability.

2.10.2. Supply Chain Relationship

The study of Huang et al. (2007) focuses on modeling the relationship between supplier and manufacturer with a game theory approach. The aim of the model is to understand how platform product development and supply chain configuration decisions affect each other for both actors.

At the end of the study in the simulation results it was found that the manufacturer aims to give more customized products when the demand is higher. Platforming strategies are more profitable for both manufacturer and suppliers in the system. The manufacturer's inventory levels drop with platforming option but the purchasing costs might increase when demand is low. Also, the manufacturer can agree to higher charges from the supplier's to be able to share the benefit and take different platform product development decisions based on suppliers' flexibility.

Year	Author	Focus
2005	Huang, Zhang and Lo	SC Configuration and performance
2007	Huang, Zhang and Lo	SC Realationships

Table 2-10 - Commonality and Platform Products Research Stream

2.11. Collaborative Product Development Research Stream

The product development research stream consists of three studies on different subjects: concurrent engineering (Kincade et al. 2007), architecture based product development (Mortensen et al. 2008) and collaborative design (Trappey and Hsiao 2008). Each subject will first be explained based on the research and then the findings will be presented.

2.11.1. Concurrent Engineering

Concurrent engineering takes the linear, traditional product management process and transforms it into a partly simultaneous, integrated process. It links different stages of product development and production. The most commonly used concurrent engineering processes are

design for cost, lifecycle (inspectability, maintainability and reliability), manufacturability, enabling technology and quality (Kincade et al. 2007).

Kincade et al. (2007) believes that with using concurrent engineering the companies can become more consumer-centric, a better mass customizer and focuses on especially apparel industry. They used a survey to assess the frequency of using the seven different concurrent engineering processes (design for cost, lifecycle etc.) at three different companies in the apparel industry. They used different operational statements to understand deeply the usage of these processes.

The results show that the operational statements based on concurrent engineering represent their different product development processes. The design for cost processes are used by product development activities which are cost-related. Design for enabling technologies is used by activities based on information and decision making. Design for inspectability covers activities related to colors and specifying the products while for maintainability covers fabric testing based on performance. For reliability includes the activities of designing different prototypes. Design for manufacturability take in activities which encompasses close to mass production efficient production processes of mass customization and finally for quality are activities which consumer-centric such as goals, consumer demand data to determine the customer needs.

2.11.2. Architecture based product development

Architecture based product development emerges from integration of three different factors into the product architecture. These factors are market demand, product architecture and production layout. By considering all these factors a design which benefits fully from modularization can be created (Mortensen et al. 2008).

Based on this concept, Mortensen et al. (2008) proposes their own methodology for designing for architecture based product development. They start from the architecture design presented in the literature. The literature shows the different characteristics that the aforementioned factors include. These are, for market aspects, market segmentation, product features and specification ranges, for product assortment aspect, interfaces, constraints and component assortment and for production/supply chains production layout and process technology. All these factors should be aligned in the design phase.

The authors develop an eight step methodology for achieving the alignment between these factors. These steps start with understanding customer needs, create overviews, combine them, visualize and evaluate the concepts. The methodology is explained in detail with a case study in the research.

2.11.3. Collaborative design

Collaboration can be simply explained as different people in a system working together without the constraints of the physical world around them. Throughout the literature different methods, like over the internet or multi-agent systems, are proposed to make this possible (Trappey and Hsiao 2008).

The study of Trappey and Hsiao (2008) focuses on implementation of an advanced production quality hub (APQP) which will make collaboration between different actors on the supply chain possible. The authors describe the current model as lacking collaboration in design phase; all designs are done independently from each other. Also due to lack of collaboration, the design changes which are needed to keep up with the changing demand cannot be shared on-time and effectively, also pointing out the lack of visibility between different supply chain actors.

The APQP hub implementation would provide a categorized part library, online combination of parts, online ordering, real time information exchange between supply chain actors and by a combination of these, collaborative design. The implementation of APQP hub is aimed to address all these problems while shortening the design phase. In the test runs the new product planning phase was shorter than the original case by 1.5 months. Additional benefits on design quality, supply chain efficiency and product visibility are also seen.

Year	Author	Focus
2007	Kincade, Regan and Gibson	Concurrent engineering
2008	Mortensen, Pedersen, Kvist and Hvam	Architecture based product development
2008	Trappey and Hsiao	Collaborative design

Table 2-11- Collaborative Product Development Research Stream

2.12. Manufacturing for Mass Customization Research Stream

The manufacturing research stream consists of two studies (Tuck and Hague 2006; Hauslmayer and Gronalt 2008), based on how manufacturing activities are designed and affected by mass customization.

Hauslmayer & Gronalt (2008) researches the manufacturing systems used on woodworking industry and how the transition to mass customization is in relation with these systems. They analyze different modularization options and how they are affecting the production process of the floor boards. After recapping current state of the floorboard production, they introduce two modularization concepts: sorted and unsorted modularization. A simulation study is run to understand how these two modularization concepts differ on several outputs as order fulfillment rate and stock levels.

The study Tuck and Hague (2006) focuses on the concept of rapid manufacturing and mass customization, more precisely on different types of supply chain strategies like lean, agile and leagile supply chains. According to the study, rapid manufacturing can aid mass customization mainly in two ways. The first one is aesthetically and the second level is by capturing the body shape of the customer to create a better fit. Rapid manufacturing could offer truly customized products.

Year	Author	Focus
2008	Hauslmayer and Gronalt	Manufacturing systems
2006	Tuck and Hague	Rapid manufacturing

Table 2-12 - Manufacturing for MC Research Stream

2.13. Critical Analysis

2.13.1. Postponement Strategy Research Stream

The postponement strategy research stream can be considered divided into two different groups. The first group focuses on different postponement strategies, how they can be optimized and what are the impacting factors while the second part focuses only on inventory management in the postponement strategy.

The postponement is centered on three main types as mentioned before: time, form and place. While time and postponement strategies find extended analysis in the literature, the place postponement is not a part of the study, sometimes even left out without mentioning next to the other two strategies (in the case of Su, 2005). Only in one study Hoek (1999), spatial configuration which is related to place postponement is considered.

The other two postponement types - form and time - are evaluated in depth by other studies (Hoek 1999; Su 2005; Trentin and Forza 2010; Kisperska-Moron et al. 2011;)comparing the strategies and giving different factors that are affecting them. Especially form postponement is well defined consistently across studies (Su 2005; Trentin and Forza 2010; Kisperska-Moron et al. 2011). In this point, all the literature focuses on the ability of the strategy to stabilize the uncertain demand environments.

Connected with the lack of place postponement in the stream, postponing to the logistic processes is an area suitable for improvement. The outsourcing of postponement activities to the logistics provider is in depth present in the research of 30 and Hoek (1999) only. It is also present in the decision making model of Hoek (1997).

Two studies, Hoek (1997) and Hoek (1999), approach the topic from a different perspective, from different industries. Even in both papers the food industry is in the center, especially Hoek (1999) provides how different industries approach the subject. It also provides which costs and factors are relevant for each industry present; even though the study is relatively small, it raises the question of the applicability of general optimizations and frames for different industries. Although the general frames, especially about for form and time postponement, gives the reader a clear understanding; a reader interested in single industries can find these frames partially applicable or incomplete in some aspects.

The second part of the research stream, inventory management and optimization, is very consistent. This might be due to the fact that two studies (Qin 2011a; Qin 2011b) are done as the follow up of an earlier study (Graman 2010). Even though this is the case, all the studies in the research stream aims to set the optimal or target inventory levels in the system to decide until when the postponement should occur. They also use the models to see how different postponement strategies are affecting the systems. As expected all models use time and cost based models to asses these decisions. Similarly all take into account different kinds of inventories - common components, semi-finished, finished goods - and what are the optimal levels for these items.

In the literature the link between the customization level (or the customer order decoupling point) and postponement is given very clearly. There are optimization models present (Ji and

Sun 2011) and also there is a clear understanding across all research mentioned above about which kinds of postponement related to which customization level or how the postponement methodology and indicators change when there is a change in the decoupling point.

Postponement Research Stream	Postponement type	Form postponement Time postponement Place postponement	Hoek (1997), Su (2005), Trentin & Forza (2010), Kisperska-Moron et al. (2011) Hoek (1997), Su (2005) Hoek (1999)
	CODP		Ji et al. (2011)
	Logistics postponement and outsourcing		Hoek (1999), Hoek (2000)
	Optimal postponement/inventory levels		Ma et al. (2002), Baozhuang et al. (2008), Graman (2010), Qin (2011a), Qin (2011b)

Table 2-13 - Postponement Critical Analysis

2.13.2. Information Technologies Research Stream

The information technologies research stream is a combination of different technological enablers for mass customization. In the group different practices and technologies are presented as well as the uses of internet.

An important trend within the stream is the uses of internet and e-commerce within the mass customization context. Out of the nine researches present six (Helander et al. 2002; Turowski 2002; Ghiassi et al. 2003; Ruohonen et al. 2006; Jiao et al. 2006) focus on these subjects. However, all the studies focus on different aspects of this general trend, some combining with other enabling technologies, such as agents.

Even though the range of the focus on these studies prevents the reader to gather different opinions or results about the exact same topic, it gives the opportunity to understand many different practices present in the industries and practices of mass customization. A clear message on the importance of internet and e-commerce activities on mass customization practices is also given.

Another focus of the studies is the usage of agent technologies for mass customization. The ability of agent technologies to exchange data is shown to be an important enabler for mass customization. Also two studies (Turowski 2002; Ghiassi et al. 2003) show agent technologies intersection with e-commerce activities and technologies.

Apart from e-commerce and interaction with the customer, also the interaction within the companies or the supply chain is also emphasized when the all the studies are taken as a whole. Especially product development (Helander et al. 2002; Peng et al. 2011) is shown to be important as well as ERP systems (Akkermans et al. 2008).

It is believed that the research stream as a whole gives a broad and clear understanding how information technologies can enable mass customization. While some studies focus on single aspects, the others combine ideas which broaden and create a better understanding. However,

when the analyses are concerned, because of the high range, validation of the ideas by different studies is hard.

Information Technologies Research Stream	synchronization in supply chain	Electronic Data Interchange (EDI)	Turowski (2002); Dietrich et al. (2006)
		e-commerce	Turowski (2002); Ghiassi and Spera (2003)
		multi-agent systems	Turowski (2002); Dietrich et al. (2006); Ghiassi and Spera (2003)
		ERP systems	Akkermans et al. (2008); Ruohonen et al. (2006)
		New product development	Helander and Jiao (2002)
	IT (supplier-manufacturer)		Peng et al. (2011)
	IT (manufacturer-retailer)		Jiao & Helander (2006); Peng et al. (2011)
	IT (manufacturer-customer)		Jiao & Helander (2006); Peng et al. (2011)
	IT (supply chain) - new prod. Dev. IT		Helander & Jiao (2002)
	State of the art		Romero et al. (2011)

Table 2-14- Information Technologies Critical Analysis

2.13.3. Relationship Management Research Stream

While the whole literature is being looked at a whole on the relationship management concept, it can be realized that there is a gap in the definitions of cooperation and integration within the system. Some research (Moser and Piller 2006; Jitpaiboon et al. 2009; Lau et al. 2010) explicitly defines that integration is the topic being investigated; with the others it is hard to draw the line between cooperation and integration. For the terms like information sharing, the level of the activity is not defined, which makes it hard to understand the nature of the relationships.

Another gap can be identified on the subject of customer relationships. The literature on downstream supply chain mainly focuses on sellers and distributors (Moser and Piller 2006; Wang et al. 2007; Qin 2012) rather than directly on the customer integration or coordination. The sellers and distributors, which are external actors, in this case are considered the bridge between the manufacturer and consumer. Direct consumer contact, where the distribution and selling channels are owned by the manufacturer, are not present in the literature.

The two well defined points in the stream are the supplier relationships; in both integration and cooperation (even tough not perfectly defined) the upstream relationships are given a lot of attention. This gives a clear idea to the reader, on both what characteristics the suppliers should have for successful relationships and how the cooperation/integration must be created.

An important point to emphasize is the significance of information sharing in the relationship management in the supply chain. The amount and type of information shared is mentioned by all the researches in the stream. Information is usually used as the indicator which defines the amount of cooperation between actors.

Apart from studies which look at the relationships between actors, there are two (Warkentin et al. 2000; Monroy and Arto 2010) which gives an overview of the value chains and how they are modified away from the traditional supply chain concept into a mass customization value chain. This gives the reader better understanding, also under a spatial considerations and structure, of how the supply chain actors are located and interacting; which creates as an introduction before going in depth to relationships of specific actors.

Relationship Management Research Stream	Supplier Cooperation/integration	Lau et al. (2010);Pan & Holland (2006); Wang et al. (2007); Moser & Piller (2006); Liao et al. (2011);Zhanga & Huangb (2010);Jitpaiboon et al. (2009)
	Internal Integration	Moser & Piller (2006); Wang et al. (2007); Lau et al. (2010)
	Consumer integration	Jitpaiboon et al. (2009); Pan & Holland (2006); Moser & Piller (2006); Wang et al. (2007)
	Distributor cooperation	Qin (2012)
	MC Value Chain	Warkentin et al. (2000); Monroy & Arto (2010)

Table 2-15 - Relationship Management Critical Analysis

2.13.4. Modularity Research Stream

The modularity research stream gives a clear understanding of the modularity strategy in two different perspectives. Because there is an agreed definition for modularity, it is easy to form an overall understanding of the concept from all studies.

The studies are grouped in two: an overall modularization strategy (Wang 2007; Ro et al. 2007; Cunha et al. 2007; Lau 2011) and the relationship between value chain actors in the modularity context (Howard and Squire 2007; Lin et al. 2009; Lau et al. 2010). In both cases the literature gives a complete understanding on how different product, company, value chain and market characteristics define the different levels of modularity.

Modularity Research Stream	Product characteristics	Lau (2011); Wang (2007)
	Value chain cooperation/integration	Howard & Squire (2007); Lau et al. (2010); Lau (2011)
	Modularity strategies and optimal modularity	Ro et al. (2007); Cunha et al. (2007)
	Value chain capabilities and configuration	Lin et al. (2009)

Table 2-16 - Modularity Critical Analysis

2.13.5. Customization Level Research Stream

The customization level research stream, aims to understand the how the systems with different customization levels behave. Two researches (Yu and Jie 2008; Wang 2011) give a clear understanding about how systems with multiple or mobile customer order decoupling points (CODP) work, while giving their advantages compared to the single-CODP systems. Even though they give a good overall understanding, they do not go into depth of the subject. The why of the multiple-CODP systems are clear, however the how such systems could be created and optimized were not given in the research group.

The rest of the literature focuses on describing and analyzing different customization configurations. The most which finds focus are assemble-to-order and make-to-order is the ones which are featured the most in the literature (Salvador et al. 2004; Poulin et al. 2006; Stavrulaki and Davis 2010; Yimer and Demirli 2010). Also two studies give clear distinctions between different strategies and their implications for different actors and processes in the supply chain (Salvador et al. 2004; Stavrulaki and Davis 2010) which shows the reader clearly the differences between these different points and what kind of factors might effect a company into choosing a certain customization level, such as demand or time related indicators.

However, the analysis of the multiple-CODP systems also comes into the picture here. Because all the studies in the second group take into account all different customization levels individually, even though the individual CODPs are understood, there is no clear understanding on how they might work together in the system.

Customization level	Mobile/multiple CODP	Yu & Jie (2008); Wang (2011)
	BTS	Salvador et al. (2004); Poulin et al. (2006); Stavrulaki & Davis (2010)
	ATO	Salvador et al. (2004); Poulin et al. (2006); Stavrulaki & Davis (2010); Yimer & Demirli (2010)
	MTO	Salvador et al. (2004); Poulin et al. (2006); Stavrulaki & Davis (2010)
	DTO	Poulin et al. (2006); Stavrulaki & Davis (2010)

Table 2-17 - Customization Level Critical Analysis

2.13.6. Flexibility and Agility Research Stream

In the agility and flexibility research stream has been put together due to the fact that agility encompasses flexibility by definition. However, in the stream there is no one single definition of what agile supply chains consists of. When looked at the overall research which talks about the subject, then a better understanding can be achieved. This is due to the fact that the descriptions are not conflicting in nature but rather complementary.

There are a number of different subjects mentioned under the agility context. Benzheng (2011) talks about incentives, Song et al. (2007) gives a technical explanation of uses of agent technologies for agile supply chains and Weizhe & Zhihua (2010) talks about agile supply

chains in clothing industry. The different perspectives help creating an overall understanding of what agility is and what are the characteristics.

The other side of the research stream talks about quick response ability (Yu et al. 2008) and flexibility (Salvador et al. 2007; Yi et al. (2011) which are sub-sections of agility. When the flexibility research is considered, the two different studies talk about different subjects under the name of "flexibility strategy". While Yi et al. (2011) talks about sourcing, operating system, organization and distribution flexibility, Salvador et al. (2007) focuses on volume and mix flexibility in build-to-order systems. Due to these different uses of flexibility strategy, it is difficult to understand to which dimensions of the subject these "strategies" translate to in case of mass customization.

Agility & Flexibility Research Stream	Flexibility	Salvador et al. (2007); Yi et al. (2011)
	Quick response ability	Yu et al. (2008); Benzheng (2011)
	Reconfiguration	Song et al. (2007)
	Agility as a strategy	Song et al. (2007); Weizhe & Zhihua (2010); Benzheng (2011)

Table 2-18 - Agility and Flexibility Critical Analysis

2.13.7. Mass Customization Strategy Research Stream

This research stream composes of different mass customization studies which either combines different strategies present in different research streams present in this thesis or give different ideas in the mass customization strategy which does not fit in other research streams. Due to this fact this research stream gives an overall understanding of mass customization and supply chains. Studies like Mikkola and Skjøtt-Larsen (2004) which focus on mass customization, postponement and modularity or Barutcu (2007) which center on customization, relationship marketing, mass customization and agile manufacturing helps understanding the links between other research streams present in the literature review.

MC Strategy Research Stream	Management enablers for MC	Liu & Deit (2011)
	MC, postponement and modularization	Mikkola & Skjøtt-Larsen (2004)
	Process framework for MC	MacCarthy et al. (2003); Dong et al. (2012)
	Literature review on MC	Trappey & Wognum (2012)
	MC vs. Generative customization	Buffington (2011)
	Customization, relationship marketing, agile manufacturing and MC	Barutcu (2007)

Table 2-19 - MC Strategy Critical Analysis

2.13.8. Performance Research Stream

This research stream consists of studies which aim to create and find indicators to measure the performance of the supply chain under mass customization. Although the studies doesn't encompass all strategies in the supply chain, some interesting ideas which are not seen in the rest of the literature review is present. To give an example, Cheng (2011) uses performance indicators such as return on investment and return on assets to asses organizational modularity and Zhang et al. (2011) tries to understand how mass customization practices are effecting operational and financial performances of supply chains.

Performance	Organizational modularity performance metrics	Cheng (2011)
	Modularity, co-development and performance	Lau et al. (2007)
	Performance on MC practices	Zhang et al. (2011)

Table 2-20 - Performance Critical Analysis

2.13.9. Inventory Management Research Stream

The inventory management research stream is divided into two parts: inventory (Aigbedo 2007; Guohua and Jihong 2010) management and scheduling (Yaoa and Liub 2009; Fei et al. 2009). The inventory part of the stream acts as a complementary addition to the inventory optimization and management techniques present in the postponement research stream. Especially Guohua and Jihong (2010) provides sensitivity analysis on supplier, manufacturer and distributor's inventory levels of market demand or order cycle times.

The other two studies gives optimization models to solve scheduling problems of mass customization supply chains while one is real-time (Fei et al. 2009) and the other is not (Yaoa and Liub 2009). It can be seen that both studies use same time and cost information to create their models on production and inventory which helps defining KPIs for a supply chain system.

Inventory Management and Scheduling Research Stream	Inventory management	Aigbedo (2007); Guohua & Jihong (2010)
	Scheduling	Yaoa & Liub (2009); Fei et al. (2009)

Table 2-21 - Inventory Managemend and Scheduling Critical Analysis

2.13.10. Commonality and Platform Products Research Stream

This research stream is beneficial in this literature review for the introduction of commonality and platform products. Even though a high number of studies are available on commonality and platform products, they are not in the supply chain and mass customization subject. The articles present in this research stream focus on performance (Huang et al. 2005) and relationships (Huang et al. 2007) which help constructing links between research streams and understanding concept better. Also they serve as a validation as the indicators and factors mentioned and used in these studies coincide with the other available in the related research streams.

Commonality and Platform Products Research Stream	Supply chain performance & configuration	Huang et al. (2005)
	Suppl chain relationship	Huang et al. (2007)

Table 2-22 - Commonality and Platform Products Critical Analysis

2.13.11. Collaborative Product Development Research Stream

This research stream, due to the low number of studies included, talks about three different aspects of product development: concurrent engineering (Kincade et al. (2007)), architecture based product development (Mortensen et al. 2008) and collaborative design (Trappey and Hsiao 2008). As present in other research streams, the studies gives an overall understanding about the different aspects, strategies and considerations about the product development phase of the value chain process however it doesn't give a full and detailed overview of the subject. However, especially the research on architecture based product development (Mortensen et al. 2008) gives the reader a perceptive that allows better understanding the product architecture considerations, in terms of in other research streams such as modularity and commonality.

Collaborative Product Development Research Stream	Concurrent engineering	Kincade et al. (2007)
	Architecture based development	Mortensen et al. (2008)
	Collaborative design	Trappey & Hsiao (2008)

Table 2-23 – Collaborative Product Development Critical Analysis

2.13.12. Manufacturing for Mass Customization Research Stream

Manufacturing research stream in the mass customization and supply chain context is very limited. Of the two studies in this stream one focuses on the modularization's effect on floorboard manufacturing (Hauslmayer & Gronalt 2008) while the other focuses on the concept of rapid manufacturing and mass customization (Tuck and Hague 2006). Due to this fact the understanding created by this research stream gives a general idea about manufacturing practices in mass customization, however for sure does not provide an overall understanding of the subject.

It should be noted that both studies give different ideas which are not present in the literature review. Hauslmayer & Gronalt (2008) brings in different indicators based on decoupling point stocks to measure modularity while Tuck and Hague (2006) makes an introduction to lean and leagile supply chains.

Manufacturing for MC Research Stream	Modularization	Hauslmayer & Gronalt (2008)
	Rapid Manufacturing	Tuck & Hague (2006)

Table 2-24 - Manufacturing for Mass Customization Critical Analysis

3. Research Objective

When the literature review and created research streams are viewed, even though the total literature covers many different methods and enablers (such as postponement, information technologies, modularity and more), there is a gap in unifying these strategies. Although there are works like MacCarthy et al. (2003), which provides frameworks for supply chains, they are usually focusing around customization level or other strategies separately rather than together.

The current literature often talks about these concepts with or without mass customization. However it is not clear how they are interrelated or how it is possible to implement them in practice. Even though different examples are given of successful mass customizer companies, one of the biggest examples being Dell, it talks about methods already implemented and not how to implement them. This identified gap has been the base of this thesis.

The objective of this work is to create a conceptual framework, which enable the firm to completely understand which factors needed to be considered and how they can managed and assessed, for the management of a supply chain under mass customization context. The framework aims to establish a comprehension on how different methods and enablers of mass customization are affected by different decisions taken about impacting factors.

At the completion of the framework it is intended to create a guideline to companies (new or already established) who want to pass to mass customization strategies. This guideline would help them understand which strategies and processes are important while creating a mass customization strategy, which kind of factors should they consider before making decisions and how can these factors effects can be measured.

To do so, the following research methodology was followed.

4. Methodology

To succeed in realizing the above mentioned objective, a literature based methodology was adapted. To create the framework with related factors, first a literature review was done. After the research, the found publications were collected in research stream clusters to create a structure within the literature review. After this step, all the main factors that are related do mass customization is identified in each research steam.

Following the identification of the main factors in each research stream, ideas were combined and refined to create a clear, consistent and understandable framework. This framework coming directly from the literature was enhanced with suggested factors and indicators based on the understanding and knowledge gained from the extensive literature review.

After the finalization of the framework, the last step is the validation in the form of case study. In the validation step it was aimed to understand if the created framework was consistent with the practices in the industry and different suggestions that can be taken from the professionals.

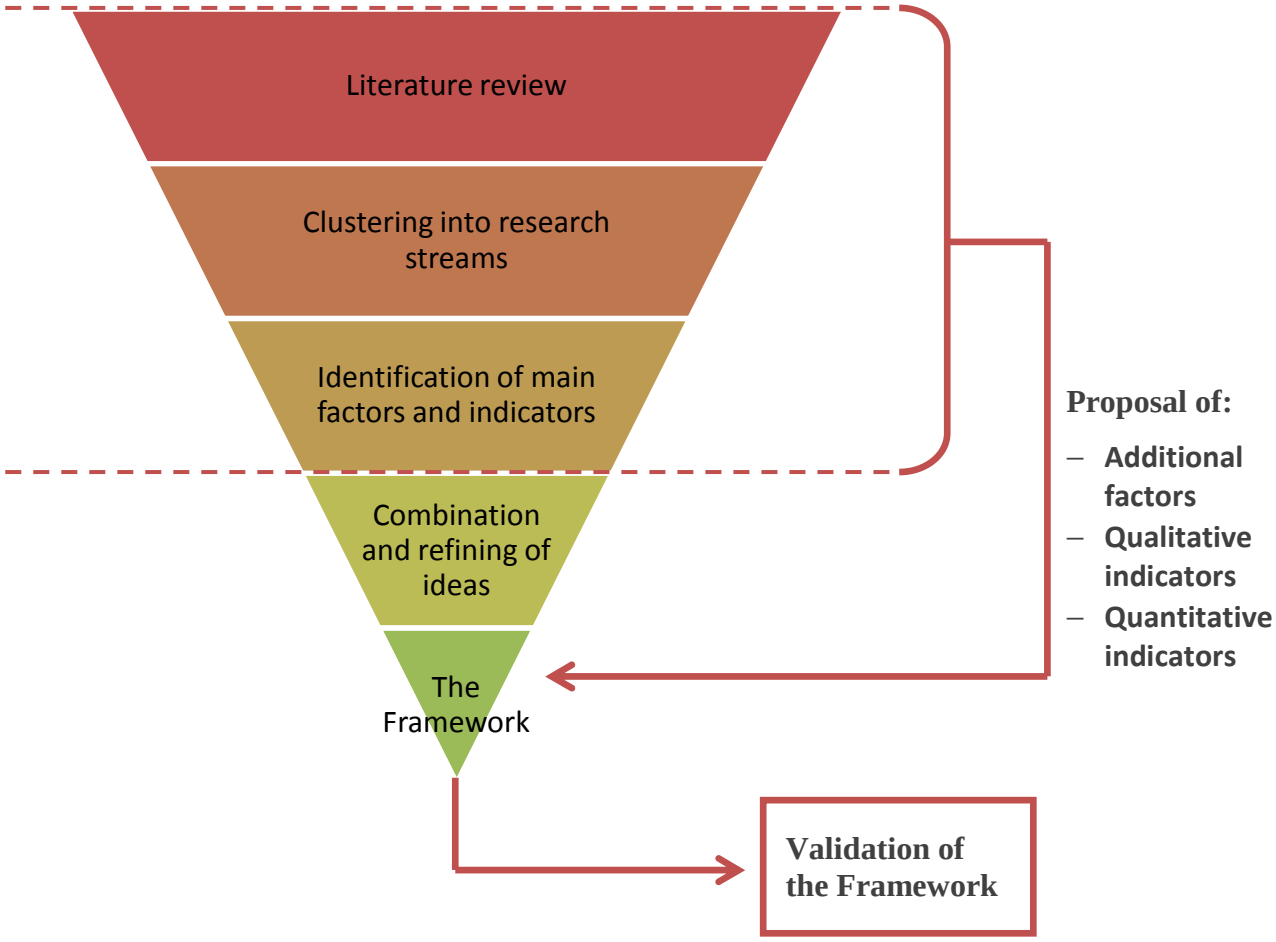


Figure 1 - The Research Methodology

In the following chapters each step will be explained in depth.

4.1. Literature review

In the first step of the research an extensive literature review was done to understand the subject and identify the objective that is going to be addressed. Because the scope of the literature review was decided beforehand – supply chain management and strategies in mass customization – the combination of two keywords were used: “supply chain” and “mass customization”. Also only the studies which focus on these subjects both, i.e. have it in their keywords and abstracts, were taken into account, other than some exceptions.

The search was first done on Science Direct and Emerald databases for easy access. After the available research is taken from these databases, the search was extended to PoliSearch (the academic search engine of Politecnico di Milano) and Google Scholar.

The literature review was done without any restrictions or preferences over journals. This was due to the fact that an overall understanding of the mass customization supply chain was searched and restricting the type or name of the journals could have resulted in missing some work which might provide insight on the subject. Due to this reason, the journals that came up in the searches range from operations research to informatics, telecommunications to logistics management. It is believed that this strategy gives a better understanding of the subject rather than searching in individual journals.

This being said, only one journal has been sought out apart from the search engines, the Journal of Mass Customization. With the highest number contribution to this literature review (in total 9 studies) this journal was searched in particular. The logic behind is that, a journal dedicated to the mass customization concept is directly and fully relevant to the subject at hand unlike the other journals. Due to this reason, it is a worthy source to get information. Also for this journal, the same keywords were used for the searching of articles. You can find a full list of articles with study numbers in Appendix A.

Journal Name	Number of Articles
International Journal of Mass Customisation	9
International Journal of Operations & Production Management	7
International Journal of Production Economics	7
European Journal of Operational Research	5
Supply Chain Management: An International Journal	3

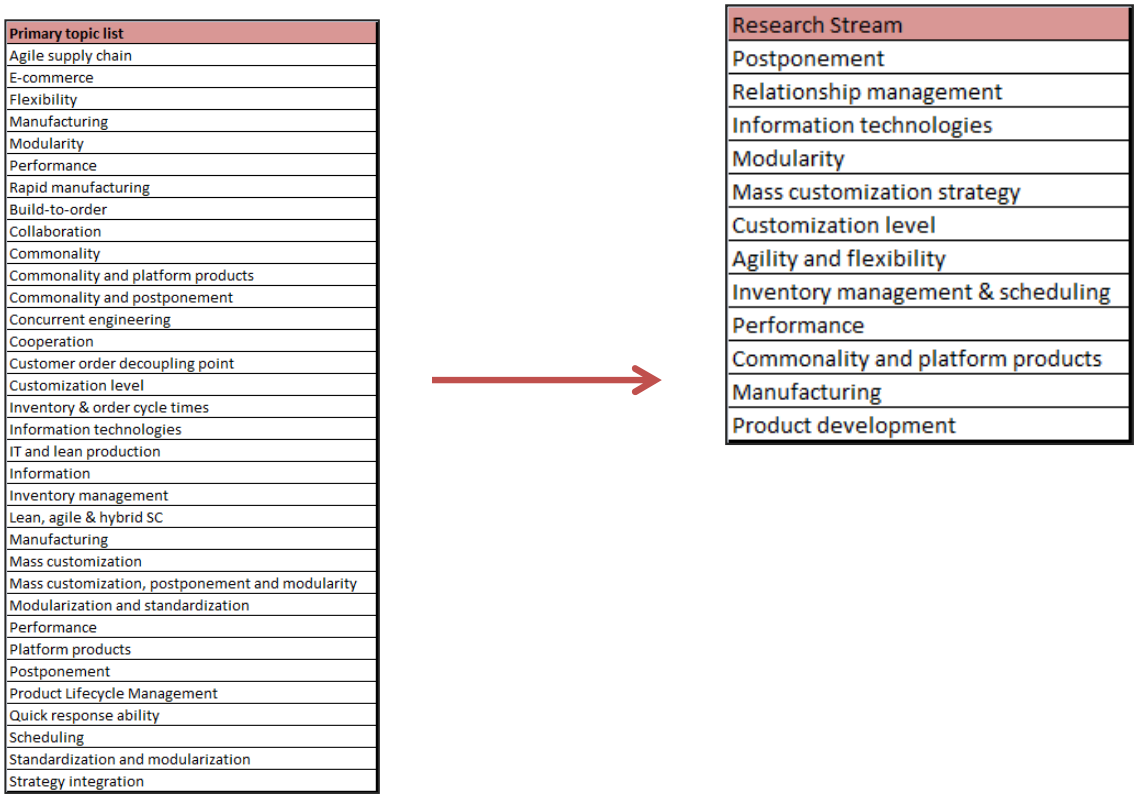
Table 4-1 - Highest Article Counts

As explained in the literature review before, in total 71 articles from 39 different articles were selected for the thesis.

4.1.1. Research Stream Clusters

After the search for publications were completed the main strategy which is underlying each study was identified. First the clusters were done based on different implications on supply chain, such as supply chain management or configuration. However this approach was later abandoned to focus on the different strategies, processes and enablers that is available in a mass customization supply chain, which gave a better understanding over the subject.

This was done in two steps: In the first step all the research was collected around 36 points, with little standardization among the points. Then these 36 points were clustered further to obtain the Jitpaiboon et al. (2009) research streams present in the work now.



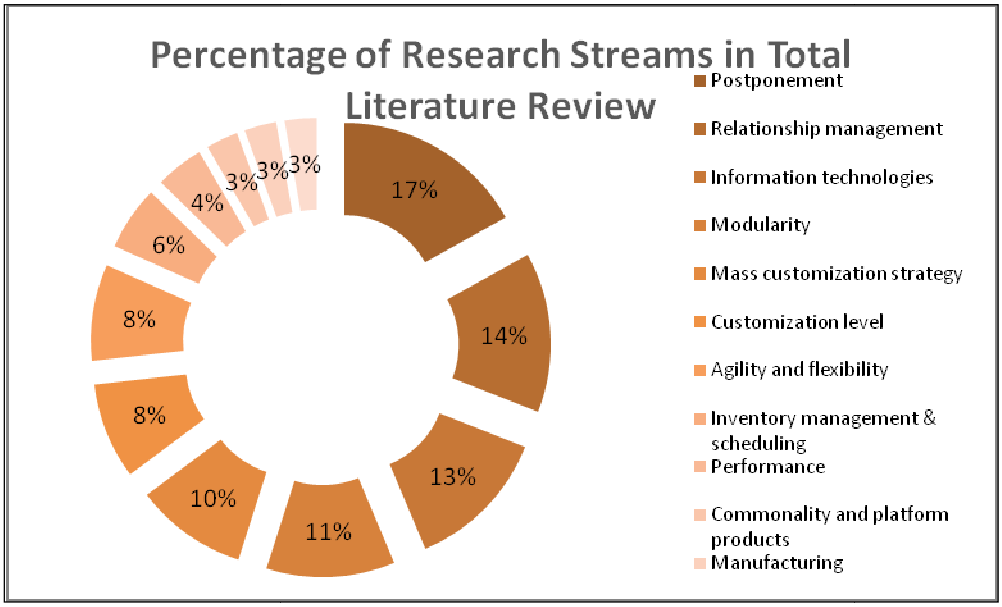
Primary topic list
Agile supply chain
E-commerce
Flexibility
Manufacturing
Modularity
Performance
Rapid manufacturing
Build-to-order
Collaboration
Commonality
Commonality and platform products
Commonality and postponement
Concurrent engineering
Cooperation
Customer order decoupling point
Customization level
Inventory & order cycle times
Information technologies
IT and lean production
Information
Inventory management
Lean, agile & hybrid SC
Manufacturing
Mass customization
Mass customization, postponement and modularity
Modularization and standardization
Performance
Platform products
Postponement
Product Lifecycle Management
Quick response ability
Scheduling
Standardization and modularization
Strategy integration

Research Stream
Postponement
Relationship management
Information technologies
Modularity
Mass customization strategy
Customization level
Agility and flexibility
Inventory management & scheduling
Performance
Commonality and platform products
Manufacturing
Product development

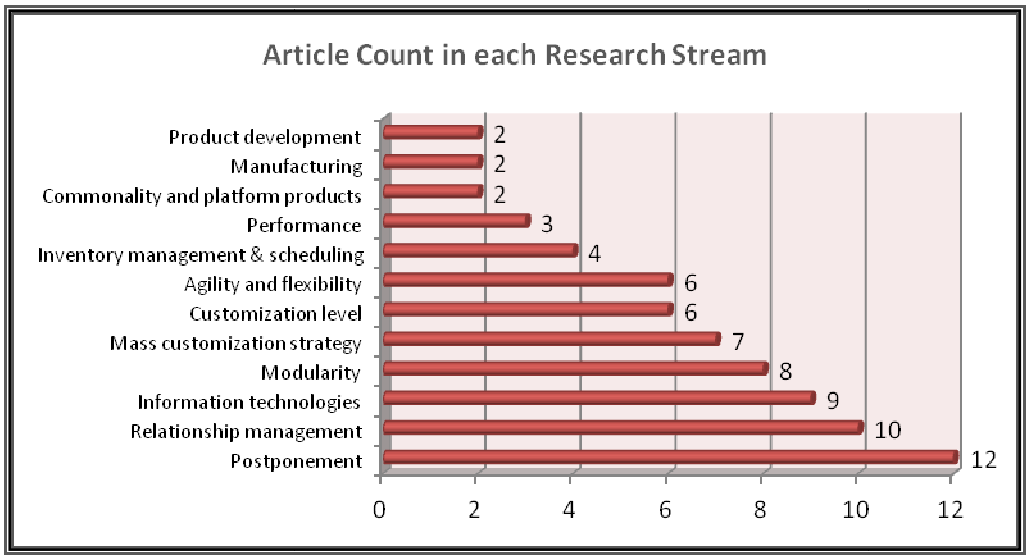
Figure 2 - Research Stream Clustering

During the clustering, the aim was to identify different strategies in the supply chain, like postponement or modularity, or processes, such as product development or manufacturing, which has an effect on mass customization. These more complete and focused research streams would serve as a base to constructing of the framework.

The clusters and numbers of articles in each cluster are given below:



Graph 2 - Percentage of Research Streams in Literature Review



Graph 3 - Article Count in Research Streams

This classification of the articles was made keeping in mind the supply chain strategies for mass customization and chosen for the best way to cluster similar strategies together. The evolution of the literature over time is given below:

Research Streams	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Research Stream Total
Postponment	1	-	1	1	-	1	-	-	1	-	-	1	-	2	4	-	**12**
Relationship management	-	-	-	1	-	-	-	-	-	2	1	-	1	3	1	1	**10**
Information technologies	-	-	-	-	-	2	1	-	-	3	-	1	-	-	2	-	**9**
Mass customization strategy	-	-	-	-	-	-	1	1	-	-	1	-	-	-	2	2	**7**
Agility and flexibility	-	-	-	-	-	-	-	-	-	-	2	1	-	1	2	-	**6**
Customization level	-	-	-	-	-	-	-	1	-	1	-	1	-	2	1	-	**6**
Modularity	-	-	-	-	-	-	-	-	-	-	4	1	1	1	1	-	**8**
Inventory management & scheduling	-	-	-	-	-	-	-	-	-	-	1	-	2	1	-	-	**4**
Performance	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	**3**
Commonality and platform products	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	**2**
Manufacturing	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	**2**
Product development	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	**2**
Grand Total	**1**	**0**	**1**	**2**	**0**	**3**	**2**	**2**	**2**	**7**	**12**	**7**	**4**	**10**	**15**	**3**	**71**

Table 4-2 - Research Stream Article Composition Across Years

As it can be seen from the Table 4-2, the amount of research present in the literature starts to increase after 2007 and reaches the highest amount on 2011. This evolution gives the impression that mass customization in the supply chain area is a relatively young subject which is attracting increased attention as the years pass. Because of this, the literature can be expected to have a lot of future research potential. Many research streams, with the exception of postponement and relationship management doesn't have any publications before 2002. This points the acceleration of the research after 2002 on the subject. However, the newness of the subject can also point to incompleteness or conflicts within the literature, which needs to be taken into account while working on the subject.

4.1.2. Identifying Main Factors and Indicators in Each Research Stream

After clustering into each of the research streams the main factors and indicators in each was identified to create a complete look to the overall strategies. In doing so, the factors which overlap or contrast with each other could be seen to be translated into the framework.

First the main ideas in each article were identified. By this way it was easy to see the similarities and differences between the works of different researchers. In this point, as it has also been underlined in the critical analysis before, the different articles were usually complimentary due to relatively low numbers and the availability of different sub-groups in the research streams.

An example of the research streams is given below (full tables can be found Appendix B). It should be noted that only the ideas related to the research stream and which can be used in the framework has been selected.

Research Stream	Source	factors		Link	Performance	KPI		Industry specification
Relationship Management	Monroy & Arto (2010)							aeronautical industry
	Zhanga & Huangb (2010)	commonality modularity platforming (with or without) level of customization demand levels			total cost	development cost purchasing cost ordering cost inventory holding cost		
	Lau et al. (2010)	information sharing product co-development organizational coordination product modularity			product performance product modularity			electronics toys plastics
	Jitpaiboon et al. (2009)	customer integration supplier integration MC capability	participation level of customer in product development participation level of customer in finished good distribution participation level of customer in manufacturing process willingness of customer to share demand customer involvement level on business plans extent of follow up for customer feedback The participation level of suppliers in manufacturing processes The participation level of suppliers in production planning processes The participation level of suppliers in product development processes The participation level of suppliers in logistics processes The level of cross-over of activities between our firm and our suppliers The level of supplier involvement in preparing our business plans Our capability of customizing products at low cost Our capability of customizing products on a large scale Our capability of translating customer requirements into technical designs quickly Our capability of adding product variety without increasing cost Our capability of customizing products while maintaining a large volume Our capability of setting up for a different product a low cost Our capability of responding to customization requirements quickly Our capability of adding product variety without sacrificing overall production volume Our capability of changeover to a different product quickly		Organisational performance	Customer retention rate Sales growth Return on investment Production throughput times Overall competitive position		
	Liao et al. (2011)	mutual trust free information sharing (with manufacturer) mass customization	openness and honesty respect for confidentiality product development information sharing manufacturing processes information sharing logistics information sharing quality management information sharing financial information sharing customization ability on large scale product variety adding without cost increase customize product features rapidly		free information sharing (from trust) mass customization capability cost rapidity			
	Pan & Holland (2006)	textile suppliers with apparel designer/brand houses garment manufacturer's with apparel designer/brand houses	sales team communication with clients Design development team's seasonal presentations approval of client requests for fabric match sample information transfer into technical specifications of production sales team communication with clients Design development team's technical service to clients garment manufacturer's technical package CAD/CAM data files to establishment for production					fashion
	Moser & Piller (2006)				cost	inventory costs		bicycle
	Qin (2012)	delivery time promised market demand orders in unit time actual time of customization penalty costs paid to manufacturer penalty costs paid to customer elasticity of response time elasticity of customized demand total time of manufacturing and distribution cost of unit of common product produced by manufacturer cost of unit of product customization done by distributor	common variables		price of customized product price of customization service quoted for manufacture by distributor time of customization profit	decision variables		
	Wang et al. (2007)	sharing of information dynamic and agility crowdedness of information technology vendor selection Internal Downstream	 Usage of ERP Usage of advanced technology Business process reengineering urging mechanism information exchange mechanism		 weighted score			
	Warkentin et al. (2000)	Value webs	Information exchange Relationships New economy					

Table 4-3 - Modularity Research Stream in Article Detail

After the identification of ideas in all studies, the ideas are aggregated together to create one overlook for each research stream. These overlooks are with few factors in each research stream and in lower level factors effecting decision variables. The aggregated version example of the research streams are given below (full versions can be found in appendix C)

	Factor	Factors Impacting Decision		who	KPIs
Modularity	Level of modularity	capabilities	design	Lin et al. (2009)	
			production	Lin et al. (2009)	
			inbound logistics	Lin et al. (2009)	separateness [Lau et al. (2010)]
			information	Lin et al. (2009)	transferability [Lau et al. (2010)]
		configuration	role structure	Lin et al. (2009)	specificity [Lau et al. (2010)]
			process structure	Lin et al. (2009)	
			information structure	Lin et al. (2009)	
		module definition		Lau (2011)	
		technological newness		Lau (2011)	
		internal integration	internal communication (forma	Lau (2011)	
			team size	Lau et al. (2010)	team size
		customer coordination	customer involvement [16]	Lau (2011)	customer knowledge [Lau et al. (2010)]
		system integration		Lau (2011)	
		product characteristics	innovative	Lau (2011)	
			functional	Lau (2011)	
			value added	Lau (2011)	
		product family	set of products	Wang (2007)	number of product sets
			general and customized modul	Wang (2007)	number of general modules
					number of customized modules
		supplier coordination	tight/loosely coordinated	Lau et al. (2010); Lau et al. (2011)	
			Module development	Lau et al. (2010)	
			information sharing	Howard & Squire (2007); Lau et al.	
			asset specificity	Howard & Squire (2007)	
					assembly times [Cunha et al. (2007)]
					transportation costs [Cunha et al. (200
					costs [Ro et al. (2007)]

Table 4-4 - Modularity Research Stream in Aggragated View

4.2. The Conceptual Framework

As the next step of the methodology, the frame is constructed. Inspired by the literature first the main strategies the framework is going to be constructed on are selected. These four main strategies are, relationship management, modularity, postponement and customization level.

For each of main aspects, some factors were defined which impact them on the value chain. These factors were later paired with indicators from the literature which can help the company measure the factors.

As a final step of the frame, additional factors have been added which are not directly present in the literature, but thought to be useful. Also, indicators have been proposed for all factors present in the framework. A detailed explanation on these points is present in the conceptual framework chapter.

4.3. Case study

The last step of this work was the validation of the created framework and assessment of its correctness and completeness. Because the framework comes from the literature (which points to mostly theory) it is important to ask the justification from companies

who are practicing mass customization. It is believed that the insights that can be obtained from the industry would make the framework more complete and applicable. To do so, a questionnaire was created to be sent to different mass customizing companies.

The questionnaire was created to include all decision impacting factors and quantitative indicators in the framework. The qualitative indicators were excluded due to the fact that they are not measureable and more like suggestions for companies which want to do mass customization.

Addition to the components of the framework, additional questions were asked such as the number of employees and turnover of the company to asses the size. Based on this information, a conclusion can be reached on different factors which affect different sized companies. This means the identification of factors which can be relevant for small companies but not for big ones and vice versa.

The same objective lies under the reason of asking the customization level of the system. Different customization levels can show different characteristics, identification of these characteristics would crate a more complete framework.

The rest of the questionnaire is divided up to four groups representing the groups present in the framework. Each group is assessed in itself, the links were not asked to the participants to due to the reasons of complexity and length of the survey. The questionnaire is available in Appendix E.

For assessing the framework three different question types were used. The first one is multiple choice questions (without the restriction on the amount of choices that the participants choose). These questions were used to asses the decision impacting factors in each group. Also for each of these questions an option with “other” was added to intercept any points that are not available in the framework but important to in the practice.

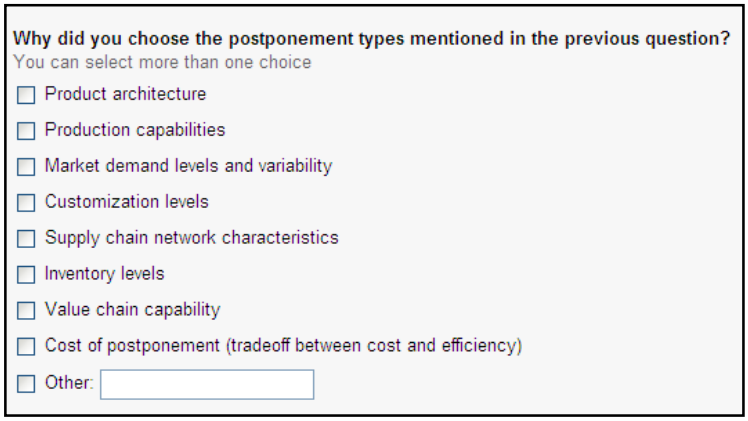


Figure 3 - Example of Multiple Choice Questions

The second types of questions were matrices used to asses key performance indicators proposed to measure each factor. These matrixes (shown in Figure 4) were constructed by putting KPIs in the rows and the factors in the columns, allowing the participant to choose multiple indicators for each factor if needed.

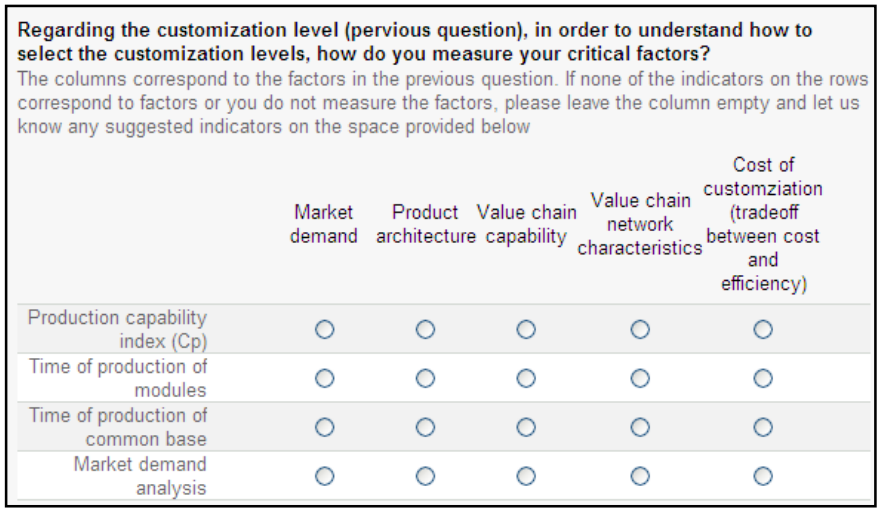


Figure 4 - Example of Matrix Questions

The last type of questions used was open-ended questions. Ideally these questions were avoided when possible and replaced with one of the previous kind of questions, due to the possibility of not being answered by the participants because of their length and lack of structure. They were used in two cases, the first at the end of each group to enter any hardships encountered during implementation of each strategy, to enable the entering of comments and the second after the matrix questions to provide comments and additional indicators.

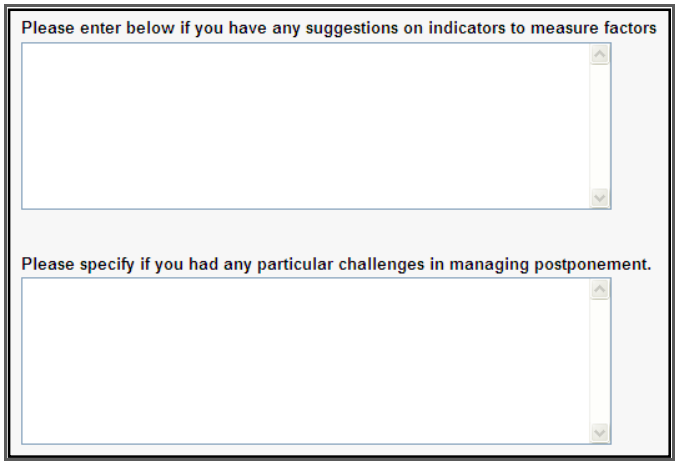


Figure 5 - Example of Open Questions

The questionnaire was created on an online platform, Google Docs, for easy distribution, data collection and analysis of answers. It is believed also to be more convenient for the respondents due to the fact that it is easy to complete with the user-friendly interfaces and eliminates the attachment and email traffic, which can be inconvenient.

After the preparation of the questionnaire, the different companies which are going to be contacted were selected. At this point two different sources were used. The first one is the literature; all the studies in the mentioned literature review were scanned for examples for companies doing mass customization. The second source is the “Mass Customization 500” list, where the companies were chosen at random to be contacted. In both selections the only criteria were that the companies should be providing some kind of customization to their customers, regardless of their size or the amount of customization. This was due to the fact that, as explained before, to understand how the framework differs for different (type of companies (based on size and customization level).

These companies were first contacted with a generic email explaining the aim of the thesis and their contribution. Also, the full report was promised to be sent at completion as a form of incentive. The companies which gave positive response were later contacted with the link of the online form.

5. The Conceptual Framework

Following the methodology presented in the previous chapter, in this section the result of the fourth and fifth steps are presented: the conceptual framework. This framework is the outcome of the steps taken to refine the ideas behind the literature review and addition of new ideas.

The framework aims to aid companies who want to start offering customized products to their consumers, adapt a mass customization strategy into their value chain. It intends to identify major decisions that the company needs to decide upon and understand the different factors which can impact these decisions and how these factors can be assessed.

A company interested in implementing one or more of the 4 aspects available in the frame will find this framework as a useful guideline related to the aspects to be considered and a list of indicators.

The companies which are targeted by this framework can be defined in three different groups, new companies who do not have operations before and already established companies with a traditional supply chain which wants to understand and pass to a mass customization value chain. As a third, companies who are already practicing mass customization but want to improve. For all these types of companies the created framework is believed to be applicable.

Adding to these factors which need managing and understanding, there are indicators proposed for each factor. These indicators are suggested to help the companies to assess the factors better. The presented factors, some quantitative and some qualitative, aims to measure the performance of the different factors.

The framework is clustered around four major strategies – relationship management, modularity, postponement and customization level - which represent different aspects of the mass customization value chain that needs managing. Each group has two lower levels, the lowest level is the factors which impact decisions based on these four aspects and the middle level is the where in the supply chain these factors belong to. You can see the first two levels (highest and middle) of the frame in figure 6.

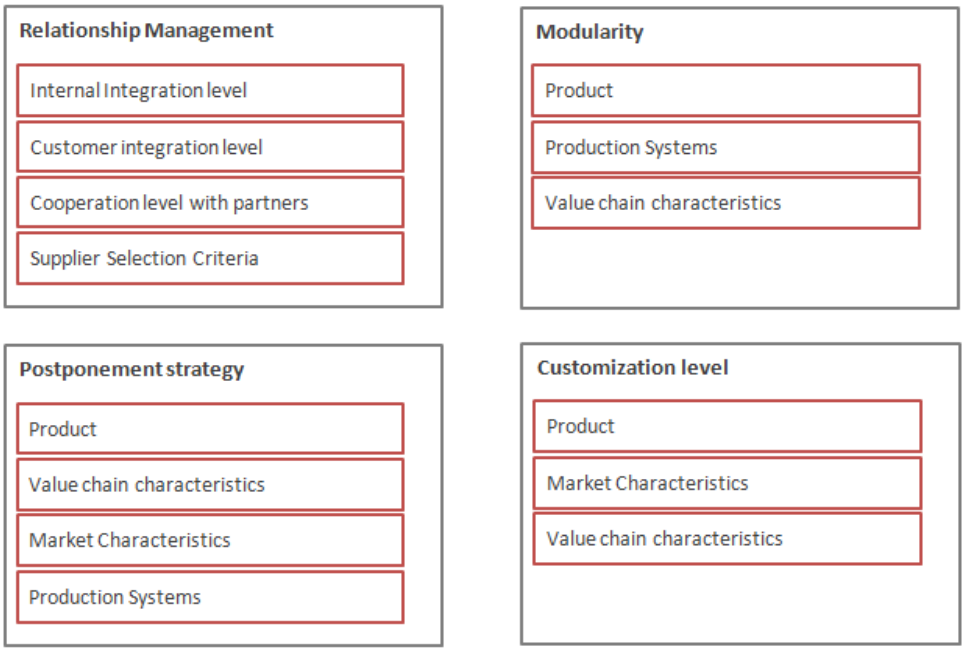


Figure 6 - The first two levels of the framework

During the creation of the framework it was aimed to standardize factors included in different groups when possible. Some examples are the product architecture which is present in modularity, postponement and customization level or the demand level in postponement and customization level groups.

The aim of this standardization was to communicate to the user that one factor can affect multiple strategies, and even sometimes oppositely. Or two different factors can have opposite effects, such as time and cost. So the user must understand these tradeoffs clearly to create and optimal strategy for mass customization.

The chapter is organized as follows. First general information about the value chain that the framework is created upon is given. After this an enablers, which are not directly in the framework but it is believed to be important, is explained. The enabler included n this study is the information technologies. As the last step, the framework is explained in detail.

5.1. The value network

In the modern context the supply chain is changing rapidly from the traditional, almost linear to downstream and upstream actors from the manufacturer, into value networks. Value networks are complex networks which host high number of actors and unlike the traditional supply chain are not bounded by time, space and geography constraints (Warkentin et al. 2000; Monroy and Arto 2010). With the modern information

technologies it is possible to form these networks and provide the customer with quick and less costly options (Warkentin et al. 2000). For mass customization this complex structure poses an advantage where the customization can be shifted through the supply chain to find an optimal solution to present to the end customer while using different competences of the actors. The simplified value chain for the framework created is given in figure 7 It should be noted that this representation only shows the links presented in this thesis.

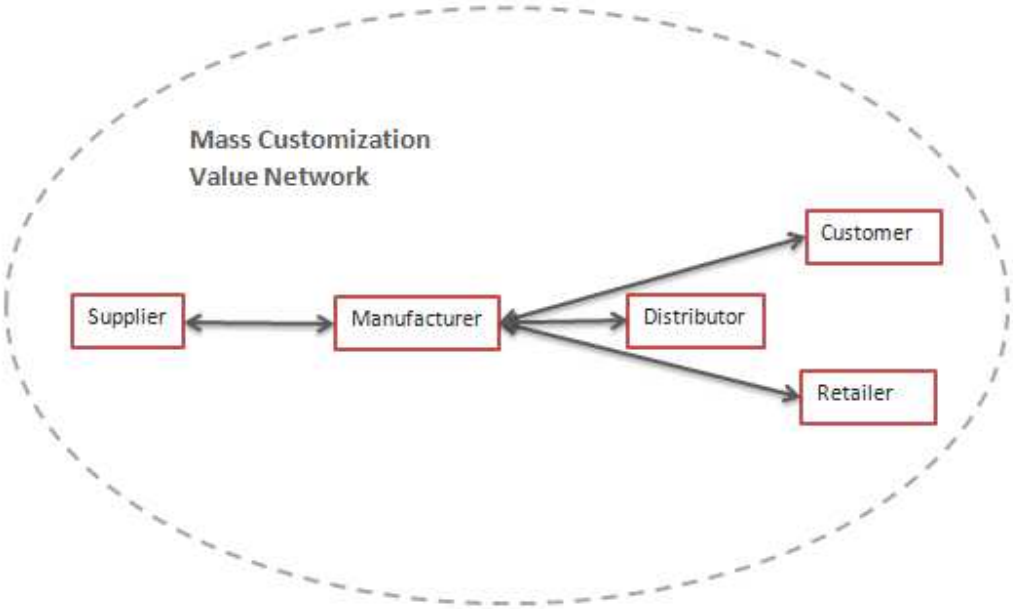


Figure 7 - The Mass Customization Value Chain for the Framework

The value networks have different features which define them. These features can be summarized as strategy, structure, communication, culture (Monroy and Arto 2010).

The first feature, strategy, denotes to the approach the manufacturer have on the market and its projections upon the value network. Differing from the traditional networks, in value networks, the vertically integrated manufacturers or linear horizontal relationships with upstream and downstream are diminishing giving way to collaboration networks where resources are shared and aimed to use optimally (Warkentin et al. 2000). The strategies of these networks are focused on four groups by Monroy and Arto (2010) which are used today: operative excellence, access to new markets, diversification of financial risks and access to new technologies. The manufacturer, based on the strategy, can structure the web in the best way choosing actors to collaborate with (even can include competitors) and the collaboration level between them to move forward with its approach. On this framework, the operational excellence strategy was focused during the creation of the framework. Operational excellence denotes “emphasize leadership in price

and customer convenience by minimizing overhead costs, eliminating intermediate production steps, reducing transaction and 'friction' costs and optimizing business processes" (Karl M. Wiig, 1997).

After the strategy, the second trait of the value networks is the structure. The structure is created based on the strategy that the manufacturer aims to follow. Different actors can be selected to be present in the network with different types of relations and collaborations. While making these decisions there are different factors which affect the outcome. The first factor is the internationalization of the manufacturing process. With the modern supply chains the manufacturing process is not bundled up in a single center like in the past, but outspread to different locations based on the strategy. The second is the supply and value chain. This factor affects the tasks which are to be completed within the supply chain, their assignment to different actors and also the control mechanism within the network. The third is the strategic alliances to be formed. While designing the value network the alliances with different nodes must be carefully considered based on the end result which want be achieved. These alliances can be different in nature ranging from long term relationships to project based collaborations. The last factor which influences the structure is the integration process, which integrates all the factors mentioned above. These factors are interconnected and cannot be considered alone, but rather should be judged within the frame of the value network strategy.

Thirdly communication the communication systems which span the supply chain is one of the features of the value network. There might be different IT and communication tools included within this feature. These tools enable the real time information flows on the network between actors and ensure a synchronized supply chain to function effectively.

The last pillar of the value network according to Monroy and Arto (2010) is the culture and knowledge sharing within the system. The companies and the employees must be reluctant towards mass customization and also communicating and information sharing with internal and external actors of the value chain. A very important aspect of this feature is the mutual trust between the collaborating actors (Jitpaiboon et al. 2009). The openness, honesty and respect for confidential information might help to crate and nurture the sharing and trusting culture.

5.2. Enablers of the Mass Customization Value Network

To create such a system different enablers are used within the organizations who adapt mass customization strategies. These enablers assist the creation of the system and its smooth running afterwards. In this study, information technologies as an enabler of mass customization are explained. Although there might be other enablers in the system, such as agility, information technologies were the only one explained further due to its relevance with the framework created.

5.2.1. Information Technologies

To create such a responsive structure to the market and customer demand, it is substantial to integrate a well running information system throughout the organization and supply chain, from the supplier to the customer. This will ensure the smooth running of the system while better decisions are made within the organization.

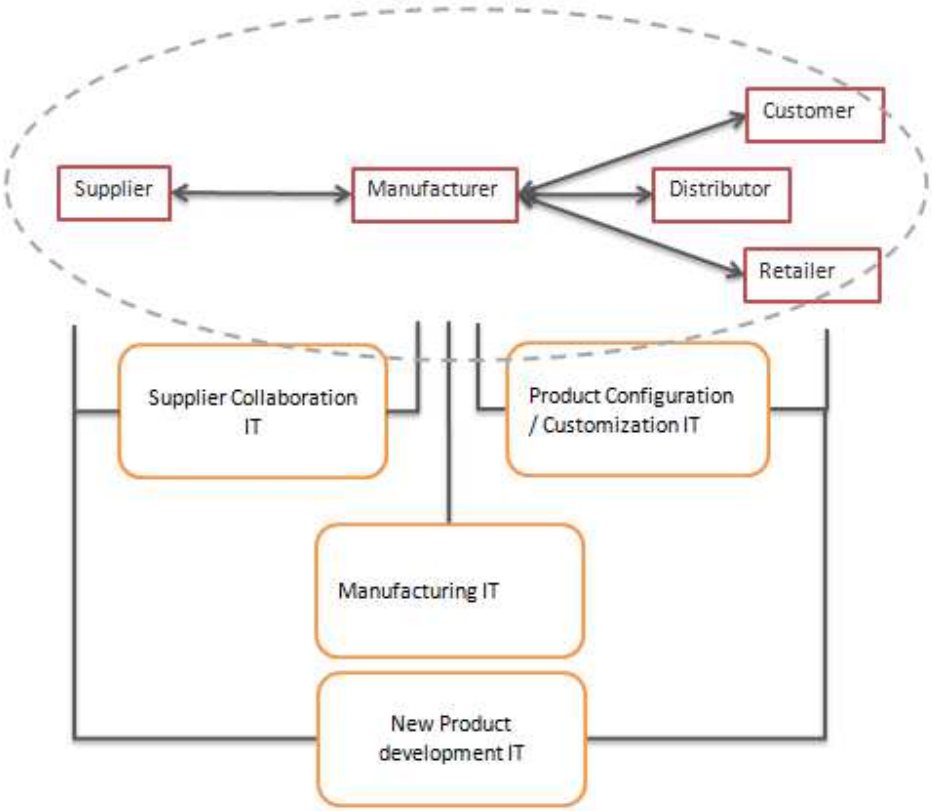


Figure 8 - The Location of Information Technologies in the Value Chain (Peng et al. 2011)

For the system to stay responsive the unblocked flow of information within the organization and outside (suppliers and customers) is essential. With the modern information technologies, the ability to manage complex situations within the company has developed. Apart from the internal processes, the information technology can be used to connect with other actors within the supply chain like suppliers or logistics providers. With the real time data connection between these actors, the capability of offering customized products within the mass customization framework increases.

Another important aspect of information technologies is the data collected from the customer via these technologies. Piller (2008) quotes that with the more information collected from the customer a better customization and better service can be given back

by better segmenting and targeting the consumer. Through this information internal processes can be better managed as well, aiding the mass customizer.

Different information technologies such as ERP systems (Ruohonen et al. 2006; Akkermans et al. 2008) to ensure information transfer between actors or within the company, multi-agent systems (Turowski 2002; Ghiassi et al. 2003; Dietrich et al. 2006), electronic data interchange systems (Turowski 2002; Dietrich et al. 2006) are a few examples that are mentioned in the literature.

5.3. Constructing the Framework: Combination and Refining of Ideas and Factors

The clear pictures of each research stream gave a clear idea of the different factors, however to create the framework these ideas needed to be combined and refined. When the tables created for all research streams were viewed, it was evident that some streams are situated inside others within the framework and are not individual strategies (as an example, inventory management research stream can be situated within postponement).

Adding to the combinations, it was realized that two research streams, information technologies and agility & flexibility, were situated outside the framework. This meant that the strategies and processes these streams represent are seen as enablers in the system rather than factors that can impact decisions. They are not within the framework, but in a way around it, helping the realization of mass customization practices in the supply chain.

There are also some research streams, such as manufacturing, mass customization strategy, commonality and product development, which are not situated in the framework exactly. This means that these ideas are not present in the framework at the first glance. However they are incorporated within different factors, such as product architecture or supply chain capabilities. It was important to identify such factors; they will be explained in detail in the next chapters.

After all the considerations four main streams in supply chain are identified to base the framework on. These are:

- Relationship Management
- Modularity
- Postponement
- Customization level

In these groups, first all the factors are put together. After the putting all the factors, they are again started to be grouped together under different titles such as product architecture or customization level.

At this point also the links between groups started to be seen due to some groups appearing as factors in others.

The same approach was also taken for the key performance indicators. A list of performance measurements were taken from the literature. At this point the indicators and performance measures were not corresponding to each decision impacting factor but to the stream as a whole.

5.4. Constructing the Framework: Proposal of Additional Factors, Qualitative and Quantitative Indicators

After the frame according to the literature was completed, both with the factors and performance measurements, some additions were done. These additions, though not coming directly from the literature, were made by the understanding gained by the literature and previous supply chain knowledge.

The main additions were done on the performance part of the framework rather than the factors. At this point the key performance indicators were divided as qualitative and quantitative. This was done to give the ability to the framework, and who will use it afterwards, to measure different factors which cannot always measured quantitatively.

For each factor one or more indicators were given, some just qualitative or quantitative and some a combination of both. In the case of the indicators, most of it was added at this step (meaning it hasn't come directly from the literature) due to the fact that it was sometimes difficult to find a single key performance indicator which measures a single factor from the literature. However, even not directly coming from the literature, like the factors they have been influenced by the literature.

5.5. The Conceptual Framework

After the explanation of the background information, such as the definition of the mass customization value chain and information technologies as an enabler, the framework is explained in this section in detail.

The overall view of the framework is given in Appendix D. The detailed tables will be given with the explained groups.

5.5.1. Relationship Management

The first group on the framework, relationship management, focuses on different relationships that a company can have with the different actors in the system. In the mass customization value chain, different relationships, which can be with customers, other companies or even internal, play an important role in. The way chosen to manage these relationships can be very important for the success of the mass customizer company.

The aim of the group is to understand how to manage these different kinds of relationships while practicing mass customization. This has been done through identification of factors which can impact decisions over the management of relations and indicators, both quantitative and qualitative, to measure the performance of the factors while making decisions. These decisions of course cannot cover every relationship management issue that needs to be addressed, however it is believed to give a clear understanding.

On the lower level, the group consists of 4 sub-groups: cooperation level with partners, internal integration level, consumer integration level, and supplier selection criteria.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Relationship Management	Internal Integration level	Information exchange level	Moser & Piller (2006); Wang et al. (2007); Lau et al. (2010)		Possibility to have information exchange	Not from literature
		Organisational readiness	Moser & Piller (2006)		ability of organization to carry out mass customization processes effectively	Not from literature
	Consumer integration level	Customer wilingness and capability	Jitpaiboon et al. (2009)		The ability to use different resources (feedback mechanis, configurator, workshops) to interact with customers	Not from literature
		Information exchange level	Moser & Piller (2006); Jitpaiboon et al. (2009); Pan & Holland (2006); Wang et al. (2007)		Possibility to have information exchange	Not from literature
	Cooperation level with partners	Joint profits	Zhanga & Huangb (2010)		Possibility to have a contract which defines joint profits	Not from literature
		Type of information shared	Qin (2012)		Amount and details of demand (number of modules or parts)	Not from literature
		Joint advantages	Qin (2012)		Possbility to share company's internal information with other actors: Delivery due date Order registered time Cost of delay Flexibility of the time to respond to orders Total time of manufacturing Total time of distribution Cost of unit of customization	Qin (2012)
	Supplier Selection Critaeria	Agility of supplier	Wang et al. (2007)	% of completed orders	Ability to ensure needed responsiveness and flexibility by type of contract, punishment and incentives	Not from literature
		Demand behavior of the product	Huang, Zhang & Lo (2007); Zhanga & Huangb (2010); Qin (2012)		Supplier's ability to follow the manufacturer's demand behaviour	Not from literature

		Capacity of supplier	Lau (2011)	capacity of supplier allocated on total capacity		Not from literature
		Information exchange level	Moser & Piller (2006); Pan & Holland (2006); Wang et al. (2007); Lau et al. (2010); Liao et al. (2011)		Possibility to gather the required information in the desired time frame	Not from literature
		Historical relationship with supplier	Not from literature	% of completed orders		Not from literature
		Sustainable price offered by supplier (discounts and low costs)	Not from literature	price per unit	Ability to ensure sustainable prices via the contract type	Not from literature
				price per delivery		Not from literature

Table 5-1 - Relationship Management Framework

Cooperation level with partners

The cooperation with partners' subgroup focuses on how to manage cooperation with the actors of the supply chain such as suppliers and distributors. This factor is situated in between two extremes, at one end there is no information sharing across actors while on the other hand there is full integration with the manufacturing company and the outside companies. The factors selected for this subgroup effects the decisions to the place of the manufacturing company between these two extremes.

Although the literature is mostly focused on to suppliers in this case, in the framework this point has been extended to include other actors as well, believing that the selected factors that are impacting the cooperation with the suppliers can also be used for other actors. The factors are selected accordingly keeping this extension in mind.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Relationship Management	Cooperation level with partners	Joint profits	Zhanga & Huangb (2010)		Possibility to have a contract which defines joint profits	Not from literature
		Type of information shared	Qin (2012)		Amount and details of demand (number of modules or parts)	Not from literature
		Joint advantages	Qin (2012		Possbility to share company's internal information with other actors: Delivery due date Order registered time Cost of delay Flexibility of the time to respond to orders Total time of manufacturing Total time of distribution Cost of unit of customization	Qin (2012

Table 5-2 - Relationship Management Group - Cooperation with Partners

Joint profits:

This factor denotes the ability of actors in a supply chain to take decisions together to maximize their joint profits rather than act separately trying to maximize their own profits. The base of this factor comes from the study of Su (2005), where they show how

jointly made ordering and pricing decisions over a common objective function is more advantageous for all parties under some circumstances. The study also uses this as an indication of cooperation level between actors, because without certain amount of cooperation it is impossible to obtain joint decisions and profits.

Building up on study of 3, this factor is up scaled to include other actors of the value chain, such as the distributor, due to the fact that the joint decisions should not be only limited to the upstream value chain. The same strategy can be used with other actors.

Due to the clear connection between cooperation and the usage of joint profits this factor has an influence over cooperation decisions. It should be kept in mind that there might be characteristics of different actors (such as flexibility shown by Su (2005)) which can affect the cooperation level in this context.

The indicator selected to measure this point is the *possibility to have a contract which defines joint profits,* a quantitative indicator. This indicator denotes that the company can control its ability to create joint profits though different contract types between the actors. As an example with incentive mechanisms built in the contract, they can enforce this point.

It should be kept in mind that this factor is closely related with the other factors within this subgroup and can be quite complex to implement in practice. However, if it can be done, it is believed that it would be advantageous for the companies.

Type of information shared and joint advantages:

Qin (2012) proposes a mathematical model which shows how decisions of a manufacturer and distributor are connected to each other, together making up the profits of the actors or the supply chain service levels. They show how profits and the service level can change when some of the decisions (customization time, price and final product price) are left to the distributor based on the information provided by the manufacturer.

Founded on this idea, it can be important for a mass customizer company to share internal information with other actors in the supply chain, which is not limited to the distributor as it is in the case of Qin (2012). The decisions on which information should be shared with the actors, or the question of it is going to be shared at all, are the questions that should be answered while putting in place a strategy and it deeply effects the amount of cooperation, or in this case even full integration depending if the shared information is real time.

Based on these different types of information shared, joint advantages can be achieved, which parallel to the previous factor, joint profits.

The performance measurements proposed for this factor are all qualitative. One is the *amount and details of demand information (number of modules or parts)* shared with the

actors, which is also used in the study of Qin (2012). Also the study of Moser and Piller (2006) mentions sharing demand information with the actors in integration, in this case with suppliers. Due to this case, this measurement can be appropriate to assess the type of information shared.

The other indicator is the *possibility to share company's internal information with other actors.* It is similar to sharing the demand data, however this time the internal information is shared among actors to make decisions. The possibility of sharing indicates the factors effect on the cooperation level. The different types of data which has been identified in this case are delivery due date, order registered time, cost of delay, flexibility of the time to respond to orders, total time of manufacturing, total time of distribution and cost of unit of customization. Some of these different types of information come from work of Qin (2012) as mentioned before, while the others are added afterwards.

Customer Integration Level

A very important influence over the company is the customer's. Their input being in the center of operations, regardless of the customization level, they pull the activities over the value chain.

Due to this reason, for a company who is starting to figure out its mass customization operations, it is crucial to understand the customer's place in all this and how they should manage this subject. It is important to understand how and how much can the customer be integrated in the system. This group focuses on aiding the companies in this aspect.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Relationship Management	Consumer integration level	Customer wilingness and capability	Jitpaiboon et al. (2009)		The ability to use different resources (feedback mechanis, configurator, workshops) to interact with customers	Not from literature
		Information exchange level	Moser & Piller (2006); Jitpaiboon et al. (2009); Pan & Holland (2006); Wang et al. (2007)		Possibility to have information exchange	Not from literature

Table 5-3 - Relationship Management - Customer Integration Level

Customer willingness and capability

Jitpaiboon et al. (2009) defines the customer integration process as a manager's understanding of the willingness and participation level of customers in a company. They tested and found support to their hypothesis that customer integration increases mass customization capability in a company. They identify customer integration as a combination of willingness of customer to share their market demands, the feedback they are willing to give, their participation in product development, finished good distribution and manufacturing processes and finally their involvement in preparing business plans.

All these identified points can be included in the customer willingness and capability factor of the framework. A mass customizing company must make decisions in all these points, to give an example deciding if they will encourage participation in processes (after understanding if the customers are willing and capable in such a context), like manufacturing or product development, and if they are able to capture this information using their resources. They should understand how their system will function best and if the customers are willing to participate.

It is important here to underline that this factor is not here to measure the willingness of the customer but the ways that they are ready to employ to capture the willingness and the ability to act on this decision. This factor merely indicates that the willingness affects the customer integration amounts in the supply chain and should be maintained. The willingness levels of the customer and their measurement are not in the scope of this framework.

For the assessment of this factor *the ability to use different resources (feedback mechanism, configurator, workshops) to interact with customers* has been proposed as a qualitative implication. This indicator is aimed to understand the ability to use these different resources to capture the willingness and capabilities of the customers for the chosen activities.

Information exchange level

The information exchange level is an important factor which can be used to understand the cooperation with the supplier. Different from the previous factor, the pervious factor focused on the capturing of the input that the customer was willing to give; this point focuses on the actual exchange of information.

In the literature, as explained in the literature review before, focuses a lot on the information sharing with customers. The works which influenced the creation of this factor shows different aspects of information sharing. Jitpaiboon et al. (2009) focuses on efficient information sharing while Pan and Holland (2006) and Moser and Piller (2006) explains the importance of information on consumer preferences and requirements, and its communication (they also talks about the ability of the retailers to capture this information). Wang et al. (2007) defines the information flow as the most important factor under mass customization and the information of client needs be obtained by the

companies. Lau et al. (2010) also support by their survey how information sharing positively influences product performance and how information sharing with customers is part of it.

The importance of information for customer integration is clear from the studies, however the studies usually focus on how to get the information rather than the amount of information shared which proposed in this framework. To represent this, the level of information exchange was chosen due to the reason that, as it has been explained in the beginning of this chapter, the information systems are seen as enablers of the system and are out of the scope of framework. This means it is assumed that the needed information technologies would be already in place based on the decision; they do not affect the availability or the exchange of information.

Due to this reasons the information exchange level was selected as a factor in the framework, representing the amount of information exchanged between parties. While a company is creating a system for mass customization, this factor needs to be considered because the amount of information planned to be exchanged defines the integration level of the customer. This factor completes the previous one, the previous factor tried to understand the willingness to share the information, and this factor tries to understand the amount.

For the indicator of this factor *possibility to have information exchange* was seen appropriate due to the fact that it captures the ability to have the desired level of exchange with the customers. Because this framework aims to help companies to create a system of mass customization and not maintain it, the level needs to be decided and the possible systems for it should be created (as the enabler). The actual quantitative measurement of the information flows can be done after the starting of the operations.

Internal Integration level

This group of factors denotes the integration levels that are present within the company itself. The internal operations of the company must be aligned to be able to create the responding supply chain needed for mass customization practices.

There are two different aspects which are needed to be controlled in this context. One is the interaction between different departments and their ability to work together. It might be important to collaborate or just be aware of the possible issues that are generated during operations. The other is the readiness of the current or feature employees' readiness to embrace the mass customization culture, which differs from the traditional supply chain approaches. Both aspects were explained below with the appropriate factors.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Relationship Management	Internal Integration level	Information exchange level	Moser & Piller (2006); Wang et al. (2007); Lau et al. (2010)		Possibility to have information exchange	Not from literature
		Organisational readiness	Moser & Piller (2006)		ability of organization to carry out mass customization processes effectively	Not from literature

Table 5-4 - Relationship Management - Internal Integration Level

Information exchange level

As for cooperation with other suppliers or the customers, information exchange plays an important role also for internal integration. The communication between different departments or functions within the company can be a key point in achieving efficient mass customization.

In the literature, Wang et al. (2007) provides the importance of internal information flows as well as across the value chain. They map the flows between different departments, both internal and external. Another point to be taken from the study is the usage of enterprise resource planning systems, which is an enabler of the system. Lau et al. (2010) also talks about internal interactions and cooperation, however does not strictly talk about information flows.

The amount of information exchange level is an important factor which defines the amount of internal integration within the company. Due to this reason, it is necessary to understand how it can be done and facilitated as well as define the levels of exchange between different departments.

For the evaluation of the factor, the implication of *possibility to have information exchange* must be understood. Because it is difficult to measure the actual amount of information that is going to be exchanged during the operations, it is more comprehensible the possibility of having the wanted information exchange.

This factor can be evaluated at the company level or at lower levels, such as inter-departments based on the processes and need. Also, the exchange between different locations, e.g. different offices of the company, can be possible and needs to be considered.

Organizational readiness

Moser and Piller (2006) defines one of the difficulties that mass customizing companies encounter is the challenges faced by the companies due to changes which take the supply chain concept away from the traditional. The employees must employ an understanding which focuses on understanding needs of the end customer, translating them into capabilities. They also must be qualified having multi- competences or need to be supervised with attention.

Due to these reasons described in Moser and Piller (2006), it is important to have an organization ready for mass customization progresses. This factor implies that the employees should be trained and ready for a change from the traditional supply chain to the mass customization value chain processes. The need to manage this transition is the reason this factor is considered effective in the internal integration of the company.

For the measurement of this factor there is a qualitative indicator which is the *ability of organization to carry out mass customization processes effectively*. With this indicator, it is aimed to understand if the organization is ready to perform efficient mass customization activities.

Supplier Selection Criteria

The different suppliers of the company gain more importance in the mass customization supply chain when compared to the traditional one. This sub-group aims to help the companies to understand what factors are important for selection of the supplier and how they should be evaluated for the selection.

It should be kept in mind that the selection of the supplier can be grouped in two different situations. The first one is selection of new suppliers for the company for the mass customization activities and the other is the retaining of old suppliers while passing to a mass customization supply chain. Of course, the second point is directed at companies who have operations already present in traditional ways who are seeking to pass to customizing and not new companies, while the first point encompasses all companies.

The factors below can be relating to the two situations differently (table 6-5) Some factors, such as the historical relationship of the company with the suppliers, is present in one of the situations, in this case the second one (where the company already exists). Or they can have different implications, as the indicators of supplier agility, for different situations.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Relationship Management	Supplier Selection Critaeria	Agility of supplier	Wang et al. (2007)	% of completed orders	Ability to ensure needed responsiveness and flexibility by type of contract, punishment and incentives	Not from literature
		Demand behavior of the product	Huang, Zhang & Lo (2007); Zhanga & Huangb (2010); Qin (2012)		Supplier's ability to follow the manufacturer's demand behaviour	Not from literature
		Capacity of supplier	Lau (2011)	capacity of supplier allocated on total capacity		Not from literature
		Information exchange level	Moser & Piller (2006); Pan & Holland (2006); Wang et al. (2007); Lau et al. (2010); Liao et al. (2011)		Possibility to gather the required information in the desired time frame	Not from literature
		Historical relationship with supplier	Not from literature	% of completed orders		Not from literature
		Sustainable price offered by supplier (discounts and low costs)	Not from literature	price per unit	Ability to ensure sustainable prices via the contract type	Not from literature
				price per delivery		Not from literature

Table 5-5 - Relationship Management - Supplier Selection Criteria

Agility of supplier

The study of Wang et al. (2007) underlines the needed characteristics of the supply chain and one of these characteristics presented is the agility. Caused by the uncertain nature of the demand, it is believed that the supply chain should be dynamic and responsive to the

changes. Due to this reason, they underline a mass customizing company should choose suppliers on their ability to fit in this dynamic supply chain.

Parallel with the vision of Wang et al. (2007), this factor is presented to understand if the selected suppliers will bring the needed flexibility and response ability to the supply chain. This is why the agility of the supplier must be taken into account while making the supplier selections.

However it should be kept in mind that not all suppliers must have a high agility. This also depends on the integration of the supplier into the mass customization activities or the nature of the relationship between companies. The needed agility level can and should be assessed and determined for each or at least each type of supplier.

For this factor two different types of indicators are present. *Percentage of completed orders* is present as a quantitative indicator while a*bility to ensure needed responsiveness and flexibility by type of contract, punishment and incentives* is quantitative.

The *percentage of completed orders* can be used if the company has access to this information about the supplier. In the two cases (re-selection of an existing supplier or acquisition of a new one) the source of this indicator can be different. If a re-selection is being done the company can turn to historical information. If internal information is not available or may not be applicable to mass customization context, information might be coming from the supplier itself or other companies which use the same supplier.

The quantitative indicator looks at the factor from a different angle. It aims to understand if different ways, such as contract type, punishment or incentives might be used to ensure the agility of the supplier. However, if the supplier doesn't have the ability to reach the agility level desired by the manufacturer, such way of measurement might not be possible.

Demand behavior of the product

Demand is an important external factor which needs to be addresses while making supply chain decisions. Different demand behaviors can have impact on the supplier decisions that the company takes.

In the relationship literature Qin (2012) and Zhanga and Huangb (2010) talks about how demand can change the optimal configuration decisions and the customization levels in the supply chain. While Qin (2012) focus on sharing of the demand information, Zhanga and Huangb (2010) use it as an important factor in the model which includes supplier selections. The last article on the subject, Huang et al. (2007), also creates a model which where they create a sensitivity analysis over different demand levels.

The usage of demand levels in forming relationships with different suppliers are evident in these literature, even though through different reasons and processes (because demand

changes customer order decoupling points, pricing decisions etc.). These points, of course, should be important factors in selection of the supplier.

However, the factor proposed in this framework aims to include another aspect of demand, which is the behavior. In two of the models (Qin (2012) and Huang et al. (2007)) it is assumed that the demand is linear, or a single known value, only Qin (2012) includes the demand elasticity in its model. It is believed that the demand behavior, with relation with other factors such as agility, can be an important factor effecting the supplier selection decisions. The company must select suppliers who can sustain the demand behavior, especially if the demand is highly uncertain.

In a parallel way, the qualitative indicator which was chosen to define the factor is *supplier's ability to follow the manufacturer's demand behavior*. This indicator shows that for the supplier it is important to follow manufacturer's demand behavior rather than the markets. This is an important point due to the fact that the manufacturer's demand behavior might not be equal to the markets. They might be smoothing out demand with inventories or reflecting the demand fluctuations directly on the suppliers.

However might be the way, the suppliers to be selected should be able to sustain the demand behavior of the manufacturer.

Capacity of supplier

The capacity of supplier, like the price which will be discussed later, is a factor which affects all supply chains regardless if it is a mass customization supply chain or not and thus should be considered as a factor while making the selection decision. The supplier should be able to sustain the demand coming from the manufacturer.

In the study 3, the authors talk about the assumption of infinite capacity of the supplier, however underlines that it is not applicable to real life situations. On a different subject, Lau et al. (2010) makes their study based on different company sizes and what kind of different suppliers with different characteristics they have.

Based on these two understandings, the factor capacity of supplier was formed. This factor is important to understand if the supplier will be able to sustain the demand that is coming from the company.

But also it is believed that there is another aspect that needs consideration. This is the amount of supplier capacity that is going to be allocated for the manufacturer. This might me important because it can indicate the cooperation amount between the supplier and manufacturer and the power that the manufacturer have over the supplier. This point impact the supplier decisions based on the preferences of the company.

For this factor the indicator *capacity of supplier allocated on total capacity* is chosen to understand the above point. This ratio gives a better understanding of how the capacity of the supplier will affect the selection process.

Information exchange level

While selecting the supplier, the forecasted information exchange levels and methods needs to be understood in order to make decisions. Different information exchange levels or expectations can influence the selection of suppliers.

In the duration of the literature review different works which talks about the information exchange with suppliers has been identified. Wang et al. (2007) mentions the sharing of information as a characteristic of supply chain management for mass customization and how client information can be acquired and shared with the suppliers along with other actors in the value chain. Similarly Moser and Piller (2006) states how forecast data of the manufacturer can be shared with the supplier to create a better mass customization system, and just-in-time models can aid the ordering processes.

Lau et al. (2010) finds support to their hypothesis which shows that information sharing positively affects product performance which also includes information sharing with the supplier in its definition. As the last point, Liao et al. (2011) made their study on the subject of information sharing among supplier and manufacturer. They have found support that higher information sharing increases the mass customization capacity of the system. They also proved that higher trust increases the information sharing levels between the actors.

Based on this information it can be seen that information sharing, even in different kinds, is an important aspect of the relationship with the supplier. Due to this reason, during the selection of the supplier, the way and amount of information that is being expected to be exchanged in the future must be considered.

To understand the implications of the information exchange level on the supplier selection, it is important to assess the *possibility to gather the required information in the desired time frame.* This will aim the company in understanding if the supplier is able to fulfill the requirements.

Historical relationship with supplier

As mentioned in the introduction of the supplier selection sub-group, this factor is only relevant for companies who are already existing, doing production and want to pass to a mass customization supply chain structure.

In this case, the historical relationship with an existing supplier can be an important factor. While evaluating the supplier, first hand information can be more valuable and

accurate from the ones gathered from other sources. This can shed light for the company about the capabilities of the supplier and their processes.

The key performance indicator for this factor is the *percentage of completed orders.* It is believed that, even though not a perfect indication, the historical data of orders can be used for the quantification of the historical relationship.

There can be other indicators which is not present in this framework, such as the "feeling" that the supplier gives to the company. It is not a proper indicator, can change from person to person, but should not be disregarded by the manufacturer.

Sustainable price offered by supplier (discounts and low costs)

In any kind of supply chain and supplier selection, let it be traditional or mass customization, the prices offered by suppliers is an important factor in the selection of the supplier. If all other factors are assumed to be equal, it would be logical to assume that the selection would be done on the lowest price available.

The low costs are a factor to be considered, however this does not mean that a company always chooses the lowest cost option, it is merely a tradeoff between lower cost and other characteristics such as quality, agility and many others. Thus a company must understand the impact of the different prices offered on the supply chain and its costs.

The idea of sustainable prices also has another aspect, which is the quantity discounts resulting in lower per item prices from the large quantities of items obtained from the supplier. 3 cover this subject in their study. Through their game-theoretic approach they show that price discounts offered by suppliers can result in differences in the supplier selection.

Three different indicators has been proposed to measure the effects if sustainable prices offered by the suppliers. The first two, the quantitative indicators, are *price per unit* and *price per delivery*. Although similar in nature, they were both included to take into account different types of measurements of costs and prices, by item or batch.

The third indicator is the *ability to ensure sustainable prices via the contract type*, which is a qualitative indicator. It aims for the company to understand the company's potential to ensure the sustainable prices by integrating them into the contract they are doing with the supplier.

5.5.2. Modularity

Modularity is the second group present in the framework. It focuses on different characteristics of the product and the value chain to understand how modularity strategy can be implemented by the companies. It should be noted that the modularity referred in this group is the product modularity only, doesn't correspond to other types (such as organizational modularity).

The idea behind the group is to comprehend if a modular product structure is going to be accepted by the company. If the answer is yes, the presented factors can be considered when making decisions based on modularity, such as the level, optimal module numbers etc.

The factors are clustered around three subgroups based on the processes and the relations on the value chain. These sub-groups are product, production system and value chain modularity. They will be explained in detail in the rest of the chapter.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Modularity	product	product architecture	Lau (2011)		Portion of cost related to the common base	Not from literature
					Modularity of the product	
		product characteristics			The innovative, value added or functional character of the product	
		Feasibility of customer requirements' translation into modules	Not from literature		Feasibility of customer requirements' translation into modules	Not from literature
	production system	production capability in making modules	Lin et al. (2009)	Time of production of modules	Availiability of technology to ensure needed production	Not from literature
		Production costs of modules		Total production costs of modues		
		Inventory costs of modules		Inventory costs of modules		
	Value chain characteristics	Cooperation with supplier	Howard & Squire (2007); Wang (2007); Lau et al. (2010); Lau (2011)	** Cooperation with partners block*	** Cooperation with partners block*	Not from literature
		customization level	Not from literature	**Customization level block*		
		Supplier selection	Not from literature	**Supplier selection block*	**Supplier selection blocl*	Huang et al. (2005); Dietrich et al. (2006)

Table 5-6 - Modularity Framework

Product

This subgroup sees modularity from a product point of view. It aims to recognize what kind of different product characteristics can have an effect on modularity decisions that are needed to be taken by the company for mass customization.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Modularity	Product	product architecture	Lau (2011)		Portion of cost related to the common base	Not from literature
					Modularity of the product	
		product characteristics	Not from literature		The innovative, value added or functional character of the product	Not from literature
		Feasibility of customer requirements' translation into modules	Not from literature			Not from literature

Table 5-7 - Modularity Framework - Product

Product architecture

While making decisions about modules, it is important to consider the architecture of the product. Lau (2011) discusses about the importance of the design of architectures that incorporate modularity across case studies.

The concept of product architecture can incorporate different mass customization strategies like commonality or modularity and get influenced by different processes as market demand, assortment of product and production and supply chain characteristics (Mortensen et al. 2008). All these different issues help shaping of the product architecture which going to be offered to the customer and thus effects the decisions made on the modularity of the product.

To understand the different consequences of the product architecture the company can aim to qualitatively assess *portion of cost related to the common base* and *modularity of the product*. By understanding these two points, the differences between different architectures can be understood and compared in terms of modularity.

Product characteristics

Lau (2011) believes that different product characteristics, namely if the product is innovative, value added or functional, has a direct effect over the different module

definitions and the level of modularity. The authors also mention the pre-defined product advantages like variety or customization's affect on the module definition.

Based Lau (2011)'s study, this factor has been decided to be included in the framework. If the product characteristics effect the definition of the product modularity, then it should be managed by the company. It is important for the mass customizer to understand how different characteristics effect the modularity and how they can be included in the design.

To see the affect the characteristics have on modularity, it is proposed for the company to evaluate the *innovative, value added or functional character of the product,* and see how they translate into the module definitions and design.

Feasibility of customer requirements' translation into modules

While defining the modules it is important to understand which customer needs and requirements are reasonable and meaningful to translate into modules while leaving out others. The feasibility can be measured in terms of the market demand (how essential is the requirement or how big of the requirements impact on demand), different costs, capabilities, constraints and other factors.

This factor is closely connected with the other factors presented before in the product sub-group, product architecture and characteristics. It can influence or be influenced by the product architecture and the characteristics of the products. This means that careful considerations must be done while understanding the feasibility of this translation.

This factor is used as a factor and a qualitative implication because it is both. It is a factor because it affects the modularity and the module definitions and it is an implication because it is based on the understanding of feasibility.

Production systems

The characteristics of the production systems of the company, such as the capability or the costs, can have effects in the definitions of the modules. This can happen if the company does not have the capabilities to create the desired modules, which can result in changes in the modules or outsourcing of some components.

The aim of this subgroup is to understand how the factors in the production systems affect modularity and how they can be measured and understood by the company when creating a mass customization structure.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Modularity	production system	production capability in making modules	Lin et al. (2009)	Time of production of modules	Availiability of technology to ensure needed production	Not from literature
		Production costs of modules	Not from literature	Total production costs of modues		Not from literature
		Inventory costs of modules	Not from literature	Inventory costs of modules		Not from literature

Table 5-8 - Modularity Framework – Production Systems

Production capability in making modules

The production capability is an important consideration while understanding the definition of modules that are going to be designed. If the company doesn't have the desired capabilities in its production systems, definition of the modules as well as the optimal module numbers must be created and investigated accordingly.

Lin et al. (2009) sees capability one of the three pillars of modularity in their framework, along with configuration and context. The authors describe these as the critical success factors of the modular supply network. According to the study this factor includes capabilities of design, production, inbound logistics and information management.

Based on this study, it can be seen that production capabilities is a essential consideration for the modularity. The different capabilities mentioned can be all seen under this factor, as the production of the manufacturer is considered in this framework and design and inbound logistics can also be seen as a continuation of the process in the same company.

An integral part of the production capabilities is the technologies needed for the production of the modules. For different modules different types of technologies might be needed which is not owned by the company, can be due to cost, time or unavailability of know-how and technology. Such cases must be considered in making decisions about modularity levels. Different options can be present as changing design of the product and needed modules, outsourcing the models or parts of the modules which cannot be produced in house.

For the assessment of the factor two different approaches are provided. The key performance indicator proposed is the *time of production of modules* which tries to

understand how the capabilities of production reflect to the production times. If the production exceeds the desired time, the production of the modules might not be feasible.

The second approach is qualitative and it tries to understand the *availability of technology to ensure needed production*. As mentioned before, the company must have the needed technologies available to go on with the production or look for other options. Due to this reason, this is an important point to asses while making modularity decisions.

Production costs of modules

The production capabilities can be enough for the production of the modules in the designed way, however may not be feasible from a cost point of view of the production.

The costs of the production of different module levels should be considered carefully before the decisions are made, to understand if the production of the modules is practical in the decided way or there should be changes made in the module definitions or production systems.

While understanding this factor, the indicator *total production costs of modules* can be used and asses different alternatives.

Inventory costs of modules

Like the production costs, inventory costs of the modules cane effect the different decisions. The inventory costs referred in this part of the framework are the costs incurred on the manufacturer only based on production. Inventory costs over the value chain are going to be discussed later on.

While considering different modularization options in mass customization, the inventory costs at different stages of production must be considered. These costs can be raw material, work in process or finished module inventory costs.

To asses this factors impact on the modularization strategy, *inventory costs of modules* can be used by the company.

Value chain characteristics

After the implications of the production systems on modularity (which is in control directly of the manufacturer), the effects of the value chain should be analyzed. The modularization strategy can be affected by the characteristics of different companies in the value chain or the level of cooperation between them.

The aim of this subgroup is to understand different factors in the value chain which can alter the decisions related to modularity and need consideration.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Modularity	Value chain characteristics	Cooperation with supplier	Howard & Squire (2007); Wang (2007); Lau et al. (2010); Lau (2011)	** Cooperation with partners block*	** Cooperation with partners block*	
		customization level	Not from literature	**Customization level block*		
		Supplier selection	Not from literature	**Supplier selection block*	**Supplier selection blocl*	Huang et al. (2005); Dietrich et al. (2006)

Table 5-9 - Modularity Framework – Value Chain Characteristics

Cooperation level with partners

As explained in the previous group, relationship management, cooperation level with partners can change based on joint profits and type of information shared. Similarly under the modularity group the same factors should be considered, because the relationship management group has a scope which covers all cooperation situations under the supply chain. However, here the influencers over the cooperation level for modularity will be explained.

Wang (2007) exclaim that under a modularity strategy, a strong cooperation, or integration, among the value chain should be present for effective management of the supply chain and reach the competitive capability needed. Lau (2011) describe system integration for a must in the modular product designs. They believe that key suppliers for the modularization process must be present in the system in design and development stages also.

Lau et al. (2010)s work is based on supply chain integration and their implications over modular and integrated product design, where they employed a case study approach. Finally, Howard & Squire (2007) believes that with modularization the sharing of information across suppliers and manufacturer increases in all the processes of the mass customization, starting from the design of the products up until the delivery. They indicate that modularity will result in more collaboration which is effected by specific assets and amount of information sharing.

Starting from the different works on the literature it would be true to conclude that the cooperation between the company and its partners would be valuable for the

modularization strategy. The amount of needed information shared among them would create an overall modularization strategy; even some partners could be a part of the design processes (Lau 2011).

So, a company who plans to start mass customization strategies must understand how the cooperation or integration of different partners would change the modularization process and must consider this on the decision based on module definitions.

For assessing this factor, same qualitative implications present in the relationship management group which are p*ossibility to have a contract which defines joint profits, amount and details of demand information* and *possibility to share company's internal information with other actors* could be used.

The standardization among the assessment factors would help the companies to understand how the same factors affect different decisions and how they are connected. It is also believed that such approach would simply the framework for the companies.

Customization level

In mass customization the customization level is one of the key points which define the characteristics of the value chain and the strategies such as postponement. For this reason there is a group dedicated to this subject.

Customization level is an important factor which has a relationship on two ways with modularity. The chosen modularity level defines customization level as also the vice versa is correct. The interaction between these two strategies calls for understanding how they affect each other, and how feasible solutions can be chosen. The customization level can influence the definition of the modules, their optimal numbers or even their availability in the system.

Because there is the customization level group present in the framework, the factors in the effecting decision of customization level would be explained later in the related group. There, modularity would be also seen as a factor inside the group.

For assessing the decisions concerning modularity and customization level, the indicators presented in the customization level group can be used.

Supplier selection

As explained in the cooperation with value chain partners' factor, the cooperation between the manufacturer and these actors can be crucial for the effective implementation of a modularization strategy. Especially if these actors would be present in processes such as design of the modular product, they should be selected based on some criteria which also translates into the modules.

The factors which effect supplier selection has been previously discussed in the relation management group, the same factors which affect the decision are also present under this factor. This means that while assessing those factors, modularity decisions should also be considered.

Like the factors, the indicator and implications associated with each factor is also the same with the previously mentioned group.

5.5.3. Postponement

The postponement group in the literature refers to the different postponement strategies that can be present in a mass customization system. These different strategies are form, time or place postponement as it has been explained before in the literature review chapter. A postponement strategy which is going to be realized can be combination of one or more of these three different approaches.

Each company, while going to a mass customization supply chain, must define the postponement strategy that they are going to implement. The definition of this strategy is important because it effects many different actors in the value chain and enables the mass customization capabilities.

This group in the framework aims for the company to understand which factors can influence the decisions based on the postponement strategy. It should be kept in mind that the factors does not point to one postponement strategy or another, it merely raises awareness of the factors to manage while implementing such strategies.

The postponement group is analyzed under four sub-groups, factors which are clustered under product, value chain characteristics, market characteristics and production systems. Each subgroup will be explained in detail.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Postponement	product	product architecture	Hoek (2000); Ma et al. (2002); Su (2005); Mortensen et al. (2008); Baozhuang et al. (2008); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011b)		Portion of cost related to the common base	Not from literature
					Modularity of the product	
	Value chain characteristics	cost of postponement (tradeoff between cost and efficiency)	Hoek (1997); Su (2005); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011a); Qin (2011b)		The desired efficiency of the actors of the value chain (supplier, manufacturer, distributor)	Not from literature
				Utilization of processes (machine utilization)=used resources/available resources		Su (2005); Graman (2010); Qin (2011b)
				Average waiting time of customer	Customer satisfaction in the company's context (includes cost and time for customer)	Expected waiting time [Su (2005)]
				Total delivery time after receiving an order		Delivery speed [Ma et al. (2002); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011b)]
				target service level	Ability to meet the service level requirments	Yimer & Demirli (2010)
		customization level	Hoek (2000); Su (2005); Kisperska-Moron et al. (2011)	**Customization level block*	**Customization level block*	Not from literature
		Inventory levels	Hoek (2000); Aigbedo (2007); Baozhuang et al. (2008); Guohua & Jihong (2010)	Inventory levels of modules, finished goods, semi-finished goods		Not from literature
				Inventory costs		
		value chain capability	Not from literature		Integrated information technology availablilty/usage	Not from literature

					Ability to fullfill the right order at the right time	Not from literature
		Value Chain network characteristics	Not from literature		Physical location and connections of actors	Not from literature
					Availability of information technologies to ensure needed customization	
	Market characteristics	Market demand levels and variability	Huang et al. (2005); Graman (2010); Trentin & Forza (2010); Kisperska-Moron et al. (2011);Qin (2011a); Qin (2011b)		Ability to diminish the demand variability by using postponement	Not from literature
	production system	production capability	Trentin & Forza (2010); Hoek (1997)	Production capability index (Cp)	Availiability of technology to ensure needed production	utilization level [Su (2005); Graman (2010); Qin (2011b)]
				Time of production of modules		Not from literature
				Time of production of common base		

Table 5-10 - Postponement Framework

Product

The product subgroup, similar to the case under modularization group, focuses on product characteristics and designs which can influence the implementation of different postponement strategies.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Postponement	product	product architecture	Hoek (2000); Ma et al. (2002); Su (2005); Mortensen et al. (2008); Baozhuang et al. (2008); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011b)		Portion of cost related to the common base Modularity of the product	Not from literature

Table 5-11 – Postponement Framework - Product

Product architecture

In a postponement strategy the product architecture can have a worthwhile effect. The modularity or percentage of the common base of the product can impact the postponement decisions in the value chain. It should be kept that form postponement is one of the major postponement types which is directly related to the architecture of the product.

In the research different articles focused on this concept from different points of view. Su (2005) includes the generic component coverage in product families as a factor while assessing different time and form postponement structures, while Hoek (2000) talks about how product configurations can effect downstream postponement. Similarly Kisperska-Moron et al. (2011) stress the importance of different product designs and their varieties for this strategy.

Mortensen et al. (2008), even though not in the postponement research stream, mention the close relation between the modular product architectures and postponement. The common modules and their coverage in the product architecture is also is emphasized especially as variables or parameters in optimal inventory and postponement cost models (Graman 2010, Qin 2011b, Baozhuang et al. 2008). The last Ma et al. (2002) uses the component cost structure in making commonality and postponement decisions.

Based on all this input taken from the literature, it can be seen that the product architecture definitely has impacts on postponement decisions. It is also evident that it has several different aspects that need to be managed.

It includes the modularity of the product, which is available in the framework as the previous group. The different module definitions or numbers can influence the postponement strategy. Similarly, the inverse is also possible; the optimal postponement strategy can influence the module definitions.

Another aspect is the commonality across the product families, how much of the cost is tied up in this common base or the percentage of the common base which makes up the products. These decisions also can influence the postponement. It should be kept in mind that these different aspects should be taken as a total; they are not disconnected from each other (as it was also seen under the product architecture factor in modularity)

Two qualitative ideas have been introduced to evaluate and understand the impacts that different product architectures can have on postponement. Parallel to what have been discussed before these are *portion of cost related to the common base* and *modularity of the product.* The evaluation of these points can make it easier to understand what the effects of different modularity are or commonality approaches have on postponement.

Value Chain Characteristics

The second subgroup present is the characteristics of the value chain. It is important to understand the different characteristics of the value chain because postponement strategies often result in postponement of different processes to other companies in the value chain (such as the logistics providers).

Due to this reason, it is also significant to understand which value characteristics can affect the implementation of the postponement strategies. In this way, the value chain can be altered or formed in line with the needed characteristics or if it is not possible, the strategy can be created by keeping the characteristics of the value chain in mind.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Postponement	Value chain characteristics	cost of postponement (tradeoff between cost and efficiency)	Hoek (1997); Su (2005); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011a); Qin (2011b)		The desired efficiency of the actors of the value chain (supplier, manufacturer, distributor)	Not from literature
				Utilization of processes (machine utilization)=used resources/available resources		Su (2005); Graman (2010); Qin (2011b)
				Average waiting time of customer Total delivery time after receiving an order	Customer satisfaction in the company's context (includes cost and time for customer)	Expected waiting time [Su (2005)] Delivery speed [Ma et al. (2002); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011b)]
				target service level	Ability to meet the service level requirments	Yimer & Demirli (2010)
		customization level	Hoek (2000); Su (2005); Kisperska-Moron et al. (2011)	**Customization level block*	**Customization level block*	Not from literature
		Inventory levels	Hoek (2000); Aigbedo (2007); Baozhuang et al. (2008); Guohua & Jihong (2010)	Inventory levels of modules, finished goods, semi-finished goods Inventory costs		Not from literature
		value chain capability	Not from literature		Integrated information technology availablilty/usage Ability to fullfill the right order at the right time	Not from literature
		Value Chain network characteristics	Not from literature		Physical location and connections of actors Availability of information technologies to ensure needed customization	Not from literature

Table 5-12 - – Postponement Framework – Value Chain Characteristics

Cost of postponement (tradeoff between cost and efficiency)

The strategy underlying postponement, or in mass customization in general, is the tradeoff between the cost and the efficiency of creating the customized products. The postponement strategies which offer the best customization to do customers might not be possible to sustain cost-wise or efficiency-wise. Similarly the cost-optimized solutions might result in decrease of customer satisfaction or the efficiency of the system.

All of these tradeoffs, including others which have a not mentioned here, enter the system as cost of postponement. Some points to be considered under this point can be utilization and time variations of processes (Su 2005), production, inventory, customization, transportation and material costs (Hoek 1997), delivery speed, flexibility, average time from start to completion (Kisperska-Moron et al. 2011), costs of packaging, postponement, holding, penalty and assembly times (Qin 2011a, Graman 2010, Qin 2011b) and investment, warehousing and inventory costs for customization (Qin 2012).

Such examples as these and others should be understood how the postponement strategy affects the different processes in the supply chain based on these variables.

To understand the factor's affects better over postponement some indicators were proposed in the framework. *Utilization of processes (machine utilization) (*Su 2005,Graman 2010,Qin 2011b) can be used to understand different decisions based on utilizations, a*verage waiting time of customer* and *total delivery time after receiving an order* are time based performance indicators which can be used to understand the strategies from a time based perspective. Also different literature talks about delivery speed (Kisperska-Moron et al. 2011, Graman 2010, Qin 2011b, Ma et al. 2002) as an indicator which these indicator has been derived from. The last indicator is influenced by the usage of service level concept by Yimer and Demirli (2010), *target service level,* can be used how the service level of the system changes.

Adding to these indicators some qualitative implications were also underlined to understand the concepts and effects better, even though they are not numerical measures. The first one is *the desired efficiency of the actors of the value chain,* which aims to make the company understand what the desired efficiency levels of the different actors are and how they affect the cost of postponement. The next one is the *customer satisfaction in the company's context (includes cost and time for customer),* which tries to evaluate the implications of customer satisfaction on the subject. The last consideration is the *ability to meet the service level requirements,* like the quantitative indicator derived from work of Yimer and Demirli (2010), which aims to understand qualitatively the service level requirements and the ability of the value chain to translate these requirements into action, which can affect the postponement strategy.

Customization level

The customization level directly affects the postponement strategy of the mass customization supply chain. While creating their models and doing their analysis some literature talks directly about the customization level. Kisperska-Moron et al. (2011) uses the level of product customization in its analysis while Su (2005) defines time and form postponement for different customization levels (make to order and assemble to order respectively). Hoek (2000), while explaining the postponement to third party logistics providers, talks about the different types of customization activities such as packaging, final assembly, installation of products at customer site and adding product features that could be postponed. Lastly Ji and Sun (2011) evaluate the delayed product differentiation based on customization levels along with other parameters.

Based on all these points it can be seen that customization level is a factor while making decisions on the postponement strategies that are going to be implemented in the value chain.

Because customization level is available as the fourth group of the framework, the factors which effect the customization and the indicators which can be used to measure it will be discussed under the customization level title.

Inventory levels

In the literature there are many models which are models talk about the inventory levels and how in postponement strategy these levels can be optimized (Hoek 1999; Graman 2010; Stavrulaki and Davis 2010; Qin 2011a; Qin 2011b), while non mathematical models (Hoek 2000) also talk about the subject. The location and levels of different inventory levels, such as modules, finished or semi-finished goods, can influence the postponement levels and can be effected by the realized postponement strategy.

According to the inventory management research in this study (present in the inventory management and scheduling research stream, different considerations such as supply frequency, customization levels (Aigbedo 2007), order cycle times and target inventory levels (Guohua and Jihong 2010) are components affecting the inventory management in the supply chain.

In a postponement strategy, it is important to maintain and manage all the inventories in the value chain, not only the manufacturer's. This is due to the fact that with the postponement strategies the types and levels of inventories in the traditional supply chains can be altered in a mass customization context.

The indicators chosen to asses such a factor is relatively straight forward in this case. They are *inventory levels of modules, finished goods, semi-finished goods* and *inventory costs*. With the help of these indicators the inventory level factor can be measured.

Value chain capability

Because postponement is a strategy which affects the value chain on all players, it is important that the value chain has the capability as a whole to carry out the different postponement strategies.

The company must understand the capabilities that the value chain must have or already have in place to create a strategy which can be carried out with efficiency. Due this reason, this factor has been chosen as a part of the value chain characteristics subgroup.

To understand the factor three points has been found to qualitatively assess the situation. The first one is the *integrated information technology availability/usage*, which aims to create an understanding if the information technologies to put in place such a strategy are available for the companies in the value chain. The information technology in place should be able to support the customization activities. The second is the *ability to fulfill the right order at the right time,* which aims to assess the capabilities of the actors. The last point is the *physical location and connections of actors,* which is important due to the understanding the capability of connecting the actors for transportation of the products in different states. The connections between the actors should be manageable, by cost and time aspects.

Market characteristics

Apart from the considerations that are based on the value chain, an important influencer of the postponement strategy is the market characteristics. The strategy cannot be put in place before understanding the market. Due to this market, this subgroup has been created.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Postponement	Market characteristics	Market demand levels and variability	Huang et al. (2005); Graman (2010); Trentin & Forza (2010); Kisperska-Moron et al. (2011);Qin (2011a); Qin (2011b)		Ability to diminish the demand variability by using postponement	Not from literature

Table 5-13 – Postponement Framework – Market Characteristics

Market demand levels and variability

The market demand and variability is an integral part of the postponement strategy. This is because; with the unknown characteristics of demand for mass customization it is difficult to put in strategies which mimic the efficiency of mass production. Actually, this is one of the reasons that in mass customization the postponement strategy is put in place.

In the literature two different aspects of the demand has been referred to, the demand itself (Trentin and Forza 2010; Graman 2010; Qin 2011a; Qin 2011b) and the demand variability (Huang et al. 2005; Kisperska-Moron et al. 2011; Qin 2011a).

Both aspects can affect the postponement strategy, so they have been both incorporated into this factor.

To comprehend the effects of demand variability the indicator *ability to diminish the demand variability by using postponement* has been proposed. The aim is to understand if the chosen postponement level can smooth the demand variability present in the market, which is one of the objectives of postponement.

Production System

The last subgroup of this group is the production systems that the manufacturer has. Apart from value chain, the company should be focused separately because the production systems are in full control of the company and the manufacturer also should understand its own production capabilities apart from the value chain.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Postponement	production system	production capability	Trentin & Forza (2010); Hoek (1997)	Production capability index (Cp)	Availiability of technology to ensure needed production	utilization level [Su (2005); Graman (2010); Qin (2011b)]
				Time of production of modules		Not from literature
				Time of production of common base		Not from literature

Table 5-14 - Postponement Framework – Production System

Production capability

The production capability factor in this case is closely connected to the module and commonality of the products which are going to be produced by the manufacturer. The manufacturer must be capable to produce the needed components before continuing with the other processes of postponement.

In the literature Hoek (1997) and Trentin and Forza (2010) touch on the subject of production capabilities. Hoek (1997) mentions process characteristics and technological

characteristics associated with processes while Trentin and Forza (2010) talks about simple production environments.

To understand the production capability three quantitative indicators can be used. These are production capability index (Cp), time of production of modules and time of production of common base. Apart from these indicators some qualitative considerations such as the availability of technology to ensure needed production must be considered.

5.5.4. Customization level

In a mass customization system, the customization level plays an important role in forming the different strategies. The customization level is based on the customer order decoupling point or in other words, the point where the customer comes into the system with the order. The main customization levels include, assemble to order, build to order, design to order and engineering to order.

While customization level influences how different strategies are put into place, there are also factors which influence the customization that takes place in the value chain. These different factors can help the companies while making their considerations about the customization degree that will be offered to the customer.

Like the previous groups, the relevant factors are collected under relevant subgroup to better understand from which point of view the factor affects the customization level. All factors are explained in detail below.

	Factor	Factors impacting decisions	Who	KPI	Qualitative implications	Who
Customization level	Market characteristics	Market demand	Poulin et al. (2006); Yu & Jie (2008); Yimer & Demirli (2010); Stavrulaki & Davis (2010)	Market demand analysis	Market demand analysis	Not from literature
	Product	Product architecture	Stavrulaki & Davis (2010); Ji & Sun (2011)		Portion of cost related to the common base	Not from literature
					Modularity of the product	Not from literature
	Value chain characteristics	value chain capability	Stavrulaki & Davis (2010)		Integrated information technology availablilty/usage	Not from literature
					Ability to fullfill the right order at the right time	Not from literature
		Value chain network characteristics	Salvador et al. (2004); Stavrulaki & Davis (2010)		Physical location and connections of actors	Not from literature
					Availability of information technologies to ensure needed customization	Not from literature
		cost of customziation (tradeoff between cost and efficiency)	Ji & Sun (2011)		The desired efficiency of the actors of the value chain (supplier, manufacturer, distributor)	Graman (2010); Qin (2011)a; Qin (2011)b
				Average waiting time of customer	Customer satisfaction in the company's context (includes cost and time for customer)	Expected waiting time [Su (2005)]
				Total delivery time after receiving an order	The desired efficiency of the actors of the value chain (supplier, manufacturer, distributor)	Delivery speed [Ma et al. (2002); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011)b]
				Target service level	Ability to meet the service level requirments	Yimer & Demirli (2010)

Table 5-15 - Customization Level Framework

Market characteristics

The market characteristics are the main drivers of the customization level in the system. The degree of customization is generated due to the demands of the market, or it believes that it will create a market for the product, as it is the case with all products offered to the customers.

To do so, it is important to understand the market characteristics, although this framework only focuses on market demand and asses their influence over the customization level.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Customization level	Market characteristics	Market demand	Poulin et al. (2006); Yu & Jie (2008); Yimer & Demirli (2010); Stavrulaki & Davis (2010)	Market demand analysis	Market demand analysis	Not from literature

Table 5-16 - Customization Level Framework – Market Characteristics

Market demand

Similar to the market demand factor in postponement strategy, for customization level also the literature focuses on two different aspects, the demand volume (Poulin et al. 2006; Yu and Jie 2008; Yimer and Demirli 2010; Stavrulaki and Davis 2010) and variability (Stavrulaki and Davis 2010). However here it can be seen that demand volume gains more importance over the demand volume. The reason for this can be that, demand variability does not affect the customization level as much as it does the postponement strategy; here the market volume has more effect.

To understand and asses the market demand factor provided here the indicator *market demand analysis* was chosen. This indicator is considered in both aspects, as quantitative and qualitative assessment, in two different ways. For the quantitative aspect, the numerical volume associated with the different customization levels (the forecasts done by the company) can be used to understand the effects. In the qualitative aspect, the demand can be analyzed qualitatively to better understand the needs of the customers and how they can be segmented.

Product

In the second subgroup, like present in the other subgroups, the aspect of the product was considered. The product, which what the customization takes place on, needs to be understood and assessed for the impacts it might have on the customization level decisions in the value chain.

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Customization level	Product	Product architecture	Stavrulaki & Davis (2010); Ji & Sun (2011)		Portion of cost related to the common base	Not from literature
					Modularity of the product	Not from literature

Table 5-17 - Customization Level Framework – Product

Product architecture

The product architecture can have different features which can be considered as a factor in the customization level. Even though it can be more logical that the customization level affects the product architecture, in some cases it can be possible that the product architecture restricts different customization options.

In the customization level research stream, Stavrulaki and Davis (2010) gives a list of product characteristics, such as product variety, modularity which is relevant to the product architecture which is discussed, and how they change over different customization levels such as build to stock, assemble to order, build to order and design to order. Similarly, a study from the postponement research stream which focuses on the customer order decoupling point (Ji and Sun 2011) does some sensitivity analysis using the product variety.

Based on this information about the customization level research stream, and from the information gathered from the other research streams (the same ideas from the previous product architecture factors can also be reflected here), two qualitative approaches to understand the factor has been provided here: portion of cost related to the common base and the modularity of the product. These are the same with the qualitative indications provided in the previous product architecture factors.

Value chain characteristics

The customer order decoupling point can be corresponding to different points on the value chain which corresponds to the activities of different actors (such as the manufacturer or the distributor). Due to this reason, it is important for a company who wants to do customization, if the value chain has the needed characteristics to support the mass customization activities.

Also, even if the decoupling point does not corresponding to an actor, mass customization is a strategy that encompasses the whole value chain and all the actors must have the capability to sustain the processes needed from them.

The different factors present in this subgroup are not considered from the perspective of the value chain as a whole and not from individual actors to create an overall understanding for the company. However, the manufacturer must understand the capabilities and characteristics of different actors and their relations with them.

	Factor	Factors impacting decisions	Who	KPI	Qualitative implications	Who
Customization level	Value chain characteristics	value chain capability	Stavrulaki & Davis (2010)		Integrated information technology availablilty/usage	Not from literature
					Ability to fullfill the right order at the right time	Not from literature
		Value chain network characteristics	Salvador et al. (2004); Stavrulaki & Davis (2010)		Physical location and connections of actors	Not from literature
					Availability of information technologies to ensure needed customization	Not from literature
		cost of customziation (tradeoff between cost and efficiency)	Ji & Sun (2011)		The desired efficiency of the actors of the value chain (supplier, manufacturer, distributor)	Graman (2010); Qin (2011)a; Qin (2011)b
				Average waiting time of customer		Expected waiting time [Su (2005)]
				Total delivery time after receiving an order		Delivery speed [Ma et al. (2002); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011)b]
					Customer satisfaction in the company's context (includes cost and time for customer)	Not from literature
				Target service level	Ability to meet the service level requirments	Yimer & Demirli (2010)

Table 5-18 - Customization Level Framework – Value Chain Characteristics

Value chain capability

The value chain capability is the capability of different actors in the value chain to support the needed mass customization activities. It is considered as a factor in the

customization level group because these needs can change based on the different customization degrees adopted by the company.

Stavrulaki and Davis (2010) talks about different supply chain strategic capabilities, as lean, agile and leagility in the supply chains.

Like the capability factors considered in the previous parts of the framework, the capabilities can be driven or driving the customization levels. If the value chain has not been created yet, or the actors have not been chosen, then based on the customization level actors with corresponding capabilities can be chosen. However, even this is the case, the actors with the needed capabilities might not be found or partnerships might not be created due to different reasons. In such cases, or the cases where the company is already operating with a value chain in place and only wants to pass to mass customization strategy, the value chain capability can be a strong influence over the customization level chosen.

Similar to other value chain capability factors, two indicators have been chosen to qualitatively asses the capability of the value chain and its actors. These are i*ntegrated information technology availability/usage* and a*bility to fulfill the right order at the right time.*

Value chain network characteristics

Like the capabilities of the value chain, the network characteristics should also be considered while making decisions on the degree of customization that is going to be offered to the customer.

Different characteristics have been identified by the literature for different actors and networks in the value network. While Stavrulaki and Davis (2010) talks about only logistic and manufacturing related characteristics, Salvador et al. (2004) also takes supply networks into consideration. Different characteristics Salvador et al. (2004) focuses on includes the physical locations of the actors, owners, lead times of suppliers, repetitiveness of the assembly, if implemented postponement strategy is present and volume for manufacturing network and similarity for mass production distribution for the distribution network. On the other hand, Stavrulaki and Davis (2010) focuses on production process, design the availability of direct contact with the end user and the process focus for the manufacturer related characteristics and number of intermediaries, the bullwhip effect, relationship with the suppliers and again process focus for the logistics providers.

Based on the characteristics mentioned above from the literature, of course, different and relevant characteristics should be added by the company. However, these characteristics act as a stepping stone in understanding the different characteristics of the value chain.

In line with the characteristics mentioned above, two viewpoints were proposed to understand this factor and how it can affect different customization degrees. The first one is the *physical location and connections of actors* and the other one is the *availability of information technologies to ensure needed customization.* Understanding these two points can help the company understand how the network characteristics can affect the customization level.

Cost of customization (tradeoff between cost and efficiency)

The last factor of the framework proposed it the cost of customization. Similar to the cost of postponement, this factor aims to understand how the cost of customization can affect the different customization levels in product.

Similar to the cost of postponement, the customization can have a cost structure which affects the degree of customization by providing a tradeoff between cost and efficiency.

Based on the studies of different authors, few different indicators have been proposed to understand this factor. The quantitative indicators are *average waiting time of customer (*Su (2005)), *total delivery time after receiving an order* (Ma et al. 2002; Graman 2010; Kisperska-Moron et al. 2011; Graman 2010; Qin 2011b) and *target service level* (Lau et al. (2010)). It can be seen that the literature and the indicators are the same with the cost of postponement in the postponement group due to the fact that the base of this factor comes from there.

The qualitative implications are also the same with other implications from cost of postponement. These are *the desired efficiency of the actors of the value chain* (Graman 2010; Qin 2011a; Qin 2011b), *customer satisfaction in the company's context (includes cost and time for customer)* and *ability to meet the service level requirements (Yimer and Demirli 2010).*

6. Validation

As the last step of the thesis the validation of the framework was done based on case studies, as it was explained in the methodology chapter. The aim of this step is to understand and validate if the framework, which was created based on the literature, will be applicable in the real life cases.

To do so, the before mentioned questionnaire was created. The full questionnaire is available in the appendix E. The questions present were designed to asses all the factors and key performance indicators in the framework. However, the questionnaire only asses the quantitative indicators present in the framework, the qualitative indications are not in scope of the questionnaire.

As explained before, the questionnaire starts with general questions to get an overview of the company profiles. After, the questions were created following the groups in the framework:

- Relationship management
- Modularity
- Postponement
- Customization level

For the validation phase a total of 179 companies were contacted through e-mail or online form applications. Out of these 179 companies, from 9 negative answers were received, 11 indicated that they forwarded it to the related department however no response was received after, 152 hasn't responded in any mode, 7 responded asking the link to the online form and in total 4 filled the questionnaire. Based on these statistics, the questionnaire had a 2.2% response rate.

In the following part each first company profiles based on the general questions will be introduced followed by the analysis of the four groups of the framework based on the answers received from the companies.

It should be noted that, although the findings are not statistically significant, some implications will be presented after the framework analysis which can serve as a starting point for the companies who use the framework.

6.1. Company profiles

The three companies who are included in this study come from different industries. One is in the textile industry (in the survey identified it's industry as e-commerce), the others on furniture, fashion and stone cutting market. The reference product families are shirt apparel, shelves, accessories and diamond wires respectively.

Industry	Reference product family	Employee count	Turnover of company	Customization level
E-commerce	Shirt apparel	50 - 999	More than 150,000	Build to stock Make to order Design to order
Furniture	Shelves	1 - 49	More than 150,000	Make to order
Fashion	Accessoires	1 - 49	Between 70,000 and 150,000	Assemble to order
Stone cutting market	Diamond wires	1 - 49	Lower than 20,000	Assemble to order

Table 6-1 - General Characteristics of Companies

While the e-commerce company has 50-999 employees, the other three are small companies with employee count between 1 and 49. Due to this reason, it can be said that all companies who have completed are small to medium enterprises. So, it can be said that the following analysis is true for small to medium sized companies.

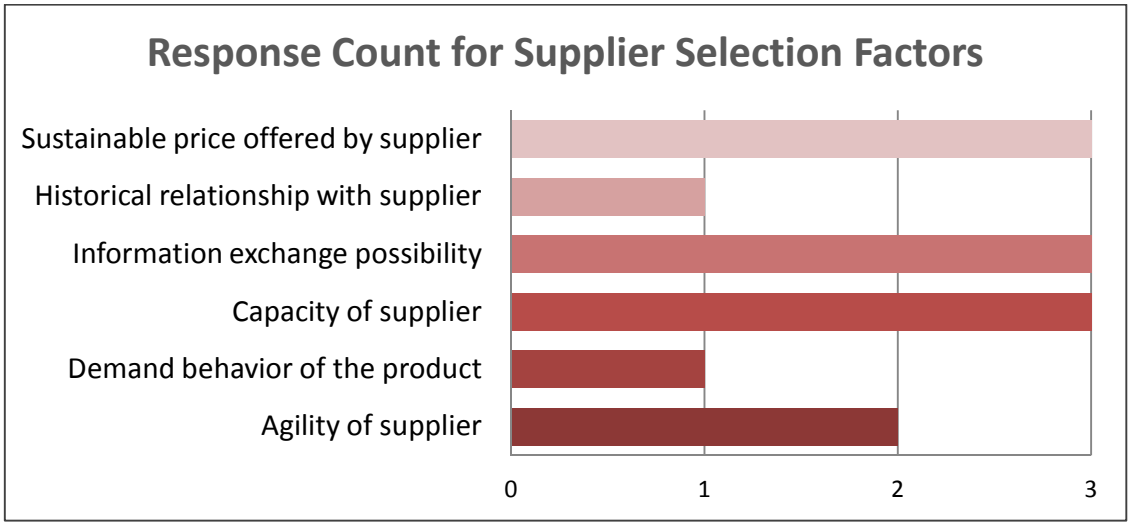
Even though, by employee amount they are small, the turnovers are usually high. The companies selected the highest option, “more than 150,000”; while one told that their turnover is between 70,000 and 150,000 Euros again except the one, which has less than 20,000.

The last general question was the put to assess the customization levels that the companies employ. While the e-commerce company chose three options, build to stock, make to order and design to order, the others chose single options, make to order and assemble to order. Because all companies base their customization on different customer order decoupling points, all their responses for the questions will be considered together to create a “generic” understanding for the framework.

6.2. Relationship management

6.2.1. Supplier Selection

For the first part of the relationship management group, supplier selection, the companies were told to choose the factors which influence their supplier selection decision. The count of the factors is given in graph 5.



Graph 4- Response count for supplier selection factors

As it can be seen that all factors were chosen by two or three companies, except the "demand behavior of the product" and "historical relationship".

It can be considered that the factors are justified, although the historical relationship and demand behavior options had few responses. For the historical relationship option it is believed there can be two underlying reasons for this: the first is that the companies didn't have historical relationships with their suppliers before, or they don't consider this an important factor in their selection process.

For the other demand behavior option the reasons can be diverse, the manufacturer might smooth out the demand behavior before it reaches the supplier so the selection affected by the demand. Unfortunately, the difference cannot be understood by the answers of this questionnaire.

For the indicators associated with the factors, a summary is done (table 7-2)

Factors	Performance Indicators			
	Percentage of completed orders	Capacity of supplier allocated on total capacity	Price per unit	Price per delivery
Agility of supplier	2	1	1	1
Demand behavior of the product	4	1	1	3
Capacity of supplier	2	2	2	0
Information exchange possibility	2	1	1	1
Historical relationship with supplier	3	1	2	1
Sustainable price offered by supplier	3	2	1	2

Table 6-2 - Supplier Selection Indicator Selections

On the performance indicators corresponding with the factors in the framework are shown in red. Due to the reasong "percentage of compeleted orders" indicator is present

in the framework twice, it is also present in the related question twice which created a higher response rate for that indicator.

When the answers are considered the it can be seen that every proposed indicator has been chosen once. However there was different conclusions came up.

It can be seen that “percentage of completed orders” has been chosen three times and “price per delivery” four times as an indicator to the factor “demand behaviour of the product”. This can be due to the fact that, order completion and delivery price can be based on the demand of the product and also the behaviour. Very fluctuating demand can result in low completion of orders during the times of high demand if there is not the capacity for it.

Price per unit and capacity of supplier allocation indicators have been chosen for all factors. This can indicate to certain misunderstanding associated with the questionnaire. Due to the almost consistent dispersion of the answers, it seems that some answers might be given based on the factor’s effect on the performance indicator. If this is the case, the conclusions driven from this question can be misleading.

6.2.2. Supplier Cooperation/Integration

When supplier cooperation is considered, there is a misalignment with the framework. While on the framework cooperation with all actors are considered, in the questionnaire questions about only supplier are asked. Due to this reason, these answers will be considered only on upstream value chain point of view and if possible can be reflected among all actors of the supply chain.

In the first question, percentage of suppliers critical for the Mass Customization activities, it can be seen that two extremes are present. While three respondents answered with high percentages (Guohua and Jihong (2010), Weizhe & Zhihua (2010) and 70) which show the importance of suppliers in their value chain, the other responded with 0, meaning that the suppliers have no effect on the value chain. This is important because, this shows that there are some companies which doesn’t consider their suppliers an important part for their mass customization activities.

Regardless of their criticalness, all respondents showed that they share information by real time or by weekly reports which shows that they all value information sharing at some level.

Shared information type	Response count
Amount and details of demand	1
Delivery due date	3
Order registered time	2
Cost of delay	1
Flexibility of the time to respond to orders	2
Total time of manufacturing	0
Total time of distribution	2
Cost of unit of customization	2

Table 6-3 - Response count for shared information type

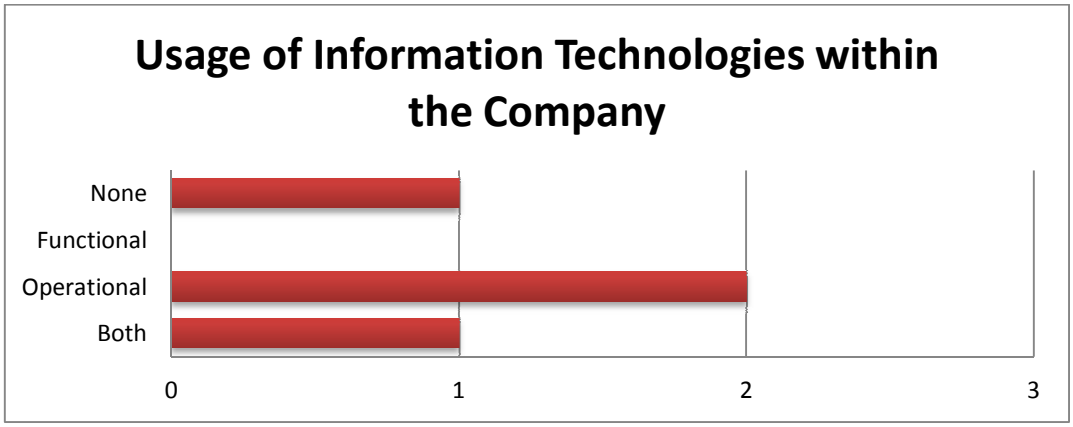
Also based on different types of information shared with the suppliers given in table..., it can be seen that usually some kind of information is shared with the suppliers, only total time of manufacturing is not shared by any participants which might point to irrelevance of the information type for mass customization operations.

However, here an important point should be emphesized. The company in the fashion sector, which doesn't see any suppliers as critical for mass customziation, shares only two types of informations, delivery due date, cost of unit of customization. It can seen that these two information types can be always shared , regardless of the criticalness of the supplier for the mass customizor company. Interestingly, this company is the only one who reported that they aim to maximize the joimt profits with the suppliers instad of individuals.

6.2.3. Internal Integration

For assessing the factors connected to internal integration in the framework, which are information exchange level and organizational readiness, two questions were asked. The first was the usage of information technologies in different operational levels, functional and operational. The results show that while almost all companies use information technologies (graph 6) in an operational level, only one uses it in a functional level. One reported no usage of information technologies in any of these levels.

However the company who reported no usage of information technologies communicated that they are currently working on improving their management systems based on information technologies, which shows that information is also an important factor for this company.



Graph 5- Usage of Information Technologies within the Company

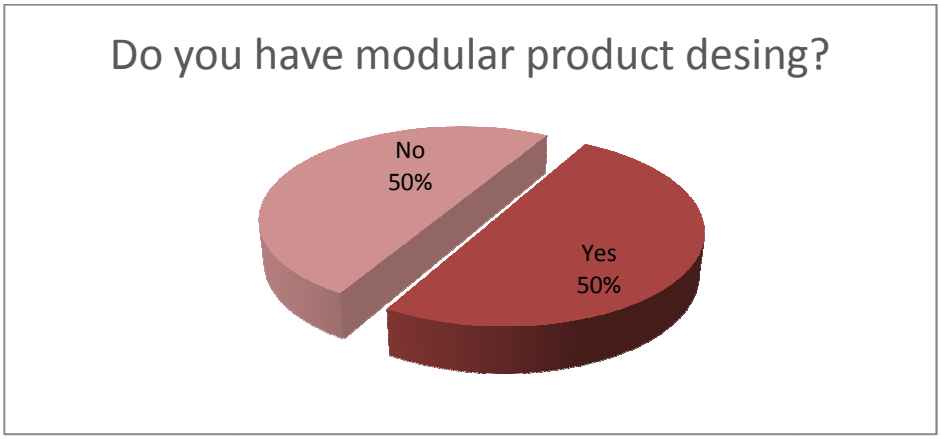
Regarding the organizational readiness, it was aimed to understand if companies employ a kind of training for the employees for mass customization practices. On this, only one of the companies reported giving trainings. The same company also indicated “making people aware of the easy implementation of MC within a system” as a problem they encountered regarding organizational readiness on mass customization. This insight suggests that organizational readiness is a factor which effects mass customization.

6.2.4. Customer Integration

The only question related to the customer integration was the usage of the resources. Three of the respondents communicated the usage of web or instore configurators with the customers, while one reported usage of workshops, feedback mechanisms and direct contact with the customers. The direct contact option was not

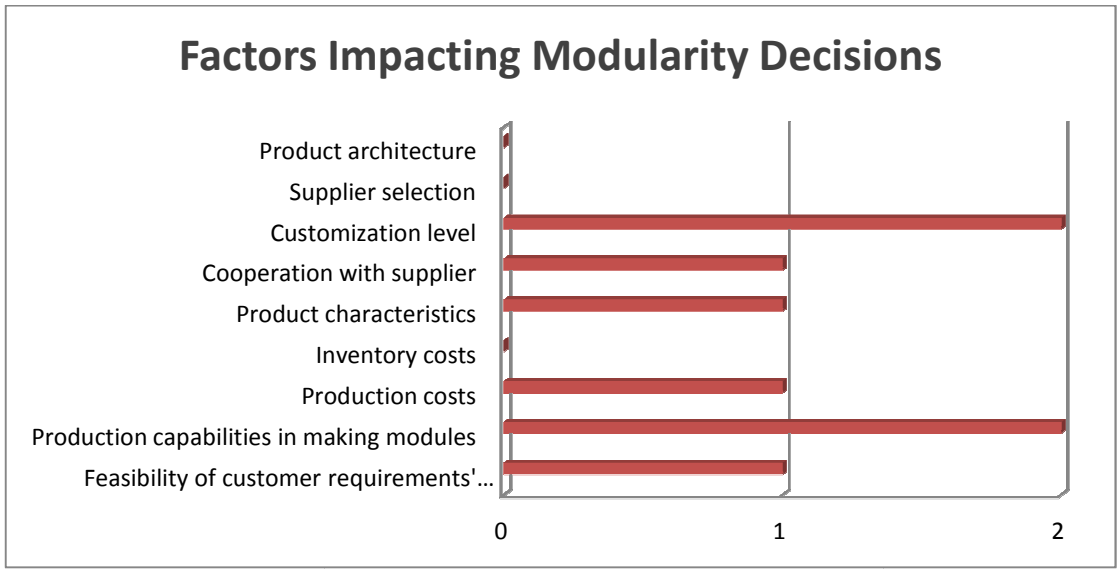
6.3. Modularity

The questions in this group were used to assess the compatibility of factors and indicators associated with modularity strategy. However out of the three companies, only one has reported to have a modular product design.



Graph 6 - Modular Product Design

The two companies who employ a modular product design reported the following factors important for their modularity decisions (graph….). With 100% the customization level and production capabilities are chosen while product architecture, supplier selection and inventory costs were not selected at all.



Graph 7 - Factors Impacting Modularity Decisions

Factors	Performance Indicators							
	Time of production of modules	Average waiting time of customer	Capacity of supplier allocated to your company on total capacity	Inventory costs of modules	Market demand analysis	Percentage of completed orders	Price per unit	Total production costs of modues
Cooperation with supplier	2	1			1			
Customization level		1	2		1	2	2	1
Feasibility of customer requirements' translation into modules	1	1		1	1	1		
Inventory costs of modules		2	1					
Product architecture	1				1	2	1	
Product characteristics	3			1		1	2	
Production capability in making modules		2	2		1	3	1	2
Production costs of modules	3		2			1		1
Supplier selection				1		1		1

Table 6-4 - Modularity Indicator Selection

The table 7-4 shows the indicators selected for different factors present in the modularity group, the red cells represent the connections present in the supply chain.

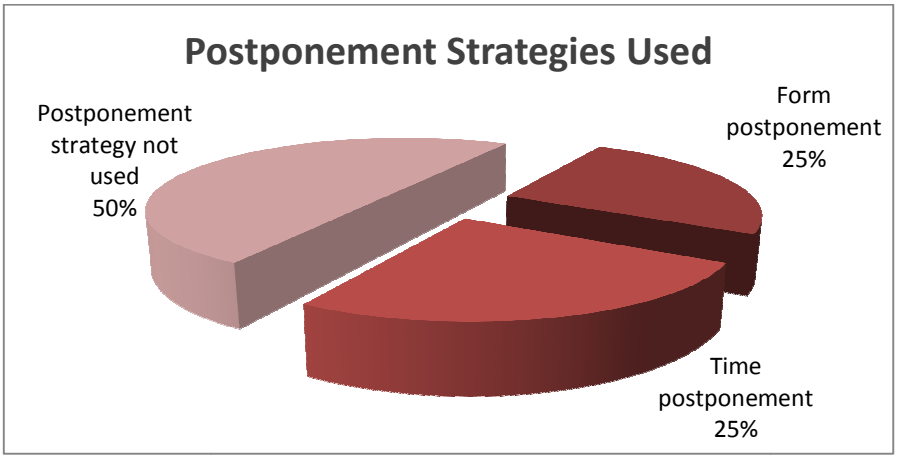
When the table is considered, it can be seen that almost none of the indicators selected in the framework were accepted by the industry. This might point to the need for reconsideration of the indicators chosen for the factors.

From the answers received, it can be seen that percentage of completed orders, similar to supplier selection questions in the previous section, seems to be almost used for all the factors present, especially production capability in making modules. Also links between production cost of module and product characteristic factors and time of production of modules indicator which was not present in the framework.

Another point that needs consideration is the number of answers received for this part of the questionnaire. While the companies who practice modularity are two, three of companies have provided answers regarding the performance indicators. This can show that these questions have been answered in a general perspective rather than a modularity perspective.

6.4. Postponement

In this group of the questionnaire the postponement strategy block in the framework was aimed to be assessed. First it was aimed to understand if postponement is used by the companies. Based on the results while 50% are not practicing any postponement strategy, one is practicing form and the other time postponement (Graph 9).



Graph 8 - Postponement Strategies Used

For the factors to be chosen in the postponement strategy, only three factors were shown as the reason of selecting the postponement strategy mentioned before. The company who chose form postponement signaled customization levels as a reason (thus a factor in the frame) and the company who chose time postponement signaled production capabilities and inventory levels.

Factors	Performance Indicators									
	Average waiting time of customer	Inventory costs	Inventory levels of modules, finished goods, semi-finished goods	Market demand analysis	Production capability index (Cp)	Target service level	Time of production of common base	Time of production of modules	Total delivery time after receiving an order	Utilization of processes (machine utilization)
Cost of postponement (tradeoff between cost and efficiency)	2			3	2	1	1	1	2	
Customization level	1	2	1	1		1	1	1	2	1
Inventory levels	1		1			1				1
Market demand levels and variability	1	1	2	1	1	1		2	2	2
Production capability	2	1		2	1	3	1		1	
Value chain capability							1			
Value chain network characteristics	1			1					1	

Table 6-5 Postponement Indicator Selection

Similar to the previous indicator selection questions, the results of postponement also shows a almost uniform allocation between indicators and factors (table 7-5). Also the low number of participants answered this question can make the results inconclusive.

6.5. Customization level

In the last group, the framework was aimed to be reviewed based on the factors and indicators for these actors as in the previous groups.

Factor	Count
Cost of customization	1
Market demand	2
Product architecture	3
Value chain capability	2
Supply chain network characteristics	0
Other: Co-design	1
Other: Cutomer needs	1

Table 6-6 - Customization Level Factors

Based on the factors chosen by the participants, it shows that all factors are considered to impact the customization level except the supply chain network characteristics. Also two other factors have been proposed: co-design and customer needs.

For the indicator selection (table 7-7), none of the chosen indicators have corresponded to the indicators selected for the factors in the framework similar to the previous groups.

Factors	Performance Indicators			
	Market demand analysis	Production capability index (Cp)	Time of production of common base	Time of production of modules
Cost of customziation (tradeoff between cost and efficiency)	1			
Market demand				1
Product architecture		3		
Value chain capability	1		2	2
Value chain network characteristics	1		1	

Table 6-7 - Customization Level Indicator Selection

7. Discussion

Based on the different responses received from the questionnaire and general considerations there are different points which can be concluded from the framework created for this thesis.

It should be underlined that, as a limitation of the validation phase, that the responses received were not statistically significant. Due to this limitation some conclusions can be drawn from the replies, however they are not enough to determine the correctness of the framework in the industry point of view, especially when there in not support for one of the factors or indicators. This is because, if support is shown, it is more logical to conclude that there are companies which consider those aspects of the supply chain. However, during the lack of evidence it is harder to justify the reason. It can be because the factor is actually not applicable to proposed strategy or it can be due to the fact that the few companies who are covered in the validation are not consulting these factors but other companies in the industry does.

Due to this reason, the analysis below is mostly based on the added points to the framework rather than points with lack of evidence. However, the lack of evidence is also highlighted in the important cases.

When the questionnaire is considered there are few points to be highlighted. In almost all groups the factors which were proposed by in the framework were justified by the responses received.

For relationship management group, the factors all found responses from the participants even though some, like demand behavior for supplier selection subgroup, received only one. In such cases the questionnaire is not extensive enough (based on number of respondents) to understand if these factors which are not chosen as much as the others should be excluded from the framework or be better defined.

One point which was emphasized by all respondents was the usage of information for the different aspects of relationship management. The factors about information exchange levels or types of information shared always showed important relevance. In one case, internal integration, one of the companies responded as not using information technologies for neither operational nor functional activities. However, they specifically indicated that this is a point they are actively working on to create a management system based on information technologies. This emphasis shows that the importance of information systems and information exchange was correctly identified in the framework.

Another point which are few of the extra feedback received from one of the open questions is based on internal integration is the importance of making people aware of easy implementation of mass customization for companies. This point, although not

considered can be included in the “organizational readiness” factor of the internal integration.

An additional point was also identified by one of the participants is in customer integration. Adding to the ways of customer interaction, it was proposed the “direct contact” which was not available as one of the options of the indicators. It is believed that this can be an important point to grasp other interaction techniques employed by different companies.

A point to be emphasized is that under the modularity framework, none of the participants have chosen the product architecture as a factor which influences modularity. This point may need to be investigated further as it was assumed that modularity directly relates to product architecture.

For the customization group, with the help of the feedback on the open questions two new potential factors were also identified as “co-design” and “customer needs”. While the customer needs aspect can be covered in the already existing demand factor, because it was proposed as an additional factor it needs to be better understood and considered to be added into the framework.

For postponement and modularity, the representativeness of the answers creates even more uncertainty due to the fact that not all companies practice modularity or postponement strategies. The answers received in these groups are based on answers of few companies. While in modularity all the related factors were almost chosen once (with the exception of product architecture as mentioned before, inventory costs and supplier selection), in postponement strategy only three points were chosen as relevant.

When the indicators for each group are considered, it can be seen from the explanations present in the previous chapter that the validation has not succeeded. In some cases the indicator were not chosen by any respondents to represent a factor, or there is almost uniform behavior of indicators over all factors. This is believed to happen for two reasons, either the selected indicators were not correct to represent the factors in the framework for the industry or again this point is due to a representativeness issue.

To further this work, a more significant validation should be implemented. This can again be in survey format with a relatively high response rate or as case studies with semi structured questions which will help to understand the understanding that lies behind the positive or negative answers.

With getting more insight the, more focused answers or frameworks can be constructed such as for different customization levels or postponement strategies. The same can be done with different industries if enough responses are gathered to make such an analysis.

8. Conclusion

To manage and improve supply chains in an effective way, the factors behind different strategies needs to be understood and measured. The aim of this thesis is to identify these factors and ways to measure them for implementation of effective mass customization strategies.

To do so, two different questions have been proposed at the beginning of this thesis:

1. Which factors are needed to be considered while implementing mass customization in supply chain level?
2. How these factors can be measured?

To answer these questions a supply chain framework has been created including factors which affect different mass customization strategies and different indicators to asses them.

To do so, starting from the literature, different strategies have been identified, by clustering and refining the ideas. These ideas were grouped together to create a framework which acts as guidelines to help companies implement mass customization strategy. The frame focuses on four different strategies for management of mass customization supply chains: relationship management, modularity, postponement and customization level.

For these four different aspects of the supply chain, different factors has been proposed to aid companies in making their decisions and understanding the affects of these factors on the different aspects. Factors have been used across strategies to see how the same factor can have impact on different strategies and how they should be managed for both of them.

As for the second question, it was aimed to propose different indicators for measurement of these factors in the supply chain. These indicators, coming from the literature or proposed afterwards, helps the companies in understanding the performance of the system for the different factors included in the frame. A company can understand these factors for effective implementation using the indicators proposed.

To understand the completeness of the framework, different case studies have been analyzed. Despite the fact that the validation phase lacked representativeness, it can be assumed that the frame gives general guidelines to the companies. The study can be taken forward by creating a more representative validation strategy to understand better how to focus on different industries or the different strategies proposed and refining also the general frame for more specific purposes, such as different customization levels.

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10.Appendices

10.1. Appendix A – Article Counts in Journals

Journal Name	Number of Articles
International Journal of Mass Customisation	9
International Journal of Operations & Production Management	7
International Journal of Production Economics	7
European Journal of Operational Research	4
Supply Chain Management: An International Journal	3
Computers & Industrial Engineering	2
Computers in Industry	2
Engineering Management	2
Industrial Management & Data Systems	2
International Journal of Logistics Management	2
Procedia Engineering	2
Production Planning & Control: The Management of Operations	2
Automation and Logistics, 2007 IEEE International Conference o	1
European Journal of Operational Research	1
Advanced Engineering Informatics	1
Automation and Logistics	1
Automation Science and Engineering	1
Business Management and Electronic Information (BMEI)	1
Concurrent Enterprising (ICE)	1
Control and Decision Conference (CCDC)	1
Ege Academic Review	1
Industrial Engineering and Engineering Management (IE&EM)	1
Information Management	1
Intelligent Computation Technology and Automation (ICICTA)	1
International Journal of Physical Distribution & Logistics Management	1
International Journal of Service Industry Management	1
Journal of Electronic Commerce Research	1
Journal of Engineering and Technology Management	1
Journal of Fashion Marketing and Management	1
Journal of Operations Management	1
Logistics Systems and Intelligent Management	1
Machine Learning and Cybernetics	1
Management Research News Volume	1
Management Research Review	1
Management Science and Engineering	1
Systems Engineering Procedia	1
Systems Engineering Procedia	1
Technovation	1
The Journal of China Universities of Posts and Telecommunications	1
Total	71

10.2. Appendix B – Research Streams Article Detail

Research Stream	Source	factors		Performance	KPI	Industry specification
Relationship Management	Monroy & Arto (2010)					aeronautical industry
	Zhanga & Huangb (2010)	commonality modularity platforming (with or without) level of customization demand levels		total cost	development cost purchasing cost ordering cost inventory holding cost	
	Lau et al. (2010)	information sharing product co-development organizational coordination product modularity		product performance product modularity		electronics toys plastics
	Jitpaiboon et al. (2009)	customer integration supplier integration MC capability	participation level of customer in product development participation level of customer in finished good distribution participation level of customer in manufacturing process willingness of customer to share demand customer involvement level on business plans extent of follow up for customer feedback The participation level of suppliers in manufacturing processes The participation level of suppliers in production planning processes The participation level of suppliers in product development processes The participation level of suppliers in logistics processes The level of cross-over of activities between our firm and our suppliers The level of supplier involvement in preparing our business plans Our capability of customizing products at low cost Our capability of customizing products on a large scale Our capability of translating customer requirements into technical designs quickly Our capability of adding product variety without increasing cost Our capability of customizing products while maintaining a large volume Our capability of setting up for a different product a low cost Our capability of responding to customization requirements quickly Our capability of adding product variety without sacrificing overall production volume Our capability of changeover to a different product quickly	Organisational performance	Customer retention rate Sales growth Return on investment Production throughput times Overall competitive position	
	Liao et al. (2011)	mutual trust free information sharing (with manufacturer) mass customization	openness and honesty respect for confidentiality product development information sharing manufacturing processes information sharing logistics information sharing quality management information sharing financial information sharing customization ability on large scale product variety adding without cost increase customize product features rapidly	free information sharing (from trust) mass customization capability cost rapidity		
	Pan & Holland (2006)	textile suppliers with apparel designer/brand hou garment manufacturer's with apparel designer/br	sales team communication with clients Design development team's seasonal presentations approval of client requests for fabric match sample information transfer into technical specifications of production sales team communication with clients Design development team's technical service to clients garment manufacturer's technical package CAD/CAM data files to establishment for production			fashion
	Moser & Piller (2006)			cost	inventory costs	bicycle
	Qin (2012)	delivery time promised market demand orders in unit time actual time of customization penalty costs paid to manufacturer penalty costs paid to customer elasticity of response time elasticity of customized demand total time of manufacturing and distribution cost of unit of common product produced by manufacturer cost of unit of product customization done by distributor	common variables	price of customized product price of customization service quoted for manufacture by distributor time of customization profit	decision variables	
	Wang et al. (2007)	sharing of information dynamic and agility crowdedness of information technology vendor selection Internal Downstream	 Usage of ERP Usage of advanced technology Business process reengineering urging mechanism information exchange mechanism	 weighted score		
	Warkentin et al. (2000)	Value webs	Information exchange Relationships New economy			

Research Stream	Source	factors		Performance	KPI	Industry specification
Information Technologies	Peng et al. (2011)	Modular product design NPD IT Supplier Collaboration IT		MC capability Modular product design Product configurator IT	Survey results p-value	
	Dietrich et al. (2006)	Business information systems Multiagent systems				
	Ghiassi & Spera (2003)	Return on Investment Intelligent agents Synchronized supply chain management LEAP	 Java, internet and object oriented technologies e-marketplaces Visibility Intelligence Real time decision making Scalability	Time to market availability of demand requirements response to changes on order configuration response to changes to level of demand flexibility marginal costs efficiencies		
	Jiao & Helander (2006)	platform collaboration customization collaboration				
	Turowski (2002)	Electronic data interchange Multiagent systems		cost flexibility		
	Akkermans et al. (2008)	Integration Flexibility Customization Driver's seat Enterprises in supply chain Information exchange Outsourcing IT-tools Globalization Transparency Standardization of information definitions	 World wide ERP systems	all used also as performance indicators, as if ERP system can achieve the wanted level on these factors		
	Helander & Jiao (2002)	Human computer interaction for customizing products customer decision making process in internet based customization product platform product family modelling on internet virtual teaming in supply chain Workflow management				
	Ruohonen et al. (2006)	size of company mass customization alternatives (transparent, collaborative, adaptive and cosmetic	 change in product change in presentation	evolution of business environment evolution of technology environment maturity of e-business applications and MC innovations potential of the innovations		metal electronics
	Romero et al. (2011)	Computer aided tools				

Research Stream	Source	factors		Performance	KPI	Industry specification
modularity	Lin et al. (2009)	context	mission	complexity		
			driver	level of modularity		
			barrier			
		capability	design (modularity level)			
			production (3rd party or no, at what level)			
			inbound logistics (3rd party or no, at what level)			
			information sharing			
		configuration	network structure			
			process structure			
			information architecture			
	Howard & Squire (2007)	modularity		collaboration level	buyer - supplier	
		asset specificity			percentage of custom sales	
		information sharing			relationship duration	
	Lau (2011)	product characteristics	innovative, functional, value added...	managing modular product design across actors		
		predefined product advantage	variety, standardization, quality, development time, customization...			
		modular definition	yes/no			
		Selectively used design rule	yes/no			
		System integration	yes/no			
		Internal communication	formal team, informal team, no...			
		Technological newness				
		supplier customer coordination	order/inventory info sharing at different stages			
	Wang (2007)	characteristics of product family	set of products	cost		
			general and customized modules	uncertainty		
			postponement of differentiation			
			frequent order reorder and replenishment inventory			
			agitility			
			customer integration			
			business collaboration			
	Cunha et al. (2007)	mean delivery time		cost	labour	automative
		number of different modules				
		assembly time				
	Lau et al. (2010)	no of employees		supplier integration	tightly coordinated	
		production process	assembly, line, batch...		loosely coordinated	
		strategic focus		customer integration	tightly coordinated	
		product modularity			loosely coordinated	
		product characteristics		internal integration	tightly coordinated	
		supplier integration			loosely coordinated	
		customer integration				
		internal integration				
		module/component newness				
		supply chain efficiency				
		product development team size				
		customers' technological know how				
	Ro et al. (2007)	modularity	traditional layer built	nature of	product development	automative
			assembly module		manufacturing	
			mature assembly module		buyer-supplier relationships	
			design module	cost		
			integrated design module			

Research Stream	Source	factors		Performance	KPI	Industry specification
customization level	Salvador et al. (2004)	product family	partially substitutable share common technology	operational performance	cost effectiveness timeliness of delivery degree of customization	transportation equipment telecommunication equipment food processing equipment
		distribution network manufacturing network supply network order timing customization level	hard/soft			
	Poulin et al. (2006)	personalization level (CODP)	popularizing varietizing acessorizing parametering tailoring adjusting monitoring collaborating	impact on key processes	manufacturing costs delivery time respect	golf club
	Yimer & Demirli (2010)	Build to Order	demand levels min customer service level regular time capacity overtime capacity storage capacity unit customization cost holding cost overtime costs penalty cost setup cost needed raw materials	cost	raw material component fabrication assembly distribution retailer total cost	
	Yu & Jie (2008)	demand levels CODP point product mix				
	Wang (2011)	demand assembly and production time CODP point				electric bycyle
	Stavrulaki & Davis (2010)	customization level product characteristics	BTS, ATO, MTO, DTO demand uncertainty profit margin product variety order leadtime labour skills product life cycle forecasting accuracy volume			
		manufacturing related characteristics	production process product design manufacturers direct contact with end user manufacturing process focus			
		logistics related characteristics	number of intermediaries bullwhip effect supplier relationship logistics process focus			
		supply chain strategic capability	lean, leagility, agility			

Research Stream	Source	factors		Performance	KPI	Industry specification
Flexibility, agile and lean supply chains	Benzheng (2011)	incentive mechanism	order reputation information price organization trust enterprise culture penalty elimination	revenue		
	Weizhe et al. (2010)	Standardization generalization modularity information platform delay manufacturing strategy management of suppliers Vendor management inventory customization place	 retail stores or online			clothing
	Yu et al. (2008)	timely material supply quick demand response quick production design quick production manufacture quick production distribution	response speed The ratio of eligibility for Product quality 4x demand information obtainment celerity Information management celerity production design speed production design reform characteristics production manufacture speed production manufacture flexibility response speed service quality	Evaluation index system on QRA		
	Song et al. (2007)	agile supply chain	dynamic quick reconfiguration			
	Yi et al. (2011)	Flexibility environmental uncertainties	sourcing operating system distribution organizational emergent orders costs aggressiveness of competition demand uncertainty supply uncertainty competition uncertainty	which flexibility strategy should be used for which types of environmental uncertainty		
	Salvador et al. (2007)	mix flexibility volume flexibility market product family and variants evolution of products and product families component sourcing distribution Flexibility	 trend seasonality product assembly workforce supplier			

Research Stream	Source	factors		Performance	KPI	Industry specification
Manufacturing	Hauslmayer & Gronalt (2008	modularization IT	sorted modularization unsorted modularization product configurator database of produced floorboards RFID - logistics	Order fulfilment rate Rate of number of fulfilled orders CODP stock level /orders CODP stock output / CODP stock input CODP stock end-level / CODP stock start-level		woodworking
	Tuck & Hague (2006)	rapid manufacturing lean supply chains agile supply chain leagile supply chain				

Research Stream	Source	factors		Performance	KPI	Industry specification
mass customization strategy	Liu & Deit (2011)	customer focused product design supplier lead time reduction supply chain planning plant size		mass customization capability customer focused product design supplier lead time	survey hypothesis	electronics industry machinary auto suppliers
	ikkola & Skjøtt-Larsen (200	postponement modularization and product configuration opportunity for modularization interface compatibility effects component customization supplier-buyer independence		opportunity for modularization cost		
	MacCarthy et al. (2003)	Catalogue order MC Fixed resource design-per-order MC Flexible resource design-per-order MC Fixed resource call of MC Flexible resource call of MC	Temporal relationship Once off/call off fixed/modifiable order fulfilment resources			
	Trappey & Wognum (2012)	reproduction decision support		demand risk	accurate sales forecast	
	Barutcu (2007)	agile manufacturing relationship marketing supply chain management mass customization				
	Dong et al. (2012)	Technology and strategy support processes	computers and internet flexible manufacturing systems reconfigurable manufacturing systems tailored system data analysis system customized design system inventory system distribution management system CAD/CAM system			garment
	Buffington (2011)	consumer willingness customer perception customer ability to participate in mass customization	wait pay price premium brand neutrality of customer			

Research Stream	Source	factors		Performance	KPI	Industry specification
Inventory management & Scheduling	Aigbedo (2007)	Original Part Manufacturer level of customization	supply frequency quantity items		stock out number customization inventory ratio	automative
	Yaoa & Liub (2009)	rush or non rush order customer order number/type production stages production capacity profit preference		cost	inventory cost production cost	
	Guohua & Jihong (2010)	market demand target inventory supplier's order cycle	supplier manufacturer distributor	inventory level	supplier manufacturer distributor	
	Fei et al. (2009)	transportation time decision making factor of time preference cost capacity of vehicles	 plant cost transportation cost	transportation time cost	penalty cost	

Research Stream	Source	factors		Performance	KPI	Industry specification
Commonality and platform products	Huang et al. (2005)	lead times platform products		cost	inventory cost production procurement transportation	
	Huang et al. (2007)	pricing ordering platform products				

Research Stream	Source	factors		Performance	KPI	Industry specification
Performance	Cheng (2011)	organisational modularity			product specialization capacity utilization ROI ROA	
	Lau et al. (2007)	supply chain product co development flexibility company size market certainty product modularity customer service		operational performances at plant level financial and business performance product performance flexibility customer service		electronics plastics toys
	Zhang et al. (2011)	elicitation practices	EL1 creating a greater level of trust with customers EL2 working with customers to improve inter-organisational processes with cust EL3 creating linkage with customers through information technology EL4 sharing information with customers.		inventory turnover obsolence cost stock out cost unit manufacturing cost	
		flexibility	FID1 involving suppliers in product development stage FID2 involving customers in product development stage FID3 quick response to customers though postponement.	operational performance/cost	overall labour productivity pre-sale customer service product support	
		automating and optimizing design	AMT1 application of computer/information technology in manufacturing process (e.g., CAM, CIM, FMS, CNC) AMT2 application of computer technology in product design (e.g., CAD, CAE, CAPP) AMT3 application of computer/information technology in manufacturing plannir and control (e.g., MRPII, ERP).	operational performance/product/service quality	customer service level overall product quality ROI growth ROS growth ROI growth in market share	
		JIT supply chain	JIT1 JIT purchasing with your suppliers JIT2 JIT production and Kanban system JIT3 JIT delivery with your customers JIT4 aiding suppliers to increase their JIT capabilities.	financial performance	ROS market share	
		ILIS interface (manufacturer-customer)	ILIS1 integrative inventory management ILIS2 real time integration and connection among all internal functions from raw material management through production, shipping, and sales ILIS3 enterprise application integration among internal functions ILIS4 data integration among internal functions.			
		operational performance				

10.3. Appendix C – Aggregated Research Streams

Research Stream	Factor	Impacting....		who	KPIs
Relationship management	Supplier Selection	Agility		Wang et al. (2007)	
		Demand		Qin (2012), Zhanga & Huangb (2010)	demand per year
		Price Discounts		Zhanga & Huangb (2010)	
		Company size / capacity		Lau et al. (2010)	size
		Common variables		Qin (2012)	yes/no
		Information Exchange		Lau et al. (2010), Pan & Holland (2006), Wang et al. (2007), Moser & Piller (2006), Liao et al. (2011)	
	Cooperation	Optimization	Joint profits	Zhanga & Huangb (2010)	profits
		Joint profits	holding costs	Zhanga & Huangb (2010)	
			total unit purchase from suppli	Zhanga & Huangb (2010)	
			fixed costs	Zhanga & Huangb (2010)	
			ordering costs	Zhanga & Huangb (2010)	
			selling price	Zhanga & Huangb (2010)	
			demand	Zhanga & Huangb (2010)	
	Internal Integration	Information technologies		Moser & Piller (2006), Wang et al. (2007), Lau et al. (2010)	
		Scalable organization		Moser & Piller (2006)	
		Organisational culture towards MC		Moser & Piller (2006)	
	onsumer integratio	Willingness		Jitpaiboon et al. (2009)	
		Information exchange		Jitpaiboon et al. (2009), Pan & Holland (2006), Moser & Piller (2006), Wang et al. (2007)	
		Feedback		Jitpaiboon et al. (2009)	amount of feedback received

Research Stream	Factor	Impacting....	who	KPIs
Information Technologies	synchronization in supply chain	Electronic Data Interchange (EDI)	Turowski (2002), Dietrich et al. (2006)	yes/no
		e-commerce	Turowski (2002)	yes/no
		multi-agent systems	Turowski (2002)	yes/no
		ERP systems	Akkermans et al. (2008), Ruohoner	yes/no
	IT (supplier-manufacturer) [Peng et al. (2011)]			yes/no
	IT (manufacturer-retailer) [Peng et al. (2011)]	internet	Jiao & Helander (2006)	yes/no
	IT (manufacturer-customer) [Peng et al. (2011)]	internet	Jiao & Helander (2006)	yes/no
	ply chain) - new prod. Dev. IT [Helander & Jiao	internet	Helander & Jiao (2002)	yes/no
		virtual teaming	Helander & Jiao (2002)	yes/no
		workflow management	Helander & Jiao (2002)	yes/no

Research Stream	Factor	Factors Impacting Decision		who	KPIs
Modularity	Level of modularity	capabilities	design	Lin et al. (2009)	separateness [Lau et al. (2010)]
			production	Lin et al. (2009)	transferability [Lau et al. (2010)]
			inbound logistics	Lin et al. (2009)	specificity [Lau et al. (2010)]
			information	Lin et al. (2009)	
		configuration	role structure	Lin et al. (2009)	
			process structure	Lin et al. (2009)	
			information structure	Lin et al. (2009)	
		module definition		Lau (2011)	
		technological newness		Lau (2011)	
		internal integration	internal communication (formal/in	Lau (2011)	
			team size	Lau et al. (2010)	team size
		customer coordination	customer involvement [16]	Lau (2011)	customer knowledge [Lau et al. (2010)]
		system integration		Lau (2011)	
		product characteristics	innovative	Lau (2011)	
			functional	Lau (2011)	
			value added	Lau (2011)	
		product family	set of products	Wang (2007)	number of product sets
			general and customized modules	Wang (2007)	number of general modules
					number of customized modules
		supplier coordination	tight/loosely coordinated	Lau et al. (2010); Lau et al. (2011)	
			Module development	Lau et al. (2010)	
			information sharing	Howard & Squire (2007); Lau et al. (2010)	
			asset specificity	Howard & Squire (2007)	
					assembly times [Cunha et al. (2007)]
					transportation costs [Cunha et al. (200
					costs [Ro et al. (2007)]

	Factor	Impacting....		who	KPIs
customization level	CODP	mobile/ multiple CODP		Yu et al. (2008), Wang (2011)	demand level [Yu & Jie (2008)]
		BTS [Poulin et al. (2006), Stavrulaki & Davis (2010), Salvador et al. (2004)]	customer relationship managemer	Stavrulaki & Davis (2010)	demand level [Yimer & Demirli (2010)]
		ATO [Poulin et al. (2006), Stavrulaki & Davis (2010), Salvador et al. (2004)]	customer service management	Stavrulaki & Davis (2010)	service level [Yimer & Demirli (2010)]
		MTO [Poulin et al. (2006), Stavrulaki & Davis (2010), Salvador et al. (2004)]	demand management	Stavrulaki & Davis (2010)	capacities [Yimer & Demirli (2010)]
		DTO [Poulin et al. (2006), Stavrulaki & Davis (2010)]	order fulfillment	Stavrulaki & Davis (2010)	costs [Yimer & Demirli (2010), Poulin et al. (200
			manufacturing flow management	Stavrulaki & Davis (2010)	raw material usage [Yimer & Demirli (2010)]
			supplier relationship management	Stavrulaki & Davis (2010)	delivery time [Poulin et al. (2006)]
			product development and comme	Stavrulaki & Davis (2010)	
			returns management	Stavrulaki & Davis (2010)	

Research Stream	Factor	Impacting....			who	KPIs
Agility & Flexibility	Flexibility [Song et al. (2007)]	Strategies	Sourcing flexibility	Environmental uncertainties: demand, supply, competition	Yi et al. (2011)	
			Operating system flexibility		Yi et al. (2011)	
			Organizational flexibility		Yi et al. (2011)	
			Distribution flexibility		Yi et al. (2011)	
			Product		Salvador et al. (2007)	fixed costs [Salvador et al. (2007)]
						operational overhead costs
			Assembly		Salvador et al. (2007)	[Salvador et al. (2007)]
			Workforce		Salvador et al. (2007)	
		Volume and mix flexibility	Supplier		Salvador et al. (2007)	
	ponse ability [Benzheng (2011), Weizhe & Zhih	timely material supply			Yu et al. (2008)	supply time [Yu et al. (2008)]
		quick demand response			Yu et al. (2008)	response time [Yu et al. (2008)]
		quick product design			Yu et al. (2008)	design time [Yu et al. (2008)]
		quick product manufacturing			Yu et al. (2008)	manufacture time [Yu et al. (2008)]
		quick product distribution			Yu et al. (2008)	distribution time [Yu et al. (2008)]
	Reconfiguration [Song et al. (2007)]					

Research Stream	Factor	Impacting Variables	who	KPIs	
Performance	.Organizational Modularity [Cheng (2011)]	Company size	Lau et al. (2007)	efficiency	Product specialization [Cheng (2011)]
	Modularity [Lau et al. (2007)]	Market Certainty	Lau et al. (2007)		Capacity utilization [Cheng (2011)]
				Profitability	ROI [Cheng (2011)]
					ROA [Cheng (2011)]
					customer service [Cheng (2011)]
					flexibility [Cheng (2011)]
					product performance [Cheng (2011)]
	Product co-development [Lau et al. (2007)]	Internal	Lau et al. (2007)		product performance [Cheng (2011)]
		Supplier	Lau et al. (2007)		
		Customer	Lau et al. (2007)		
		Company size	Lau et al. (2007)		
		Market Certainty	Lau et al. (2007)		
	Elicitation	information technology	Zhang et al. (2011)	operational performance [Zhang et al. (2011	cost [Zhang et al. (2011)]
		trust	Zhang et al. (2011)		product/service quality [Zhang et al. (2011)
	Flexibility in design	involving customers	Zhang et al. (2011)	financial performance [Zhang et al. (2011)]	
		involving suppliers	Zhang et al. (2011)		
		quick response to customers	Zhang et al. (2011)		
	Advanced manufacturing technologies	information technology	Zhang et al. (2011)		
	Just in time	purchasing	Zhang et al. (2011)		
		delivery	Zhang et al. (2011)		
		production	Zhang et al. (2011)		

Research Stream	Factor	Impacting....	who	KPIs
Manufacturing	modularization [Hauslmayer & Gronalt (2008)]	sorted/unsorted modularization	Hauslmayer & Gronalt (2008)	Order Fulfillment rate [Hauslmayer & Gronalt (2008)]
		product configurator	Hauslmayer & Gronalt (2008)	CODP stock level / orders [Hauslmayer & Gronalt (2008)]
				CODP stock output / CODP stock input [Hauslmayer & Gronalt (2008)]
				CODP stock end level / CODP stock start level [Hauslmayer & Gronalt (2008)]
	rapid manufacturing [Tuck & Hague (2006)]	lean supply chain	Tuck & Hague (2006)	
		agile supply chain	Tuck & Hague (2006)	
		leagile supply chain	Tuck & Hague (2006)	

	Factor	Impacting....	who	KPIs
Mass Customization Strategy	Supply chain planning [Liu & Deit (2011)]	customer focused product design		supplier lead time [Liu & Deit (2011)]
	postponement [Mikkola & Skjøtt-Larsen (2004)]			
	modularity [Mikkola & Skjøtt-Larsen (2004)]			
	Design to order, engineer to order [MacCarthy	temporal relationships	MacCarthy et al. (2003)	
		mixed/modifiable order fulfillme	MacCarthy et al. (2003)	
	mass customization	transparency	Trappey & Wognum (2012)	demand risk [Trappey & Wognum (2012)]
	relationship marketing [Barutcu (2007)			
	Mass customization IT Barutcu (2007)]			
	Flexible processes [Barutcu (2007)]			
	Agile supply chain [Barutcu (2007)]			
	Organizational structure [Barutcu (2007)]			
	Customer	customers willingness to pay	Buffington (2011)	
		customers' willingness to wait	Buffington (2011)	
	Supply chain processes [Dong et al. (2012)]	collection and storing of data	Dong et al. (2012)	
		data analysis system	Dong et al. (2012)	
		design system	Dong et al. (2012)	
		inventory system	Dong et al. (2012)	
		distribution management system	Dong et al. (2012)	
		CAD/CAM system	Dong et al. (2012)	

Research Stream	Factor	Impacting Variables	who	KPIs
Inventory management and scheduling	Inventory management	Supply frequency	Aigbedo (2007)	inventory levels [Aigbedo (2007)]
		Customization level	Aigbedo (2007)	stocktout ratio [Guohua & Jihong (2010)]
		Order cycle time	Guohua & Jihong (2010)	delivery ratio [Guohua & Jihong (2010)]
		Target inventory level	Guohua & Jihong (2010)	
	Scheduling [4, 96]	transportation time	Fei et al. (2009)	costs [Yaoa & Liub (2009), Fei et al. (2009)]
		capacity of vehicles	Fei et al. (2009)	penalty cost [Fei et al. (2009]
		customer orders	Yaoa & Liub (2009)	inventory cost [Yaoa & Liub (2009)]
		delivery date of orders	Yaoa & Liub (2009)	production cost [Yaoa & Liub (2009)]
		production time	Yaoa & Liub (2009), Fei et al.	
		production cost	Yaoa & Liub (2009), Fei et al.	
		inventory time	Yaoa & Liub (2009), Fei et al.	
		inventory cost	Yaoa & Liub (2009), Fei et al.	
		production capacity	Yaoa & Liub (2009)	
		quality demand of order	Yaoa & Liub (2009)	
		profit preference	Yaoa & Liub (2009)	

Research Stream	Factor	Impacting Variables	who	KPIs
Commonality and Platform products	Supply chain performance & configuration	option selection	Huang et al. (2005)	service time [Huang et al. (2005)]
		service time	Huang et al. (2005)	costs [Huang et al. (2005)]
		demand variety	Huang et al. (2005)	lead time [Huang et al. (2005)]
		demand level	Huang et al. (2005)	
		quantity discounts	Huang et al. (2005)	
	Supply chain relationship	demand	Huang et al. (2007)	profit [Huang et al. (2007)]
		customization level	Huang et al. (2007)	purchasing costs [Huang et al. (2007)]
		supplier flexibility	Huang et al. (2007)	inventory levels [Huang et al. (2007)]

Research Stream	Factor	Impacting Variables		who	KPIs
Product development	Concurrent engineering	product development processes	Design for cost	Kincade et al. (2007)	
			Design for enabling technologies	Kincade et al. (2007)	
			Design for inspectability	Kincade et al. (2007)	
			Design for maintainability	Kincade et al. (2007)	
			Design for reliability	Kincade et al. (2007)	
			Design for manufacturability	Kincade et al. (2007)	
			Design for quality	Kincade et al. (2007)	
	Architecture based development	Market demand	Market segmentation	Mortensen et al. (2008)	
			Product features and specification	Mortensen et al. (2008)	
		Product assortment	Interfaces	Mortensen et al. (2008)	
			Constraints	Mortensen et al. (2008)	
			Component assortment		
		Production/supply chain	Production layout	Mortensen et al. (2008)	
			Process layout	Mortensen et al. (2008)	
	Collaborative design	Advanced production quality hub	Categorized part library	Trappey & Hsiao (2008)	
			Online combination of parts	Trappey & Hsiao (2008)	
			Online ordering	Trappey & Hsiao (2008)	
			Real time information exchange	Trappey & Hsiao (2008)	
			Collaborative design	Trappey & Hsiao (2008)	

Research Stream	Factor	Impacting Variables	who	KPIs
Postponement	postponement type (form/time) & (full, production, assembly)	Utilization rate	Su (2005)	Total cost [Su (2005), 26]
		arrival time variation	Su (2005)	Expected waiting time [Su (2005)]
		process time variation	Su (2005)	benefits [26]
		interest rate	Su (2005)	Delivery speed [Kisperska-Moron et al. (2011)]
		percentage of generic component coverage	Su (2005)	Delivery as promised [Kisperska-Moron et al. (2011)]
		number of products	Su (2005)	Delivery flexibility [Kisperska-Moron et al. (2011)]
		Market and demand characteristics	Kisperska-Moron et al. (2011), 26	Internal performance in terms of delivery speed [Kisperska-Moron et al. (2011)]
		Internal time-based processes and demand variability	Kisperska-Moron et al. (2011)	Average time from start to completion [Kisperska-Moron et al. (2011)]
		Forecast errors	Kisperska-Moron et al. (2011)	benefits [Hoek (1997)]
		Importance of products' design and variety	Kisperska-Moron et al. (2011)	
		The level of product customization	Kisperska-Moron et al. (2011),Su (2005)	
		Demand level for a peak month	Kisperska-Moron et al. (2011)	
		Demand level for a through month	Kisperska-Moron et al. (2011)	
		simple production planning environment	Trentin & Forza (2010)	
		self containment of the production planning tasks	Trentin & Forza (2010)	
		production planning frequency	Trentin & Forza (2010)	
		lateral relations in the production planning process	Trentin & Forza (2010)	
		product differentiation	Hoek (1997)	
		process characteristics	Hoek (1997)	
		technological characteristic	Hoek (1997)	
	CODP	correlative coefficient	Ji & Sun (2011)	cost (product, manufacturing, supply chain) [Ji & Sun (2011)]
		customization ratio of the products	Ji & Sun (2011)	Waiting time [Ji & Sun (2011)]
		expected waiting time's coefficient on total cost	Ji & Sun (2011)	
		product variety	Ji & Sun (2011)	
	third-party logistics postponement	Packaging activities	Hoek (2000)	inventory levels [Hoek (2000)]
		Final assembly	Hoek (2000)	inventory turn around times [Hoek (2000)]
		Product configuration	Hoek (2000)	quality [Hoek (2000)]
		Reconditioning of products	Hoek (2000)	functionality [Hoek (2000)]
		Advice about logistics concepts of customers in tendering	Hoek (2000)	transportation damage [Hoek (2000)]
		Advice about logistics concepts of customers as a separat	Hoek (2000)	scrap percentage from manufacturing [Hoek (2000)]
		Financing inventories	Hoek (2000)	customer specific product degree [Hoek (2000)]
		Billing the final customer 1.	Hoek (2000)	
		Testing/repair of products	Hoek (2000)	
		Installation of products at final customer's site	Hoek (2000)	
		Building of displays with products	Hoek (2000)	
		Receiving and inspecting return shipments	Hoek (2000)	
		Sizing products	Hoek (2000)	
		Adding product features	Hoek (2000)	
		Inventory management and registration	Hoek (2000)	
	optimal postponement level / finished goods inventory	interactions of component cost structure	Ma et al. (2002)	
		replenishment lead times	Ma et al. (2002)	WIP costs [Ma et al. (2002)]
		assembly times	Graman (2010), Qin (2011b)	
		the product value	Graman (2010), Qin (2011b)	labor cost [Graman (2010), Qin (2011b), Qin (2011a)]
		packaging cost	Graman (2010), Qin (2011b)	material cost [Graman (2010), Qin (2011b), Qin (2011a)]
		postponement cost	Graman (2010), Qin (2011b)	postponement cost [Graman (2010), Qin (2011b), Qin (2011a)]
		holding cost	Graman (2010), Qin (2011b)	packaging cost [Graman (2010), Qin (2011b), Qin (2011a)]
		fill rate	Graman (2010), Qin (2011b)	inventory costs (finished, postponed) [Graman (2010), Qin (2011b), Qin (2011a), Ma et al. (200
		correlation of demand	Graman (2010), Qin (2011b)	shortage costs [Graman (2010), Qin (2011b), Qin (2011a)]
		coefficient of variation	Graman (2010), Qin (2011b)	lead times [Qin (2011a)]
		common modules	Baozhuang et al. (2008)	
		semi-finished	Baozhuang et al. (2008)	
		finished	Baozhuang et al. (2008)	penalty costs [Qin (2011b), Qin (2011a)]
		demand	in (2011a), Graman (2010), Qin (2011b)	

10.4. Appendix D – The Conceptual Framework

	Factor	Factors impacting decisions	who	KPI	Qualitative implications	Who
Relationship Management	Internal Integration level	Information exchange level	Moser & Piller (2006); Wang et al. (2007); Lau et al. (2010)		Possibility to have information exchange	not from literature
		Organisational readiness	Moser & Piller (2006)		ability of organization to carry out mass customization processes effectively	not from literature
	Consumer integration level	Customer wilingness and capability	Jitpaiboon et al. (2009)		The ability to use different resources (feedback mechanis, configurator, workshops) to interact with customers	not from literature
		Information exchange level	Moser & Piller (2006); Jitpaiboon et al. (2009); Pan & Holland (2006); Wang et al. (2007)		Possibility to have information exchange	
	Cooperation level with partners	Joint profits	Zhanga & Huangb (2010)		Possibility to have a contract which defines joint profits	not from literature
		Type of information shared	Qin (2012)		Amount and details of demand (number of modules or parts)	
		Joint advantages	Qin (2012)		Possbility to share company's internal information with other actors: Delivery due date Order registered time Cost of delay Flexibility of the time to respond to orders Total time of manufacturing Total time of distribution Cost of unit of customization	Qin (2012)
	Supplier Selection Critaeria	Agility of supplier	Wang et al. (2007)	% of completed orders	Ability to ensure needed responsiveness and flexibility by type of contract, punishment and incentives	not from literature
		Demand behavior of the product	Huang, Zhang & Lo (2007); Zhanga & Huangb (2010); Qin (2012)		Supplier's ability to follow the manufacturer's demand behaviour	not from literature

		Capacity of supplier	Lau (2011)	capacity of supplier allocated on total capacity		not from literature
		Information exchange level	Moser & Piller (2006); Pan & Holland (2006); Wang et al. (2007); Lau et al. (2010); Liao et al. (2011)		Possibility to gather the required information in the desired time frame	not from literature
		Historical relationship with supplier		% of completed orders		not from literature
		Sustainable price offered by supplier (discounts and low costs)		price per unit	Ability to ensure sustainable prices via the contract type	not from literature
				price per delivery		not from literature
Modularity	product	product architecture	Lau (2011)		Portion of cost related to the common base	not from literature
					Modularity of the product	not from literature
		product characteristics			The innovative, value added or functional character of the product	not from literature
		Feasibility of customer requirements' translation into modules	not from literature			not from literature
	production system	production capability in making modules	Lin et al. (2009)	Time of production of modules	Availiability of technology to ensure needed production	not from literature
		Production costs of modules		Total production costs of modues		not from literature
		Inventory costs of modules		Inventory costs of modules		not from literature
	Value chain characteristics	Cooperation with supplier	Howard & Squire (2007); Wang (2007); Lau et al. (2010); Lau (2011)	** Cooperation with partners block*	** Cooperation with partners block*	not from literature
		customization level	not from literature	**Customization level block*		not from literature
		Supplier selection	not from literature	**Supplier selection block*	**Supplier selection blocl*	Huang et al. (2005); Dietrich et al. (2006)
Postponement	product	product architecture	Hoek (2000); Ma et al. (2002); Su (2005); Mortensen et al. (2008); Baozhuang et al. (2008); Graman (2010);		Portion of cost related to the common base	not from literature
					Modularity of the product	

			Kisperska-Moron et al. (2011); Qin (2011b)			
	Value chain characteristics	cost of postponement (tradeoff between cost and efficiency)	Hoek (1997); Su (2005); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011a); Qin (2011b)		The desired efficiency of the actors of the value chain (supplier, manufacturer, distributor)	
				Utilization of processes (machine utilization)=used resources/available resources		Su (2005); Graman (2010); Qin (2011b)
				Average waiting time of customer	Customer satisfaction in the company's context (includes cost and time for customer)	Expected waiting time [Su (2005)]
				Total delivery time after receiving an order		Delivery speed [Ma et al. (2002); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011b)]
				target service level	Ability to meet the service level requirments	Yimer & Demirli (2010)
		customization level	Hoek (2000); Su (2005); Kisperska-Moron et al. (2011)	**Customization level block*	**Customization level block*	not from literature
		Inventory levels	Hoek (2000); Aigbedo (2007); Baozhuang et al. (2008); Guohua & Jihong (2010)	Inventory levels of modules, finished goods, semi-finished goods		not from literature
				Inventory costs		
		value chain capability	not from literature		Integrated information technology availablilty/usage	
					Ability to fullfill the right order at the right time	not from literature
		Value Chain network characteristics	not from literature		Physical location and connections of actors	not from literature
					Availability of information technologies to ensure needed customization	not from literature
	Market characteristics	Market demand levels and variability	Huang et al. (2005); Graman (2010); Trentin & Forza (2010); Kisperska-Moron et al. (2011);Qin (2011a); Qin (2011b)		Ability to diminish the demand variability by using postponement	not from literature

	production system	production capability	Trentin & Forza (2010); Hoek (1997)	Production capability index (Cp)	Availiability of technology to ensure needed production	utilization level [Su (2005); Graman (2010); Qin (2011b)]
				Time of production of modules		not from literature
				Time of production of common base		not from literature
Customization level	Market characteristics	Market demand	Poulin et al. (2006); Yu & Jie (2008); Yimer & Demirli (2010); Stavrulaki & Davis (2010)	Market demand analysis	Market demand analysis	not from literature
	Product	Product architecture	Stavrulaki & Davis (2010); Ji & Sun (2011)		Portion of cost related to the common base	not from literature
					Modularity of the product	
	Value chain characteristics	value chain capability	Stavrulaki & Davis (2010)		Integrated information technology availablilty/usage	not from literature
					Ability to fullfill the right order at the right time	not from literature
		Value chain network characteristics	Salvador et al. (2004); Stavrulaki & Davis (2010)		Physical location and connections of actors	not from literature
					Availability of information technologies to ensure needed customization	not from literature
		cost of customziation (tradeoff between cost and efficiency)	Ji & Sun (2011)		The desired efficiency of the actors of the value chain (supplier, manufacturer, distributor)	Graman (2010); Qin (2011)a; Qin (2011)b
				Average waiting time of customer	Customer satisfaction in the company's context (includes cost and time for customer)	Expected waiting time [Su (2005)]
				Total delivery time after receiving an order		Delivery speed [Ma et al. (2002); Graman (2010); Kisperska-Moron et al. (2011); Qin (2011)b]
				Target service level	Ability to meet the service level requirments	Yimer & Demirli (2010)

10.5. Appendix E – Questionnaire

If your company has more than one product family line, please consider one type of product family and fill out the questionnaire. Choose a reference family of product which you use in mass customization practices. While answering the following questions, please consider this product family.

Reference product family:_____

Industry of company:_____

Your position in the company:_____

GENERAL QUESTIONS

1. What is approximately the number of employees in your company?
   - ☐ 1 - 49
   - ☐ 50 - 999
   - ☐ 1,000 - 4,999
   - ☐ 5,000 or more
   - ☐ Don't know

2. What is the approximate turnover of your company?
   - ☐ .lower than 20,000
   - ☐ .between 20,000 and 70,000
   - ☐ .between 70,000 and 150,000
   - ☐ .more than 150,000
   - ☐ Don't know

3. What are the different customization levels present in the system (you can select more than one):
   - ☐ Build to Stock: the products are undifferentiated, off the shelf
   - ☐ Assemble to order: the products are assembled after customer order is received
   - ☐ Make to order: the products are produced after customer order is received
   - ☐ Design to order: the products are designed after customer order is received
   - ☐ Engineer to order: the products are engineered after customer order is received

RELATIONSHIP MANAGEMENT

SUPPLIER SELECTION

4. What factors are considered when selecting a supplier? Please rank to from 1 to n, (1 being the most important and n the least)
   - Agility of supplier: the supplier is able to respond fast to changes in the demand size or mix and is flexible
   - Capacity of supplier: if the supplier has a big capacity to sustain the demand coming from your company
   - Previous relationship with the supplier: history of relationship between companies and knowledge from each other which facilitates working together
   - Sustainable price offered by supplier: discounts and low costs
   - Possibility to integrate your information with them and have real time and open information flow
   - Demand behavior of the product: demand behavior restricts selection criteria, in other words constant or fluctuating demand patterns leads to the selection of a supplier
   - Other: _____

5. Regarding the supplier selection factors (perviouse question), do you measure your critical factors to better understand who to select? İf no, cross non (put it in options) and let us know if suggested options can be helpful, if yes, cross the indicators you use and if it is not in proposed indicators let us know what is it.

	% of completed orders	capacity of supplier allocated on total capacity	% of completed orders	price per unit	price per delivery
Agility of supplier					
Demand behavior of the product					
Capacity of supplier					
Information exchange level					
Historical relationship with supplier					
Sustainable price offered by supplier (discounts and low costs)					

What were your main challenges you encounter when you select your supplier? Please add any comments you have on the challenges encountered.

SUPPLIER COOPERATION/INTEGRATION

6. What percentage of your suppliers are critical for the Mass Customization activities and why?

Please answer the following questions based on the supplier's mentioned in question 6.

7. Which information do you share with your supplier in order to fulfill the right demand to the right customer at the right time?
   - Amount and details of demand (number of modules or parts)
   - Delivery due date

- Order registered time
- Cost of delay
- Flexibility of the time to respond to orders
- Total time of manufacturing
- Total time of distribution
- Cost of unit of customization
- No information is shared
- Other

8. If you share some information with your suppliers how do you share it?
   - By Real time
   - By Weekly reports
   - By Monthly reports
   - Not shared
   - Other _____

9. Do you adopt a strategy which aims to maximize the joint profit with your supplier:
   - YES
   - NO

INTERNAL INTEGRATION

10. Do you use information technologies to share data in the operational and functional level?
- Both
- Operational
- Functional
- No

(operational: operator level, have an overall idea or only their)

(functional: manager level: do production production manager knows what happens in supply chain, supplier, distribution…)

11. Did you give trainings to your employees about how to implement Mass Customization regarding its practices & ideas, such as concurrent flexibility and efficiency of processes until customer order is received or integrating customer in the design process?
    - Yes
    - No

12. What kind of problems did you encounter regarding organizational readiness on Mass Customization? (A few examples are: being reluctant to share data across departments,

CONSUMER INTEGRATION

13. Which of these resources do you have to interact with the customer?
    - ☐ Feedback mechanism
    - ☐ Configurator (web or in-store)
    - ☐ Workshops
    - ☐ None
    - ☐ Other_____

MODULARITY

14. Do you have a modular product design? (Modularity refers to "building a complex product or process from smaller subsystems that can be designed independently yet functions together as a whole.")
    - ☐ YES
    - ☐ NO

15. If your answer to question 15 is YES then what factors affect your module designs?
    - ☐ Feasibility of customer requirements' translation into modules
    - ☐ Production capabilities in making modules
    - ☐ Production costs
    - ☐ Inventory costs
    - ☐ Product characteristics (innovative, value added or functional)
    - ☐ Cooperation with supplier
    - ☐ Customization level
    - ☐ Supplier selection
    - ☐ Product architecture
    - ☐ Other: _____

16. Regarding the modularity (perviouse question), do you measure your critical factors to better understand its effect on the supply chain performance? If yes, cross the indicators you use and if it is not in proposed indicators let us know what is it.

	Time of production of modules	Total production costs of modues	Inventory costs of modules	% of completed orders	capacity of supplier allocated on total capacity	% of completed orders	price per unit	price per delivery	Market demand analysis	Average waiting time of customer	Total delivery time after receiving	Target service level
product architecture												
product characteristics												
Feasibility of customer requirements' translation into modules												
production capability in making modules												
Production costs of modules												
Inventory costs of modules												
Cooperation with supplier												
customization level												
Supplier selection												

If you have selected none, what can be suggested indicators to measure your critical factors?

17. Please specify if you had any particular challenges in managing modules.

POSTPONEMENT

Postponement: *"the strategy to delay customization of a product until more information about the demand of the product is known"*

18. Which types of postponement do you practice?

- Holding up of the delivery of the product in the supply chain at different processes until a customer order has been received **(time postponement)**
- Shipping of products in a semi-finished state from the manufacturing process to be customized further in the downstream supply chain **(form postponement)**
- Moving of the inventories in the upstream supply chain in selected centralized locations where manufacturing or distribution activities occur delaying shipment until customer order **(place postponement)**
- We don't practice postponement

19. Why did you choose the postponement types mentioned in question 24?
    - Product architecture
    - Production capabilities
    - Market demand levels and variability
    - Customization levels
    - Supply chain network characteristics
    - Inventory levels
    - Value chain capability
    - cost of postponement (tradeoff between cost and efficiency)
    - Other

20. Regarding the postponement factors (perviouse question), do you measure your critical factors to better understand the effects of postponement on the supply chain? If yes, cross the indicators you use and if it is not in proposed indicators let us know what is it.

	Market demand analysis	Average waiting time of customer	Total delivery time after receiving an order	Target service level	Utilization of processes (machine utilization)=used resources/available resources	Average waiting time of customer	Total delivery time after receiving an order	target service level	Inventory levels of modules, finished goods, semi-finished goods	Inventory costs	Production capability index (Cp)	Time of production of modules	Time of production of common base	Market demand analysis
product architecture														
cost of postponement (tradeoff between cost and efficiency)														
customization level														
Inventory levels														
value chain capability														
Market demand levels and variability														
production capability														
Supply chain network characteristics														

If you have selected none, what can be suggested indicators to measure your critical factors?

21. Please specify if you had any particular challenges in managing postponement.

CUSTOMIZATION LEVEL

22. Which factors effect where the customer comes into the mass customization process (based on the customization level)? Please rank to from 1 to n, (1 being the most important and n the least)

- ☐ Cost of customization
- ☐ Market demand
- ☐ Product architecture
- ☐ Value chain capability
- ☐ Supply chain network characteristics
- ☐ None
- ☐ Other

23. Regarding the customization level factors, do you measure your critical factors to better understand the effects of customization level on the supply chain? Please cross the indicators you use and if it is not in proposed indicators let us know what is it.

	Production capability index (Cp)	Time of production of modules	Time of production of common base	Market demand analysis
Market demand				
Product architecture				
value chain capability				
Value chain network characteristics				
cost of customziation (tradeoff between cost and efficiency)				

21. Please specify if you had any particular challenges in managing customization levels