THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Report L2009:032

One-piece fashion

Demand driven supply chain management

JONAS LARSSON

Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2009

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ISSN 1654-9732

Report number

Deparment of Technology Management and Economics

Division of Logistics and Transportation

Chalmers University of Technology

SE 412 96 Göteborg

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Swedish School of Textiles

University of Borås

Allégatan 1

SE-501 90 Borås

Cover:
Illustration of the Knit-on-Demand project done by Pia Mouwitz. The picture symbolises a demand driven supply chain. The are three main elements in the picture: First is the customised sweater which is seen on the lady and in the knitting machine. Second is the yarncone which is built up by zeros and ones and symbolises the the equal importance of information and material. Third is the knitting machine that produces the garment.

Printed by Chalmers Reproservice

Göteborg 2009

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Abstract

The fashion market is characterised by short life cycles, low predictability, and high impulse purchasing. In order to respond to these characteristics, companies are constantly introducing new collections and models. There are now so many new models introduced that the seasons have been erased and the leader of fast fashion, Zara, introduces 211 new models each week. Not all of these garments are sold at full price—the sell-through factor in fashion, which indicates how many of the total SKUs are sold at full price, is approximately 65 percent. One of the reasons why so much must be sold at a reduced price is that the fashion companies might have created a new buying behaviour among their customers by offering everything quickly. This new buying behaviour cannot be answered with traditional supply-chain management.

Knit-on-Demand is a research project in the Swedish School of Textiles. The objective of the project is to demonstrate a production method for knitwear that may strongly influence the ability of the fashion industry to meet new demands for agility in customer relations. It will also provide insight and transparency in the total cost picture related to logistics and supply chain management, which leads to improved decision support in outsourcing and off-shoring strategies and may contribute to increased local fashion production. Knit-on-Demand differs from traditional garment manufacturing since nothing is produced to forecast and everything is produced to order from the end customer.

Together with Ivanhoe AB, a producer of knitwear, and SOMconcept, a tailored fashion retailer, the idea of on-demand knitting has developed into a business concept where the customer is allowed to design their own garments. The customer chooses his or her fit, colour and model, places an order, and one week later the garment is delivered. The customer is not completely free in his or her design because the quality and lead-times of the production processes have to be guaranteed. Therefore, the process is really more a configuration of pre-engineered modules.

The methods used are case studies with some action research as the researchers have taken an active role in the development of the project.

Mass customisation as a concept and on-demand business have great potential to decrease wasteful overproduction of garments and benefit the customer, company, and society: The customer receives a garment that better fits his or her needs, the company is able to meet customer demand more accurately, and society does not have to pay for overproduction.

Keywords: Fashion logistics, Mass customisation, Demand driven supply chain management, Knitwear, Demand chain management, Agility

List of appended papers

This thesis is based on the following papers. The papers are appended in full.

Paper I

Peterson, J., Larsson, J., Carlsson, J. & Andersson, P. (2008). Knit-on-Demand – development and simulation of a production shop model for customised knitted garments. *International Journal of Fashion Design, Technology and Education,* 1: 2, 89–99

Paper II

Larsson, J. & Peterson, J. (2007). A multiple choice system for Mass Customized Knitted Garments. Presented at the Intelligent Textiles and Mass Customization conference in Casablanca, Morocco, Nov. 2008. The paper is published in the proceedings.

Paper III

Larsson, J. & Mouwitz P. (2008). Design for Mass Customized Knitted Garments. Presented at the Textile Future Conference 2008 at North Carolina State University, USA. The paper is published in the proceedings.

Paper IV

Larsson, J. & Peterson, J. (2008). Logistics for Mass Customized Knitted Garments, Presented at the Textile Institute World Conference 2008 in Hong Kong. The paper is published in the proceedings.

Acknowledgements

The work presented in this thesis has been carried out at the University College of Borås at Swedish School of Textile and in the Division of Logistics and Transportation at Chalmers University of Technology.

I am grateful to the Knowledge Foundation (KK-stiftelsen) for financing this work. I would also like to thank the companies involved for participating with their time and effort. I would like to thank all the people at Ivanhoe AB, especially Ulf Göthager. I am also grateful to Simon and Lotta Hjelte at SOMconcept.

I would like to express my gratitude to my professors, Håkan Torstensson and Kenth Lumsden, for their support and guidance and to Dag Ericsson and Jan Carlsson for interesting discussions and challenges. Johan Wikander has also given me a lot of valuable insight into the textile business.

My project partners Joel Peterson and Pia Mouwitz deserve a special thank for writing papers together with me, helping me fulfilling the project, and for pushing the boundaries. Also, thank you both for making all the travelling fun.

I would also like to thank my friends and family for always being there, for relieving me from the thesis from time to time, and for making my life one of the best.

For those of you who never understood what I was working with, here is your chance to find the answers.

Jonas Larsson

Borås June 9, 2009

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1. Introduction

This chapter describes the problem, background, and purpose of the thesis. It also presents the research project Knit-On-Demand, which is the focus of the thesis. Furthermore, the scope is specified and the outline of the thesis is given.

1.1 Background: The unpredictable fashion market

The fashion market is characterised by short life cycles, low predictability, and high impulse purchasing (Christopher et al., 2004; Cerruti & Harrison, 2006; Ghemawat, 2003). In order to respond to these characteristics, companies are constantly introducing new collections and models. There are now so many new models introduced that the seasons have been erased and the leader of fast fashion, Zara, introduces 211 new models each week. It is a true, if not impossible, challenge to sell all these garments at full price. The result is that a large part of the produced garments have to be marked down and sold at a reduced price or be liquidated. The sell-through factor in fashion, which indicates how many of the total SKUs that are sold at full price, is approximately 65 percent (Mattila, 2004). One of the reasons why so much must be sold at a reduced price is that the fashion companies might have created a new buying behaviour among their customers by offering everything quickly. This new buying behaviour cannot be answered with traditional supply-chain management.

The reason why the sell-through factor is low is that it is difficult to forecast new models by using historical data since that data corresponds to another model. Even if the models are similar it will still be very uncertain; instead, fashion companies have to rely on their judgment. The main purpose of a forecast is to assess the future demand and demand patterns since they have a decisive influence for planning and controlling a company's production. Since a forecast is an assessment of the future demand, they are seldom correct. There are several reasons why a forecast is wrong, including poor forecast methods, inaccurate basic data, or conflicting interests (Mattsson & Jonsson, 2003). The major reason forecasts within the fashion industry are wrong is the long lead-times from design to delivery, sometimes as much as one year (Cerruti & Harrison, 2006). The result of the poor forecasts and the long lead-times is that nearly 9 million of the 26 million people working in the clothing sector are producing the wrong items (Allwood, et al., 2006). This production is very resource intensive; for example, cotton production requires vast amount of farmland and fresh water.

A faster fashion world increases the pressure on fashion companies and many companies have trouble keeping up with the higher demands for fashion. One reason why is that they lack sufficient information and control over their supply chain. Small production companies might be very good at producing but cannot access customer demand since they never meet the customer. The other way around, small fashion stores meet the customer every day and know exactly what the customers want but have little ability to answer particular demand since they do not manufacture. Another problem is that these companies usually keep an arm's length distance between each other. Such disintegration in the supply chain might be one of the reasons why the larger companies such as Zara, H&M, and Gina Tricot are increasing their market shares, because they have a better overview of their supply chain and are able to respond quickly and accurately to market fluctuations.

The value total adding time in a supply chain for fashion garments is small, and in a traditional supply chain it constitutes such a small part of the total lead-time that it has to be counted in per mill. The longer time a garment spends on its way to the customer the lower the value of the garment. Each hour it spends on the shelf decreases the accuracy of the forecast and the garment becomes more difficult to sell. Eventually the garment has to be marked down; by that time it is only worth half the price, but is has cost a lot in handling and floor space. Approximately 70 percent of the logistic costs in the supply chain can be allocated to not having the right product in stock, i.e., 45 percent of the costs for lost sales or things that would have been bought if they were in stock and 33 percent is costs for mark-downs or costs for products that no one would buy because the model is wrong in some way (Kleiby, 2007).

As mentioned earlier, a large proportion of the logistic costs is due having the wrong product in stock, which often is due to poor forecasts. A forecast is a guess of a future state and the longer into the future the harder it is to guess. Therefore, it could be stated that the longer lead-times, the more inaccurate the forecasts.

Since 1995 the Japanese knitting machine manufacturer Shima Seiki has had a store in Japan that sells customized knitwear on demand. The store is called Factory Boutique and is a combination of a store and a factory. The purpose of Factory Boutique is to more accurately answer customer demand (Shima Seiki, 2008). In the South Korean project iFashion, the consumer is allowed to customize almost their entire wardrobe, from underwear to suits. There are many more examples of mass customized fashion goods. Via the Internet, customers can build bags from recycled trailer-tarpaulins, customize a pair of sneakers, or mix their own muesli. Most of the mass customisation initiatives are found online; one reason for that might be that these companies will have difficulties finding a customer base large enough, even in a larger city. Other benefits of on-line configuration tools are that the customer does the configuration and the company does not need to be located in the middle of a city where production costs and rents are high. In Europe there is only one more initiative like Knit-On-Demand, a German retailer of customized apparel that has started a similar business in Kaiserslautern.

Extensive research has been carried out on mass customisation, many articles have been written, and basically any product is customisable. Yet there is very little in the literature about actual cases, except for cases such as NikeID and MiAdidas. Both companies have managed to sell customized shoes but with slightly different approaches: in the NikeID case the customer is allowed to change the appearance of the shoe, bag, or watch but it comes in standard sizes, while Adidas also lets the customer change appearance and adds the possibility to adapt the shape of the shoe to the consumer’s foot. Even though many companies are offering customised goods, there is still space on the market and in the literature for customised knitwear. Most articles about mass customized fashion discuss the customisation of fashion in general and do not examine sub-categories such as knitwear or shirts.

1.2 Knit-on-Demand

Knit-on-Demand is a research project financed by the Knowledge Foundation and carried out at the Swedish School of Textiles. The objective of the project is to demonstrate a production method for knitwear that may strongly influence the ability of the fashion industry to meet new demands for agility in customer relations. It will also provide insight and transparency in the total cost picture related to logistics and supply chain management, which leads to improved decision support in outsourcing and off-shoring strategies and may contribute to increased local fashion production. The complete-garment knitting methodology is implemented to create a fashion production laboratory, where various sourcing, logistics, production, and quality concepts can be tested and evaluated.

Three industrial partners have participated in the project: Ivanhoe, a fashion design and production enterprise, Gällstads Ylle, a textile retail company, and Total Logistik, a third-party logistics provider. SOMconcept, a company not included in the original constellation of companies, joined the projected and will sell the garments in their store in Stockholm.

During the course of the project, Total Logistik was taken over by Tradimus, and through a series of transformations it is now a part of Aditro Logistics. While Total Logistik initially brought much insight and knowledge regarding third-party fashion and textile logistics, the company no longer provides this sort of competence and a new partner in this field is sought.

Figure 1 is an illustration of the original idea of how the store in Gällstad would be set up. The original idea was to have a complete garment machine in the store connected directly connected to the design computers

Figure 1. Design in Shop

Customers would be offered two different options when buying a garment: the first is Designer's Place where ready-made garments were sold in the traditional way. The major difference compared to traditional retailing is that as soon as a garment is bought an order is sent to the knitting machine and a new garment is immediately knitted to replenish the one sold, all according to Kanban principles. The second option for the customer was to buy a garment in the Design in Shop section, where the customer uses a multiple-choice system to configure his or her garment. Samples of garments, colour swatches, and other effects of an inspirational kind would be available in the store to help the customer design the garment. When the customer designed the garment the production order was sent to the knitting machine and three hours later the customer could pick up the garment.

However, the business risk of investment in a complete-garment knitting machine was, in the end, unacceptable for Ivanhoe and Gällstads Ylle. This has led to a reorientation of the project plan with regard to knitwear production resources, but the collaboration with these partners continues. The essential objectives of the project: demand-driven design and delivery of knitted garments with logistics implications such as reduced lead times, made-to-order production, obvious connections between design, production and logistics, case studies, and testing on site in Gällstad, will be retained.

1.3 Scope

The focus of the research has been to develop an on-demand business concept for knitted fashion garments. Development includes the entire supply chain, i.e., design, logistics, manufacturing and marketing. The solution is specific for the textile industry and the focus is on knitwear sales. However, during the project knowledge from other industries was applied to this specific solution. Since the purpose of the project is to develop a fully functioning business concept, the approach has been rather wide and it treats major parts of the demand-driven supply chain. As a consequence of the scope of the project, the thesis is more exploratory. Figure 2 illustrates a typical supply chain for the fashion industry.

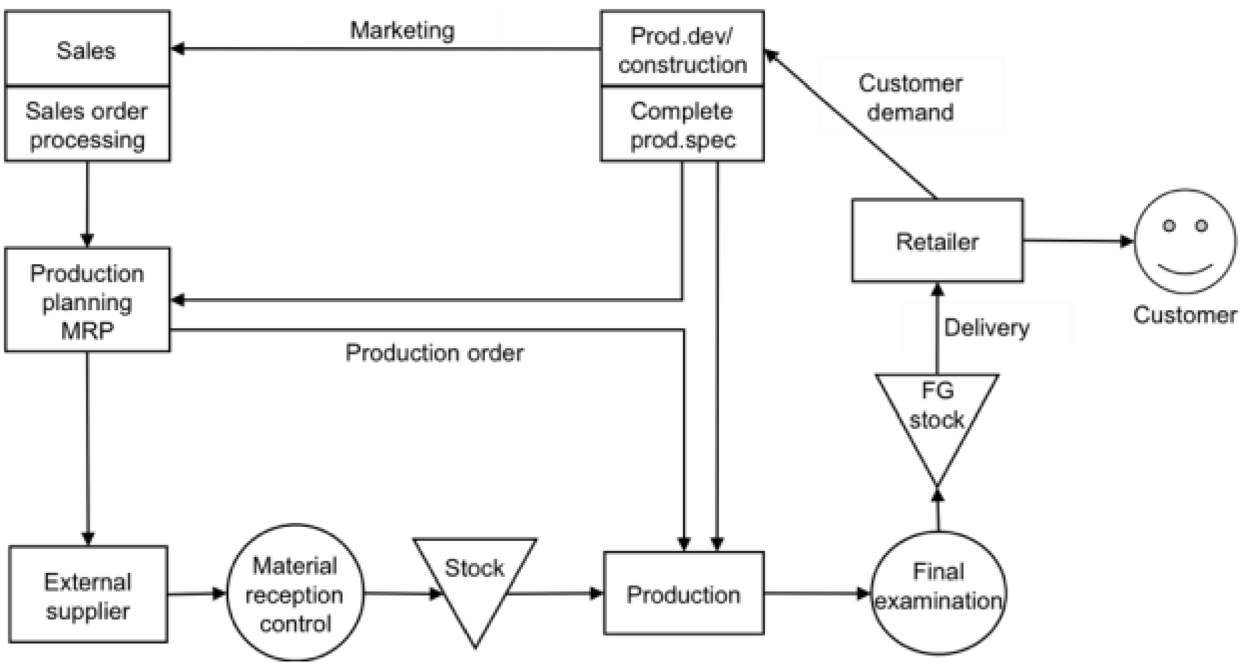

Figure 2. A Fashion Supply Chain

It is an ambitious task to develop an entire supply chain for knitted garments and it could hardly be accomplished within the frames of the project. Luckily there already exists a supply chain, and the demand-driven solution will be fitted onto that and tested. The existing supply chain is rather traditional in its set-up and is characterised by long lead-times and traditional supply chain mindsets. Therefore, it is quite a challenge just to change the mindsets of the supply chain managers. The retailer—which already sells tailored fashion—has a customer base that is familiar with customized and made-to-measure clothes. So far, the focus of the project has been to develop the sales and sales order processes, the product development process, and the order-fulfilment process from stock to customer.

1.4 Overall research question and purpose

The purpose of the project is to demonstrate a production method for knitwear that may strongly influence the ability of the fashion industry to meet new demands for agility in customer relations. It will also provide insight and transparency in the total cost picture related to logistics and supply chain management, which leads to improved decision support in outsourcing and off-shoring strategies and may contribute to increased local fashion production. Therefore, the following overall research question is stated:

What supply chain solution is needed for customized knitted garments?

Although such a research question is rather ambitious, the purpose of the thesis is to contribute to the development of the demand-driven supply chain for the business concept Knit-on-Demand so it is not heading in the wrong direction. However, it is wide in its scope, leaves room for extensive exploration, and needs to be more specific. The overall research question will remain as a guiding star but with specific questions:

1. ***What logistic and production solutions are needed for mass-customised knitwear?***
2. ***How will the garments be designed to fit into the supply chain?***
3. ***What is needed to sell the garments?***

These questions narrow the thesis, but it is still wide in its scope. However, one of the aims of the thesis is to describe the development of a total business concept from concept to carry-a-bag and to provide guidance for business professionals. Figure 3 explains how the research questions and research objectives are connected.

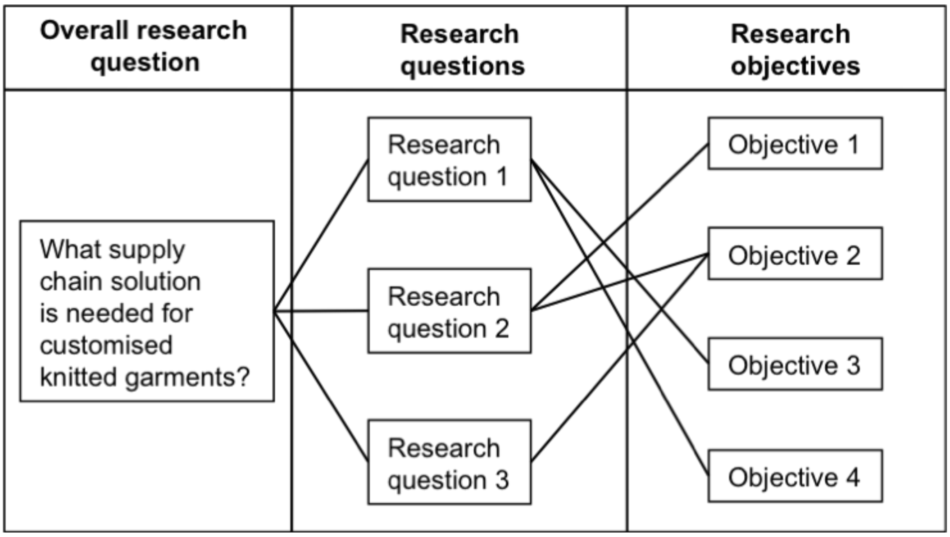

Figure 3, Connection between research questions and research objectives

1.5 Research objectives

In order to answer the research question, we had to develop the parts of the supply chain. For that purpose, a few research objectives that are closely related to the research questions have been stated.

1. Identify, structure, and describe consumer behaviour and needs and build a multiple choice/configuration system in which the customer can design their own garments.
2. Investigate consumer requirements for a customized garment and develop a design that is flexible enough to meet the requirements.
3. Analyze production of customized knitted garments, describe what is required of production, and develop a production method that suits both production and the customer.
4. Analyze the requirements of a logistic system that will support the manufacturing of customized knitted garments and set up a solution.

When these research objectives are fulfilled, we would have a fully functioning supply chain that can be measured and tested.

1.6 Thesis outline

The thesis is structured as presented below:

Chapter 1 – Introduction

This chapter describes the problem, background, and purpose of the thesis. It also presents the research project Knit-On-Demand, which is the focus of the thesis. Furthermore, the scope is specified and the outline of the thesis is given.

Chapter 2 - Method

This chapter provides an explanation of how the research was designed and how data was collected. The case study and simulation methods are also presented here.

Chapter 3 – Theoretical framework

This chapter presents the theoretical framework for the development of the Knit-on-Demand project. The frame of reference is broad and comprehensive perspective rather than deep and narrow, to cover most of the areas necessary to understand the Knit-On-Demand business concept.

Chapter 4 – Results and summary of the appended papers

The results from the appended papers are presented in this chapter and connections between them are described.

Chapter 5 – Analysis and concluding discussion

The results from the papers are analysed and conclusions are made based on the overall research question. The synthesis of the thesis is made in this chapter.

Chapter 6 – Further research

The research on mass customized knitwear will continue and some of the thoughts regarding future research directions are presented here.

1.7 Definitions

The following key performance indicators are important in fashion logistics and are used in this thesis.

- **Sell-through factor**
  The sell-through factor indicates what percentage of the items were sold at full price. When selling garments on demand, everything that is produced is sold, so this KPI might be redundant, but it is important to address it and use it for comparison.

  $$\text{Sell through} = \frac{\text{No. of sold items to full price}}{\text{No. of sold items in total}}$$

- **Lost sales**
  Lost sales are very difficult KPI to measure and therefore, the numbers presented in the thesis might be wrong. However, this is the case for the future research to prove. When measuring lost sales, it has to be considered that all customers that enter a store or browse a Web page are not planning to purchase a product. These assumed customers could be looking for their husband or spouse or might just be out window-shopping.

  $$\text{Lost sales} = \frac{\text{No. of customer who find no SKU preference}}{\text{Total number of customer visits}}$$

- **Service level**
  Indicates what portion of the original assortment is available throughout the season. It might seem redundant to measure the service level.

  $$\text{Service level} = \frac{\text{No. of different SKU's available in the store}}{\text{Total no. of SKU's in collection}}$$

2. Methodology

This chapter provides an explanation of how the research was designed and how data was collected. The case study and simulation methods are also presented here.

The methodology is the guiding principle for the creation of knowledge. Therefore, it is very important that the methodology suits the purpose of the thesis. The knowledge created in this thesis is meant to be useful for developing a commercial product, so the emphasis has been on developing frameworks for design, production, and sales rather than developing theories. This chapter describes the methodologies from the researchers' perspective and the research process from the kick off in the Knit-on-Demand project in May 2006 to the first garment sold in fall 2008.

2.1 Research process

Knit-on-Demand is a joint project between the Swedish School of Textiles, Ivanhoe AB, Total Logistik AB, Centiro AB, and SOMconcept. The author of the thesis is enrolled at Chalmers University at the division of transports and logistics. Knit-on-Demand started in May 2006 with a kick off in Gällstad. The project spanned over three years and there were in three researchers involved: one with a focus on design, one with a focus on textile technology, and the author of the thesis who focused on logistics. In order to reach the targets of the project the group developed the solutions together and developed an interdisciplinary thesis. Figure 4 illustrates the research method in which theory and empirical observations were combined to develop applied solutions that were later adopted in manufacturing and sales.

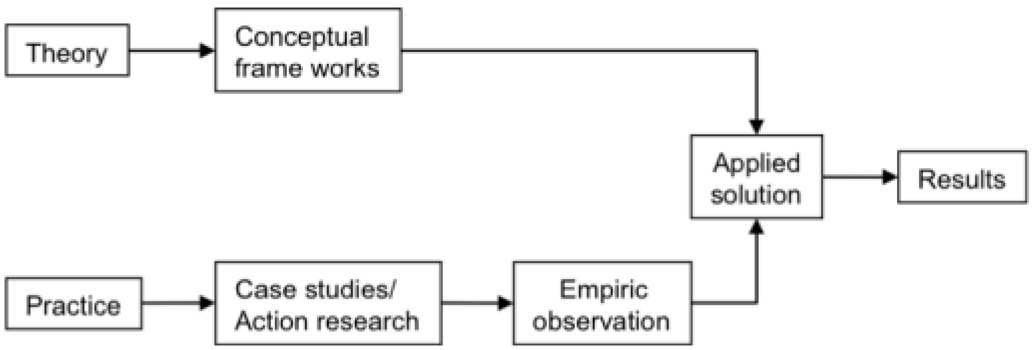

Figure 4. Research method

The papers have their starting point in the Knit-on-Demand project and they are a result of the process of developing the project toward production and sales. One of the purposes of the project was to test the complete garment technology in a demand-driven supply chain, and the main focus of the logistics part of the project was to develop a logistics solution and test it. Each paper describes the development of a vital function to produce and sell customized garments. The thesis is descriptive in its characteristics and it defines the development of a business concept and the prerequisites for its functioning.

Chronology

The papers follow the development of the Knit-on-Demand research project. A simulation is the empirical data for the first paper (I) and the three following case studies (II-IV), while the empirical data is gathered from a great deal of action research. Figure 5 illustrates the research process beginning in May 2006.

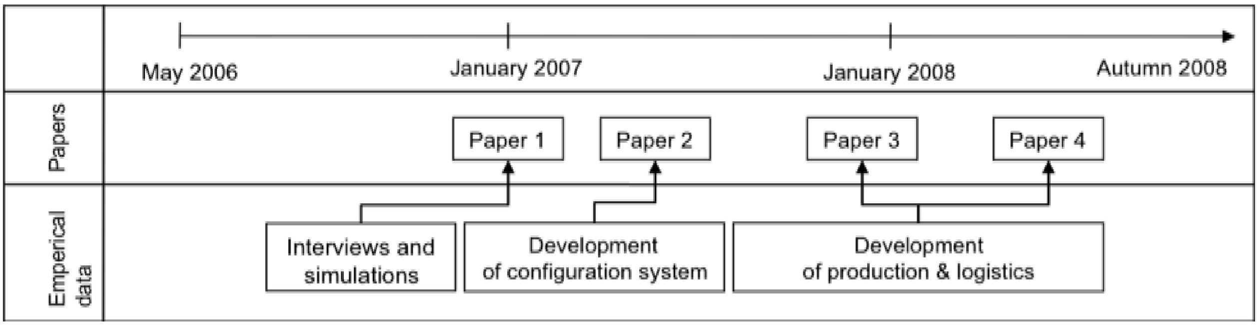

Figure 5. Research process

This thesis is built on one simulation (Paper I) and case studies (Papers II-IV). A simulation of the supply chain was constructed and run together with the School of Engineering at the University College of Borås. The purpose was to open a small window on how the final solution might look. Case studies were carried out with different companies and the researchers took an active role in developing the functions needed for project. Since the project was conducted in collaboration with a company, it is important that the knowledge created have commercial value and is marketable. Discovery, application, and use of knowledge are well integrated so nothing is developed that cannot be commercialised.

It should also be mentioned that the process of developing the Knit-on-Demand project has been everything but a straight line. It has, from the day it started, taken every possible direction and been far away from the original plan from time-to-time.

Paper characteristics

Table 1 presents the characteristics of the four appended papers. In Paper I the purpose was to simulate the agile supply chain with a focus on production and sales. The distinction on production and sales was done for complexity reasons, because a simulation that involved the entire supply chain would be complex to manage. Papers II-VI are explanatory and develop an applied solution for a specific purpose in the Knit-on-Demand project. Therefore, the latter papers are the result of adopting frameworks from literature and combining them with knowledge from interviews and workshops.

	Paper I	Paper II	Paper III	Paper IV
Scope	Simulation of a supply chain	Development of multiple choice system	Development of the garments	Defining the logistic environment
Purpose type	Describe	Describe and develop	Describe and develop	Explanatory
Research design	Quantitative	Qualitative	Qualitative	Qualitative
Data collection	Interviews and documents	Interviews and workshops	Interviews and workshops	Interviews
Sample	One case study	One case study, 13 interviews	One case study, 9 interviews	One case study, 7 interviews

Table 1. Paper characteristics

2.2 Simulation

A simulation opens up a window for analyzing a process or a method where there is no full-scale environment available. It can be defined as an "*imitation of the operation of a real-world process or system over time"* (Banks, et al., 2004). A simulation is an appropriate tool when new policies, production processes, information flows, and decision rules need to be analysed without interrupting the ongoing processes of the real system.

When the system is modelled it is important to understand what is included in the system and what is not. A system is a group of objects that interacts with each other to accomplish a purpose. Outside the system is the system environment, which often affects the system and it is necessary to decide on the boundaries between the system and its environment.

Simulation study

Paper I is built on a simulation study of the Design in Shop concept. The purpose of the simulation was to analyse the concepts' performance regarding demand fulfilment time, production time, and system efficiency. The model was built in AutoMod with the Logistics Department at the School of Engineering at the University College of Borås. AutoMod is a system for building models and simulating detailed design and production processes. Version 11.2 of AutoMod was used for this particular simulation.

The simulation method used is a process-interaction method that simulates the flow of objects through a system and the interactions of the objects with the system. The model is built as a discrete event model which means that the state of the system changes discretely at a fixed set of points over time. Objects move through the system until they are delayed, enter an activity, or have been completed by the system. The emphasis in the model has been on time: production time, fulfilment time, and system efficiency. Since time probably is the most important performance indicator in production and logistics and the aim of the project is to reduce lead-time, the simulation method suits the means.

Input data used in the simulation model was based on information from knitting machine manufacturers and data from the Prototype Lab at the Swedish School of Textiles. Data of customer behaviour were gathered at the location of the future store. Based on the data on how often customers are entering the store an exponential distribution was used to model random arrivals at the store. The exponential distribution is without memory which means that customers arrive at the store independent of each other. Each run of the simulation corresponds to one month of customers entering the store. The output data were summarized in charts and visualized for better understanding of the system's performance.

Validity and reliability

To ensure the correctness of the simulation and its result, it has to be validated and verified. Banks et al. (2003) lists eight suggested methods for validating the simulation, three of which were used: 1) have the model checked by someone other than the developer; 2) closely examine the model output for reasonableness under a variety of settings of the input parameters; and 3) present the simulation in a graphical interface that makes it easier to analyse the correctness of the simulation. Since it was not a very complicated simulation, the methods used to validate its reliability were considered sufficient.

2.3 Case studies

The definition of a case study according to Yin (2003) is, "…an empirical investigation of a contemporary phenomenon, especially where the boundary between phenomena and context is unclear". Finding the exact boundary between the phenomenon and the context is very difficult in this case, because the border has been redrawn during the lapse of the project. In this case the phenomena studied are on-demand business and mass-customisation, and the context is a supply chain for knitwear. According to Yin (2003), a case study illuminates a set of decisions: why they were made, how they where implemented, and with what result (Yin, 2003). The case studies focused on the development of the Knit-on-Demand concept and each case study presents one part of the project.

In the project a number of case studies were carried out to study the development of such a business case. The case studies were not limited to just studying one particular phenomena or a process from an outside point of view; they have a relatively high degree of action research in them. During the development process the researchers intervened in the development process and are sometimes more responsible for the end result than the company analysed.

The case studies in combination with knowledge gained from interviews, inspirational journeys and empirical observation are the basis of the development of the project. The companies interviewed can be found in Appendix 1.

Case Study 1 - The development of a multiple choice system

The purpose of Case Study I was to develop a sales system for the garments. The project team found it necessary to develop the sales system first in order to get sales started. The empirical data was collected from interviews, workshops, and from information about the systems supplied by the different companies.

In total 12 companies were contacted in the case study. These companies either had an already existing solution or had the capabilities to develop a system. The development was done in collaboration with InnovationLab, a function at University College of Borås at the School of Business and Informatics and a supplier of software for the textile industry.

During spring 2007 several existing multiple choice systems were analysed mainly on their structure, compatibility with the other systems, and their graphics solution. The data from the interviews was analysed and combined with frameworks from literature to define a system-specification. When the analysis of existing systems was ready, the development of the project specific solution began. A prototype system also was developed in PowerPoint for demonstration purposes. The specifications were sent to the system developers, which proposed a solution for the system. After that a number of workshops were held during which the system was further developed. The project team from the Swedish School of Textiles (THS), the software supplier (IMDA), and system developer, InnovationLab, participated in the workshops. Figure 6 illustrates which role each participant had in the development of the system and what knowledge they possess.

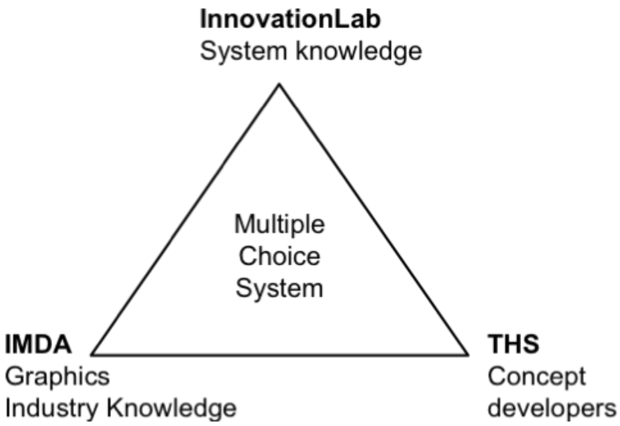

Figure 6, Participants in the development of the multiple choice system

After each workshop the system specifications were revised and rewritten so the system developers knew how to build the system. It was a new experience both for the system developers and the research group to develop a multiple choice system. Hence the development process was not linear but changed direction many times.

The result of development of the multiple choice system is presented in the appended system specification. It was decided not to continue with the development of the system due to the inabilities of the system developers to offer a fixed price and adhere to the tight time frame.

Case Study II – Development of design and production

The purpose of Case Study II was to develop the remaining parts of the project: the design of the garment, production, and logistics. Design and production are very closely related since the design of the garments has to be flexible enough for customisation purposes and simple enough to keep production costs at a minimum. Design and production were developed together with Ivanhoe AB and SOMconcept. In total nine companies were contacted and interviewed or visited during the case study.

The methods used for collecting empirical data were interviews, inspiration journeys, and workshops on several occasions during fall 2007 and spring 2008. Knowledge gained from the inspiration journeys, interviews, and workshops was combined with theoretical frameworks for developing and applying a solution.

The design process started in spring 2006 but it did not take off until autumn 2007. During the lapse of the project several inspiration journeys were done to analyse existing garments and manufacturing techniques and to decide upon the final design of the garments and the production technique to be used. Documentation from the journeys was made mainly with a camera. The data from the inspiration journeys were translated into a design that suits both customers and manufacturing. Design and production of the customized garments was developed along with the two project partners Ivanhoe AB and SOMconcept. Several workshops were held where the development of the concept evolved. Figure 7 explains which participant had which role in the development of the concept.

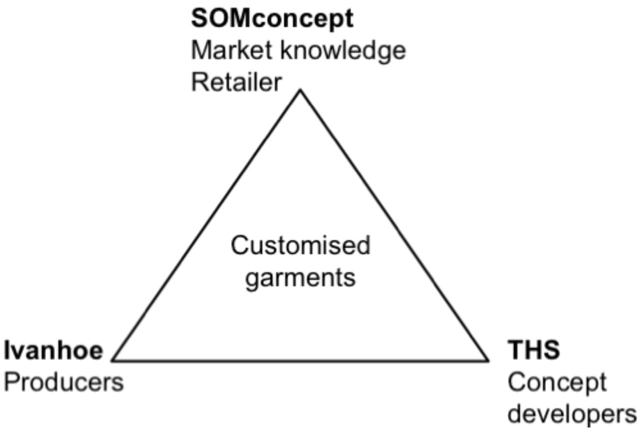

Figure 7. Participants in the development of the design

The result is presented in reports from the workshops and as the finished business concept.

Validity and reliability

One difficulty with case studies is that they are hard to replicate. Even if the method of the case study is well documented, one could not expect to achieve the exact same results as in previous case studies. However the purpose of the thesis is to develop a concept for selling customized knitwear so the solutions are applied as presented. Therefore, if the solutions suggested by the thesis are approved by the companies involved, reliability and validity should be ensured. Paper IV is more explanatory in its nature and its internal validity is of concern. To ensure the validity of the paper multiple sources of evidence were used.

2.4 Chronicles of Knit-on-Demand

These are the chronicles of how the Knit-on-Demand concept has evolved during 2,5 years.

Spring 2006

Grand opening at Gällstad Ylle & Ivanhoe AB in Gällstad, Sweden. The kick off of the Knowledge Foundation (KK-stiftelsen)-financed project Knit-On-Demand ’05 was held on 30 April in Gällstad, which is the heart of the remaining knitting industry in Sweden. It was the start of something new--customers could design their own garments and have them knitted directly in the store. The concept was called “Design in Shop.” A couple of hours later the customized garment could be picked up in the same store and taken home.

New and advanced complete garment knitting technology makes it possible to produce entire garments in one piece directly in the knitting machine. The project received a lot of attention in media and people generally liked the idea of buying individualized garments.

Fall 2006

After summer 2006 it was time to get the show on the road. A knitting machine had to be bought, a customer interface for the design system and a logistics solution had to be developed, and a store had to be built. Meetings were held with the two suppliers of complete garment machines (Stoll and Shima Seiki) and it was concluded that Shima Seiki was the best alternative because they offered to most integrated solution. A smaller project considering the ICT solution had begun in collaboration with a local ICT-solution provider. The aim of that project was to evaluate the risks of the project and how these risks could be reduced or eliminated using the complete garment technique and up-to-date ICT systems. Very conveniently it concluded that most of the risks in a demand-driven supply chain would be significantly reduced or eliminated using the complete garment technique in an ICT field demand-driven system. A model for the ICT solution also was developed and it efficiently integrated all the parts of the demand chain, even the older supply chain that would still produce in a traditional way.

In addition to the knitting machine and the ICT system a customer interface for configuring and selling the garment had to be developed. Customers want to see what the finished product looks like before they decide upon a purchase.

A survey conducted during fall 2006 confirmed that people would like to buy customized clothes. All the respondents below the age of 18 would by a customized garment given the opportunity. However, the study did not consider to what extent these respondents would like to have their garments customized.

Winter/Spring 2007

It was very clear that the customers themselves could not handle the design systems of the knitting machines. To create an efficient system, the customers should be able to do most of the configuration of the garment themselves. During the fall the first steps toward a customer interface had been taken. Many discussions evolved around what the visualization would look like. Should it be a rotating 3D image or is a plain two dimensional image enough? After some studies it was agreed upon that a non-rotating fake 3D image was the aim. It was also not clear what the customer should be offered.

Discussions began with the IT developers at the University College of Borås and a knitting software developer/provider. A visit to Shima Seiki in Derby, England, was done to get clues on how to build an interface. The further the discussions with the developers went, the more complicated it seemed to build an interface. In the early spring an attempt to simply buy an already existing system was made. However, the owners of the system (which is a successful manufacturer of mass-customized shirts) did not let the system go that easy. It became more and more evident that it was not as easy to produce and sell on-demand garments as the project team had imagined and the production company started to have its doubts that producing garments on-demand would actually work.

Summer 2007

The development of the customer interface, the Multiple Choice System, came to a stage where the specifications of the system had to be given to software developers. They had an estimated a price tag of 250 000 SEK and the delivery date was set for November 2007. Experience said the price would increase and the time frame was set too tight, and that it was more likely that the system would be up and running by Christmas 2007 and cost twice as much. Due to the delays in the project, this was considered too late and the further development of the Multiple Choice System was put on hold. Instead an RFID-based smart retail system for up-sales and cross sales was considered and evaluated to tweak it a little bit and use it as a multiple choice system.

Autumn 2007

Plans regarding the spring were made and a conference on the subject of mass customisation was planned to March. Mr. Mass Customization, Dr. Frank Piller at the University of Aachen, was contacted and asked if he could appear on the conference, but he kindly directed us to the owner of a store in Germany. In retrospect, that contact was a turning point for the good in the project. He had proven that it is possible to produce and sell customized garments in a physical store in the centre of town with decent prices (others had already proven that it was possible on the Internet). He did accept the invitation as a speaker. The CEO of a company that sells customized shirts on-line was also invited as a speaker to the conference and accepted, so the outlook for the conference was good.

Winter 2008

The managing director of the Hong Kong-based company that provides the smart retail system visited Borås to discuss the set up of a demo store in Sweden. The meetings were quite successful and it was decided that a demo store would be built during the "Textile Challenge on Mass Customization and Innovations in Retailing." In February a study trip to Kaiserslautern in Germany was done with the purpose to see how the "on-demand" business works in reality.

In March, the conference "Textile Challenge – Mass Customisation and Innovations in Retailing" was held at the Swedish School of Textiles. The conference was successful and the organizing committee managed to gather very knowledgeable speakers, including the former managing director of design at KIA Motors. Unfortunately, Ryan Air decided not to let one of the key speakers board the plane in Frankfurt so the part on "Mass Customisation in Physical Retailing" missed out.

The Textile Challenge was kick-off number two for the Knit-On-Demand project, and for some of the project members it felt like a new start because many of the old ideas had been revised. For example:

- The investment in a complete garment machine – It is as easy to produce customized knitwear on a traditional knitting machine. Therefore, there is no need to invest in expensive new knitting equipment.

- Computer based multiple choice system/Smart Retail System (SRS) – After the decision to buy a RFID-based SRS-system, a few of the project members continued to work on a multiple choice system on a limited basis, without funding. Instead of a computer based system, a physical system was developed that had many similarities to a traditional tailor but was adapted to knitwear.

- "Design in Shop" in Gällstad – During the spring 2007 a Stockholm-based retailer of tailored fashion contacted the Swedish School of Textiles and wanted to sell customized knitwear. At the time the Multiple Choice System was still under development and it was decided the system would be available in his store when it was finished. Unfortunately no multiple choice system was ever built, but the contact with the retailer continued.

Spring 2008

In connection to the Textile Challenge things started to change and the critical mass of the partners involved realized there is a market for customized garments. Together with retailers in Stockholm and Ivanhoe, it was decided that sales of customized knitted sweaters would start in the last week in September 2008.

Autumn 2008

The first garments were produced in November by Ivanhoe and sent to SOMconcept for controlling measurements and shape. The development of the Multiple Choice System started again with IMDA, this time as an attachment to PISA, a product management system. The plan was that when the garment was suitable, the size samples would be produced and sales could start by Christmas. The garments would be produced using the cut and sew technique.

Spring 2009

The second garment was produced in January and instead of cut and sew we used the Fully Fashion technique. Fully Fashion creates a more agile garment without bulky seams. The first customer garment has been produced for a gentleman that is 2,10 metres tall. On Maj 20 sales of the customized garments will begin in PUB huset in Stockholm.

3. Frame of reference

This chapter presents the theoretical framework for the development of the Knit-on-Demand project. The frame of reference is broad and comprehensive perspective rather than deep and narrow, to cover most of the areas necessary to understand the Knit-On-Demand business concept.

3.1 Treated areas

The frames of reference are divided into three main areas that address the theories that support the project.

The first area is logistics and supply and demand chain management. Chapter 3.1 to 3.6 explains the environment in which the business concept has to operate and what is required from the supply chain. It also presents a number of theories that support the idea of one-piece garment manufacturing.

The second area explains the paradigm shift in how products are sold and produced. Chapter 3.7 and 3.8 explain mass customisation and the Long Tail Economy and how it might affect the way products are purchased. Knit-On-Demand and one-piece manufacturing fit very well into that new economy.

The third area treats the production methods that are used to make the products. Chapter 2.9 briefly describes the flat knitting technique used to produce the garments. It also discusses which knitting technology would be best for one-piece manufacturing.

3.2 Fashion Supply Chain Management

It is difficult to forecast fashion due to the high complexity of the market. Many factors, such as the weather, what was on MTV yesterday, or the current temper of the buyer affect the final decision. There is a constant demand for low-prices, and low-priced fashion is gaining a lot of market shares (Habit, 2008). The result is off-shore manufacturing where wages are low. On the other had, lead-times are long and difficult to manage, so companies have to rely on forecasts (Christopher et al., 2004). Fashion is by definition hard to forecast and attempts to do so are usually unsuccessful. The average sell-through factor is between 30 and 40 percent for clothing (Mattila, 2004; Bruce & Daly, 2006). However, garments are not the worst in the apparel industry: the sell-through factor for shoes is approximately 45 percent (Habit, 2007). The garments that have not been sold at the end of the season have to be marked down and sold at a reduced price. It is not only the markdown that creates a loss of money, because the products kept in the store have to be handled, folded, and moved around. It is argued that 70 percent of the logistics costs for a garment can be allocated to the store (Kleiby, 2007). Fashion markets usually exhibit these characteristics:

1. Short life cycles – Customers require more fashion and they are not willing to wait. The period in which a garment is sellable is shortening (Christopher et al., 2004). This puts stresses on the logistics system to deliver the goods more accurately (Cerruti & Harrison, 2006). One day of delay causes a lot of lost sales if the length of the season is only a couple of weeks (Ghemawat, 2003).

2. Low predictability – Fashion companies have a high proportion of new models each year and therefore it is hard to use past data to build reliable forecasts. A fashion customer's complex buying behaviour also adds to the difficulties of forecasting. However, variations of demand

in both style and volumes are considered part of the fashion business (Cerruti & Harrison, 2006).

3. High impulse purchasing - The customer buys what is available in the store and purchases are often spontaneous. Generally customers have not decided exactly what to purchase when they enter the store (Christopher et al., 2004)

3.3 Demand Chain Management

Demand Chain Management (DCM) is a further development of supply chain management (SCM), and some would even argue that the only difference between the two is the spelling. Perhaps the major difference between a supply chain and a demand chain the mindset of the management. What is important and what distinguishes demand chain management from supply chain management is the focus on the customer. The customer is present in the supply chain, but often the literature on logistics and supply chain management fails to recognize the true importance of consumer needs. Also, customer behaviour and integration are seldom discussed at supply chain management conferences. There are even simulations of supply chains that do not mention the customer or include customer demand of any kind. The focus of demand chain management is to effectively integrate demand creation and demand fulfilment processes throughout an organisation. Another attribute of demand chain management that separates it from supply chain management is the incorporation of the marketing department into the value network. The marketing department is rarely regarded as a part of the value flow in SCM literature—more often the marketing department is blamed for trouble such as sales activities (Jüttner et al., 2007).

3.4 Time

Time is probably the most important measure in fashion business and the ability to rapidly answer demand is increasingly important (Christopher, 2000; Bruce & Daly, 2006; Harrison & van Hoek, 2008). Well-managed time can provide a competitive advantage (Harrison & van Hoek, 2008): time-to-market, time-to-serve, and time-to-react are critical lead-times for any organisation, and especially for the companies that compete in today's fashion market (Christopher et al., 2004). A benefit of using time as a performance driver is that time is very easy to measure. The only question that has to be answered is, "How long did it take from discovered demand, to demand fulfilment?" (Mason-Jones & Towill, 1999). Time-to-market, time-to-serve, and time-to-react are included in that question. Information lead-time is equally as important as product lead-time. It is necessary when calculating delays in the system not only to look at the delays in the material flow but also in the information flow, because as data gets old it loses its value (Mason-Jones & Towill, 1999). Mattila (2004) found a positive relationship between stock-turnover rate and revenues. Since a high stock-turnover rate is largely dependent on short lead-times it could be stated that short lead-times have a positive relation to high revenue.

However, the problem is not the time it takes to source material, convert the material into product, and move them to the final customer. The problem is the time between those steps when nothing is done to the product. The non-value adding time that accounts for a very large proportion of the total lead-time can be allocated very often to non-value adding activities which are referred to as the eight kinds of waste (Liker, 2004):

1. **Overproduction**
   Producing items for which there are no orders or no use. It causes waste in storage and transportation plus the negative environmental impact from growing the cotton and dying the fabrics, for example.

2. **Waiting**
   Workers waiting for material to arrive at the working station, tools to be ready, information on what to be produced, or on the next production step.

3. **Unnecessary transport or conveyance**
   Moving work in progress around the factory and in and out of storage.

4. **Over processing or incorrect processing**
   Unnecessary processing due to poor tools or bad product design. Waste is also generated if the quality of the product is higher than necessary.

5. **Excess inventory**
   Excess inventory causes longer lead-times, obsolescence, damaged goods, higher transportation costs, and delays. It also hides delivery problems, quality problems, production imbalances, and production problems such as long lead-times and long set-up times.

6. **Unnecessary movement**
   When the operator has to move in wasteful ways such as looking or reaching for tools or walking.

7. **Defects**
   Causes rework and replacement production and requires inspectors, which means wasteful handling time.

8. **Unused employee creativity**
   Employees that are working in production possess valuable knowledge about processes. Time, skills, and ideas might be lost if they are not engaged in production development.

Very often the lead-time gap between the production time (P-time) and the demand time (D-time) (Figure 8) (van Hoek, & Harrison, 2008) consists of waste of many kinds. The most expensive kind of waste in fashion production is overproduction, which constitutes approximately 30 percent of the logistic costs (Kleiby, 2007).

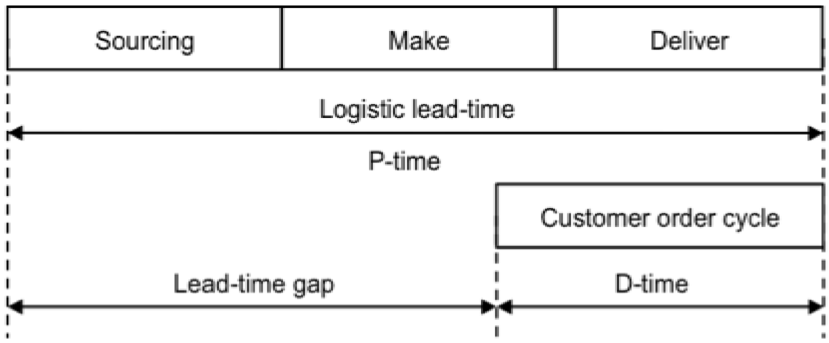

Figure 8. The lead-time gap

It takes approximately 12 months to develop a garment, sell, produce, and ship it to the retailers (P-time) (Cerruti & Harrison, 2006), and a customer is willing to wait between zero to eight days for a garment (D-time). In the past, forecasts have been based on traditional data, which is based on historic sales. These forecasts have been made one year before the season for design purposes and orders have been placed six months before the product is available in the shelf (Bruce & Daly, 2006). The lead-time gap of nearly one year has to be filled with something and traditionally it has been forecasted inventory (Christopher et al., 2004). However, for each day that passes, the forecast accuracy for that inventory is reduced and the chances of selling the goods decrease. Figure 9 illustrates the lead times in a traditional supply chain for fashion products. The top bar is the time each production step takes and the bottom bar represents value-adding production time. One might argue that there are also value-added activities in distribution since a garment has no use or value to a customer until it is in a store.

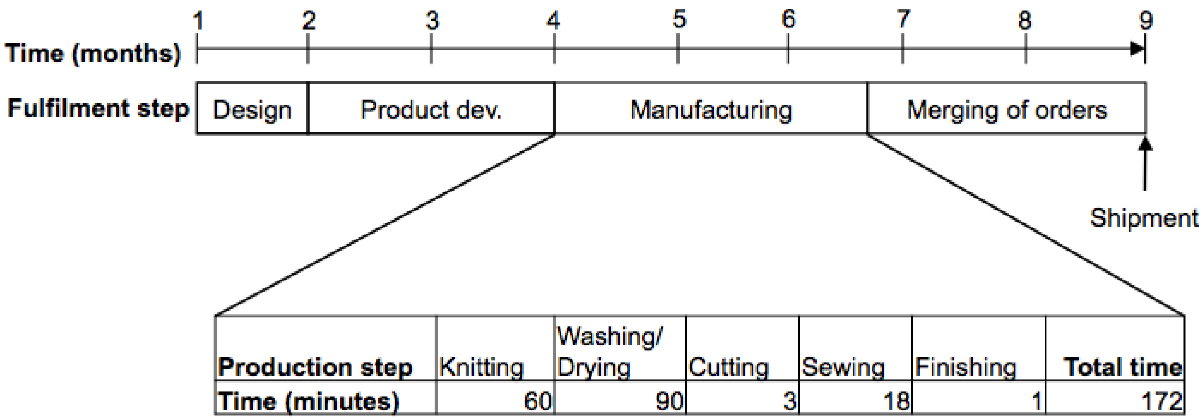

Figure 9. A traditional supply chain for fashion garments

The total lead-time from design to delivery is nine months in this case, and time-to-cash might be as much as 11 months. When the total value-added time is compared to the total lead-time, it is found that the value-added proportion only constitutes 0,0004 percent of the total lead-time.

3.5 The right supply chain for the right product

There is no basic formula for creating an effective supply chain. If there were, each company would be successful. The only two certain ways to success are short lead-times in any process and the sharing of timely information throughout the supply chain. While short lead-times and information sharing is vital for success, there are other things that influence the performance of a supply chain such as what was on MTV last night or geopolitical threats. Different markets and products have various properties and therefore require differentiated supply chains. In literature there are two defined supply chain strategies: lean supply chain management and agile supply chain management. The focus of lean supply chain management is waste reduction and the creation of continuous flow. The focus of agile supply chains is to use market knowledge to profit from unpredictable and volatile marketplaces (Mason-Jones, et al., 2000). There are also combinations of the two that are referred to as leagile.

Fisher (1997) divides products into functional and innovative products. Functional products are commodities such as soap and basic food that have a steady and continuous flow to the market, so lean strategies suit them well. Innovative products, such as fashion garments, are products with high sales peaks and short life cycles that need a more agile supply chain (Figure 10).

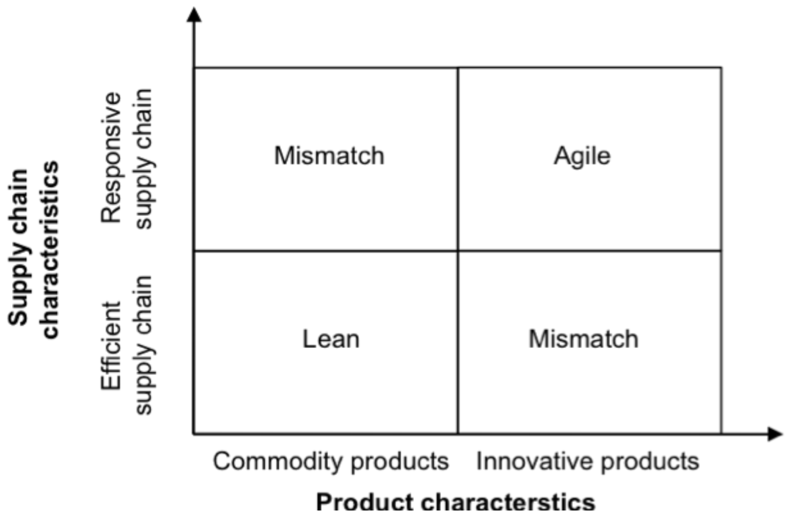

Figure 10. What is the right supply chain for your product?

3.6 The agile supply chain

The idea of the agile supply chain comes from the need to respond quickly to customer demand and is a result of characteristics of the fashion markets (Christopher et al., 2004). The definition of an agile supply chain could be:

"Agility is a business wide capability that embraces organizational structures, information systems, logistic processes and, in particular, mindsets… Agile organizations have the ability to respond rapidly to changes in demand, both in variability and volume" (Christopher, 2000).

An agile supply chain is market sensitive and operates best in unpredictable environments where variability is high, volumes are low, and availability rather than cost is the order winner (Christopher & Towill, 2001). The agile organisation benefits from a volatile marketplace by understanding its mechanisms (Mason-Jones & Towill, 1999). Leading fashion companies have learned to live with the volatility and are able to respond to and profit from it. The method most of them use is an increased number of collections each year to respond to the shifting demand of their customers.

An agile demand-driven supply chain focuses, by its definition, on true demand. It requires integration in the supply chain to function properly (Bruce & Daly, 2006) and sharing of customer-demand data throughout the supply chain (Christopher et al., 2004). Shared accurate and timely data helps the companies align their processes and create an integrated supply chain with a high level of collaboration in product development and common systems (Christopher, 2000). By aligning their processes, the companies in the chain strengthen each other (Harrison & van Hoek, 2008), because an integrated agile strategy can reduce forecast error to five percent (Bruce & Daly, 2006). Ellinger (2000) suggests that a company's competitiveness is largely dependent on its ability to collaborate across traditional functional boundaries. Frohlich and Westbrook (2001) have developed theories around integration in supply chains that they call "arcs of integration." Figure 11 illustrates the theory. They suggest that companies with the broadest arc of integration have better performance than the companies with narrow arcs.

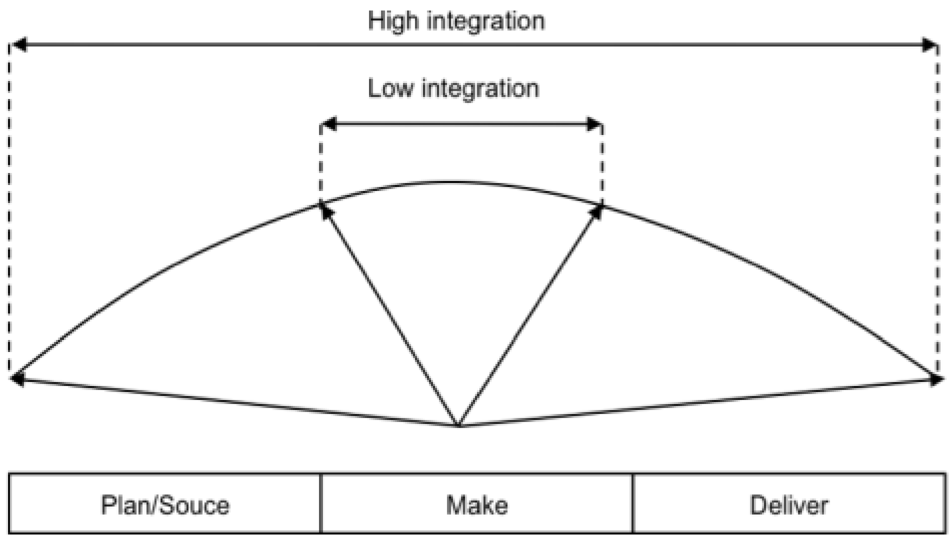

Figure 11. Arcs of integration

Often, collaboration is needed to ensure high quality of products, services and delivery. Figure 12 illustrates the agile supply chain and its attributes. An agile supply chain is *market sensitive* and capable of reading and responding to true demand. The agile supply chain should not be viewed as a chain but rather a *network* that works toward a common goal. Characteristic of the network is the *process integration* that creates synergy for all the partners. The integration of the processes has its basis in the sharing of true demand information and it creates a virtual supply chain that is information-based rather than inventory-based (Harrison & van Hoek, 2008).

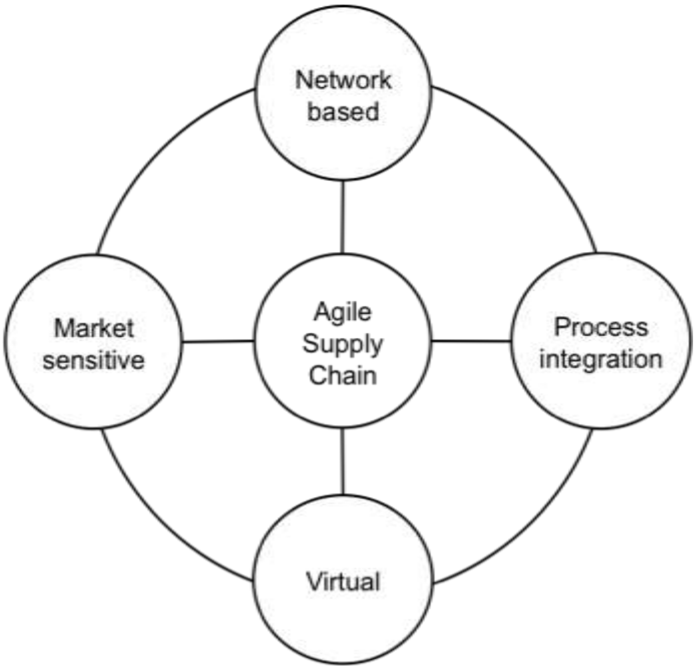

Figure 12. The agile supply chain (Harrison & van Hoek, 2008)

3.7 The Japanese river

Agile organizations are characteristically manoeuvrable. One way of illustrating it could be a theory of the Japanese lake. In lean practises the grounds in the lake are assumed to be problems or wastes such as poor forecast methods, quality issues, or long lead-times, etc., and the water in the lake represents the inventory needed to hide or cope with the problems. As long as the inventory levels are high, no problems will emerge from the depths of the lake (Lumsden, 2001). Most organisations wish to lower their inventory due to the positive connection between increased stock turnover rate and increased revenue (Mattila, 2004). The ship represents the products moving through the production system—the larger the ship the more products. Figure 13 illustrates the ship moving along a river with the velocity V_1 filled with inventory (A_1) that effectively hides problems.

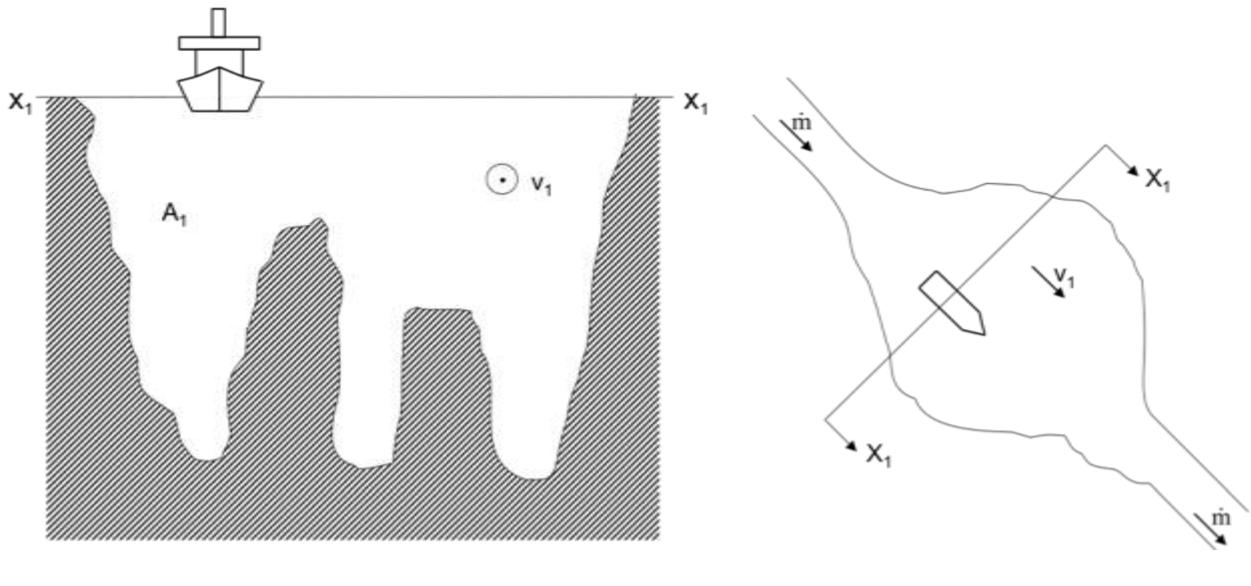

Figure 13. Lake filled with inventory

However, if the inventory levels are reduced, grounds will emerge (P_1 and P_2 in Figure 7), problems will become visible, and the company can either choose to solve problems by using lean-principles or six-sigma tools or to increase their inventory and once again hide the problems. Now assume that the grounds are problems such as trends and increased demand for variety that cannot be removed using lean-principles or six sigma tools, or that might be impossible to hide with inventory. For example, a new, unpredictable, and fast emerging trend may be impossible to hedge for with inventory, so to keep the speed of the flow constant it has to become more agile. In Figure 14 the ship moves along the river, but the inventory levels are lower (A_2) so the flow has to speed up to maintain the same volumes per time unit (V_2). However, with high speed the ship has problems moving around and cannot keep the speed up due to the risks of hitting the ground. Therefore, the ship has to slow down and is slower to respond to customer demand.

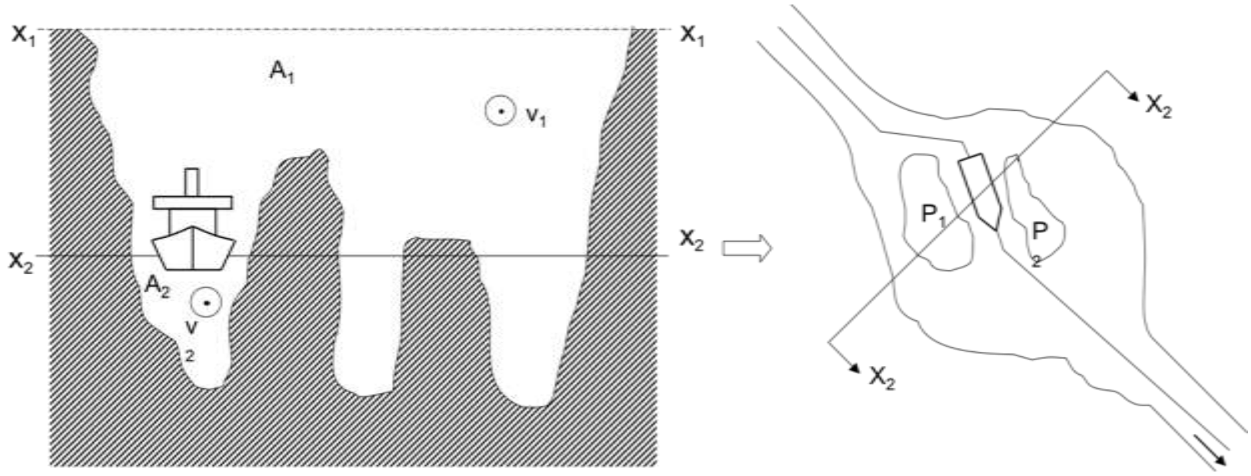

Figure 14. Large ship on a lake with grounds

If the company wants to ship the same amount of products they did before, they have to increase the speed of the logistics system from V_1 to V_2. The idea is that when the inventory levels are lowered the batch sizes decrease as well. Therefore, the ship decreases its size and more ships are added (Figure 15) to keep the volumes up. It creates and a better, more agile logistics system that is able to manoeuvre around the grounds at a high speed. Such a system requires more control than the original one (Figure 8) but it is more agile and will be able to respond better to customer demands. It is also likely more expensive to run with smaller ships since it requires more captains, more seamen and more chefs. Figure 8 illustrates the situation with smaller ships that are better and more agile in manouvering around the obstacles in the market (Lumsden, 2001).

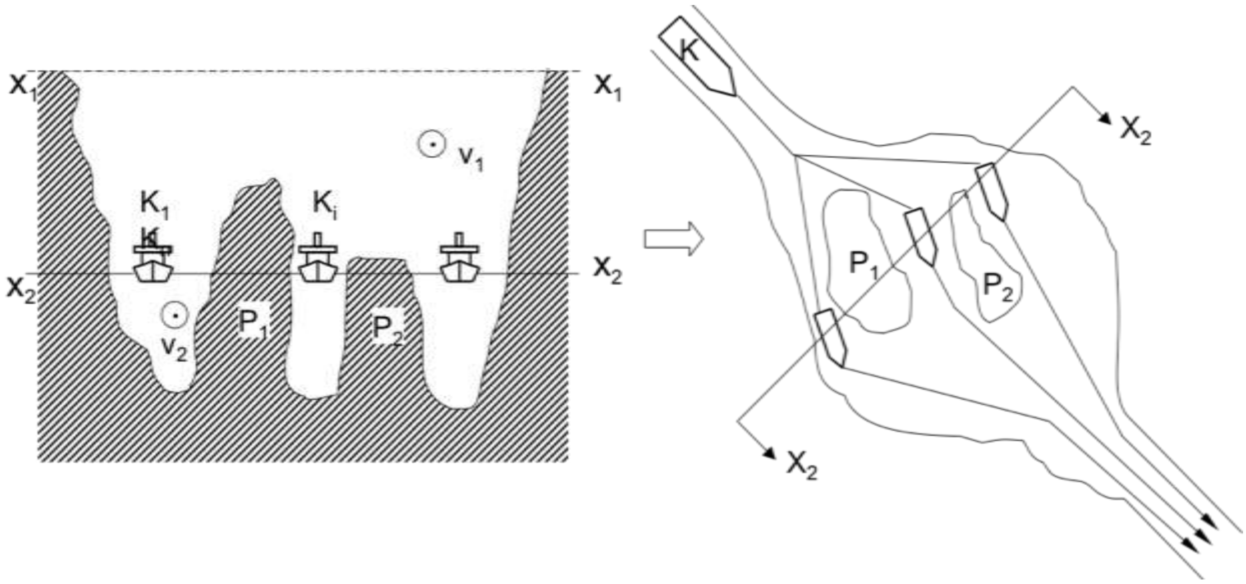

Figure 15. Agile and more manoeuverable ships

The fashion market of today very much resembles this theory where obstacles such as MTV, numerous fashion blogs, and emerging underground trends cannot be avoided. Instead, the companies have to become more agile and responsive to customer demand.

3.8 Mass Customisation

During the past centuries the technical development and demand for higher variety has made it possible and necessary to produce customised garments at near mass production efficiency. Toffler anticipated mass customisation in 1973 and Pine et al. defined it in 1993. Pine et al. (1993) mainly discuss mass customisation in production but not the product configuration process that is vital for success. The lack of discussion around configuration systems as they are known today is because the Internet was not as accessible then as it is today. But with increasing bandwidth, customers can be reached easily now and they can easily access the on-line retailers of mass customised goods (Anderson, 2006).

Mass customisation is a response to consumer demand for higher variety, more authenticity and a better shopping experience (Gilmore & Pine, 2007; Luximon, 2003). An apparel-related example is running shoes: in the beginning of the 1970s there were approximately five different running shoes to choose from; in 1988, that number had increased to 285 (Luximon, 2003), and in 2008 one single on-line retailer offered more than 550 running shoes (Footlocker, 2008). In addition to these 550 running shoes the company offers nearly 2000 other models in all sizes. The Spanish clothing company Zara now develops and presents 11,000 different models each year (Lindahl, 2008). At some point the variety might become unmanageable, not only for the company but also for the customer. Figure 16 illustrates the correlation between variety and customer satisfaction.

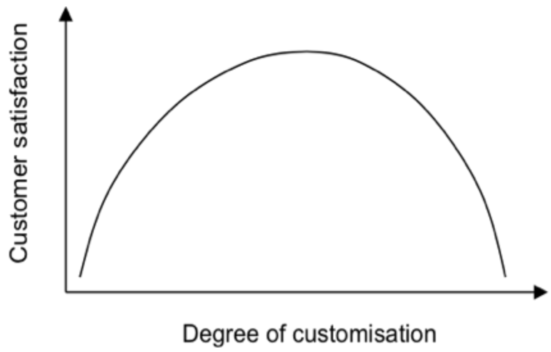

Figure 16. Variety vs. customer satisfaction

In a survey conducted at Columbia University and Stanford University, researchers analyzed how variety affects people's choice. A table with jars of jam was set up and customers were given a one-dollar coupon to buy a jar of jam. Half the time customers were offered six types of jam and half the time they were offered 24 types of jam. When the customers where offered the standard six choices (blueberry, raspberry, strawberry, etc.) 30 percent of the customers made a purchase. When they were offered 24 types, only three percent purchased the jam. However, what was forgotten in the experiment was the presentation of the variety. The jars were randomly placed for the customers to choose from without regard to how customers select products. The result was that variety confuses the customer, but if the variety is presented in an understandable way, it benefits an organisation (Anderson, 2006).

Mass customised products can by definition only be made, designed, engineered, or assembled to order. It is a company's ability to offer customized products that creates a competitive advantage within their segment. According to Amaro et al. (1999), the decision to produce to order is strategic; most companies that offer mass-customized products only offer customized products. One of the reasons for this might be that traditional supply chain management cannot mix customized products and mass products.

Since the market for mass customized goods is marginal, companies offering mass customized goods have to operate in environments with high customer density or where the customers easily can be reached, such as the Internet or in the centre of a very large city. The most renowned initiative of mass customisation is probably NikeID because it allows the customers to add text to the shoes and alter the colours and to some extent the materials of the shoes. There are many other companies offering a wide range of customized goods spanning from muesli to drums (Configurator-Database, 2008).

There are several degrees of customisation. Gilmore and Pine (1997) identified four distinct approaches to mass customisation, represented in Figure 17.

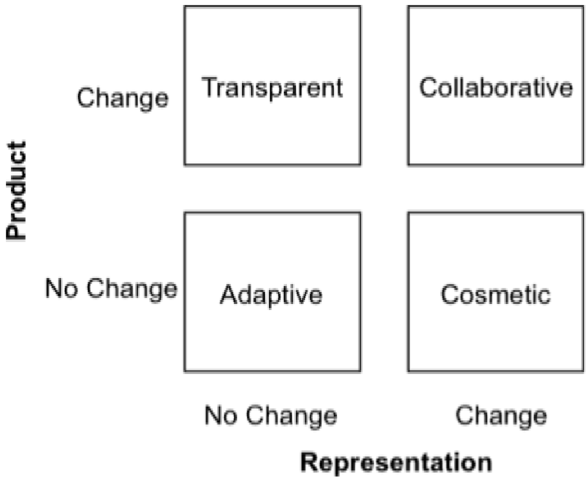

Figure 17. Four faces of mass customisation (Gilmore & Pine, 1997).

- **Collaborative Customisation**
  A high level of interaction with the customer to identify each customer's specific needs and processes and help to fulfil those needs. Collaborative customisation has many similarities to traditional tailor-made garments.

- **Adaptive Customisation**
  One customizable standard is offered and the customers can alter the products themselves. NikeID lets the customer alter the colours of the shoes and the customer can add to the shoe.

- **Cosmetic Customisation**
  One standard product is presented differently to different customers. For example, food with different packaging.

- **Transparent Customisation**
  Individual customisation without explicitly selling the product as "customized." Glasses are an example of transparent customisation.

Mass customisation of garments is often collaborative due to the interaction between the buyer and the seller. In the Knit-On-Demand project, the clothes will be sold in a store so the seller can guide the customer through the purchase.

According to Åhlström and Westbrook (1999), the drawbacks of customisation are: 1) increased material costs; 2) increased manufacturing costs; and 3) fewer on-time deliveries. Pine et al. (1993) writes that one of the reasons Toyota failed when they pursued mass customisation was that they kept the infrastructure of continuous improvement. Managers did not realize the problems were caused by failure to transform the organisation from an organisation of continuous improvement to one that could also handle mass customisation.

Critics of mass customisation mainly ask why it has not been done earlier, since most of the tools are available readily. The reason for that might be a shift in how people are shopping. Gilmore and Pine (2007) write that customers are looking for authenticity and experiences when they shop. One way to add to the shopping experience is to let the customer design or configure his or her garment. It also adds to the authenticity of the purchase since the customer believes the design is unique. And it sometimes is. One Swedish on-line retailer of customized shirts offers more than 43 000 billion different combinations, sizes excluded (Tailor Store AB, 2008). Whether the design is unique or not is in the eye of the beholder. While most customers feel like they are designing their own garment, a few would like even more freedom.

3.9 The Long Tail economy

Chris Anderson, the chief editor of *Wired*, coined the term “Long Tail Economy” in 2006. It first became evident in the music and movie business where people no longer bought records and DVDs in the stores but rather downloaded - legally or illegally - tracks and movies via the Internet. Figure 18 describes the Long Tail Economy with the hits in the head of the curve and the niche products in the tail.

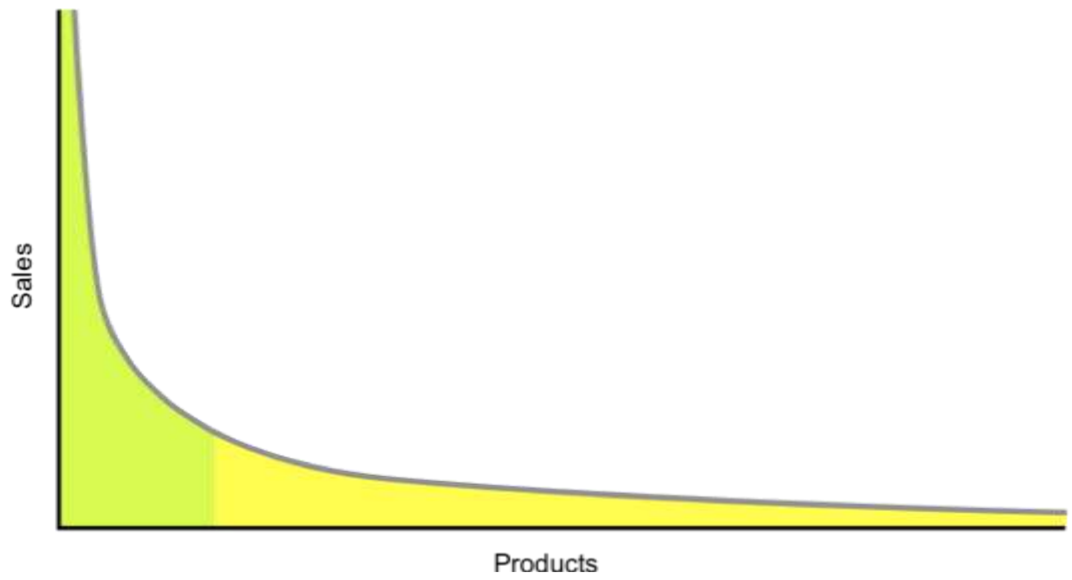

Figure 18. The Long Tail (Anderson, 2006)

The Long Tail was visible first with in music, home electronics, and books, but clothes and apparel had to wait a few years, because customers need a certain degree of “visualization-abilities” when purchasing a garment, and they likes to know whether the garment fits or not (Franke & Piller, 2002). It was difficult in the early days of the Internet for the online retailers to provide sufficient visualization for the customer to decide on a purchase. The bandwidth of connections was simply too narrow to transmit the visualization of the garments, something that the online retailer Boo.com did not consider when designing their online fashion shop in the late 1990s. Slow Internet connection was not the only reason why Boo.com failed miserably, but in a time when the almost everybody used dial-up connections, it surely contributed. Boo.com is regarded number five on the Top Ten of Internet flops (German, 2008).

Almost everybody in business is today aware of the Pareto law or the 80/20 rule developed by the Italian Professor in Economics Vilfredo Pareto (1848-1923), who worked at the University of Lusanne between 1893 and 1911. The Pareto Law claims that the distribution of incomes in a society changes very little over time and the relationship is generally that 80 percent of the income is owned by 20 percent of the population (Pålsson Syll, 2008). The Pareto Law also is used to explain the phenomenon that 20 percent of businesses account for 80 percent of the revenues, which is true in the non-connected physical world, but in the connected world, things look different. The Pareto Law is not as visible as in the physical world because the laws of physics do not apply to the online world.

Music, movies, and even products can be moved between vast locations within the matter of seconds. Books, CDs, DVDs, and other products can be stored digitally and produced on demand.

Every market produces a lot more niche products than hits, but since distribution channels cannot handle all the products, only a small amount of those products will reach the store shelves. The products that do not make it to the shelves generally are considered failures, but in the online world shelf space is very cheap and the store is only a mouse-click away.

There are three forces (Figure 19) that drive demand down the long tail of products. The number one enabler for the Long Tail Economy is the spread of the Internet and rapid increase in bandwidth. Access to the Internet and increasing bandwidth has resulted in the costs of distribution falling dramatically and a local garage band has as much opportunity to reach the market as Sony/BMG (Anderson, 2006). Seventy-one percent of Swedes were connected to the Internet via broadband or ADSL in 2007 and 10 percent via modem or ISDN (Statistics Sweden, 2007), in total 81 percent.

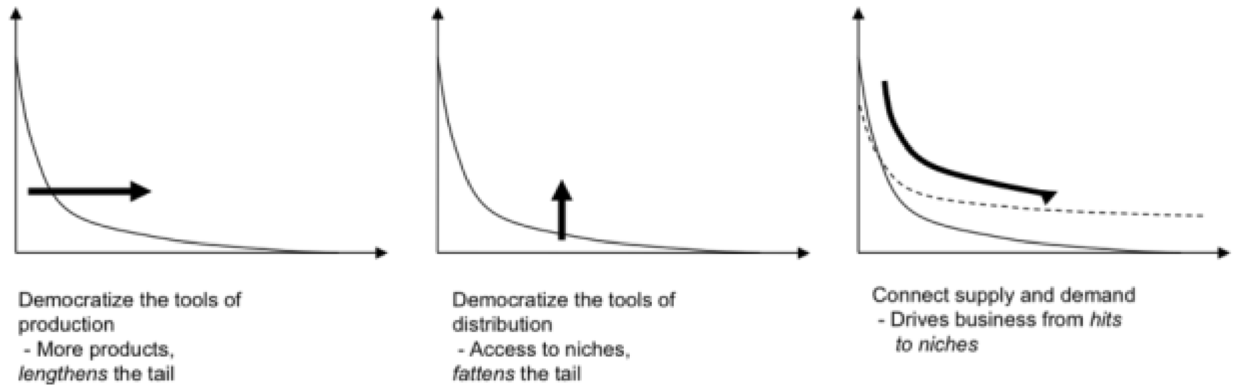

Figure 19. The three forces of the Long Tail (Anderson, 2006)

- The first force is *democratization of the production tools*. Everybody with a PC and an Internet connection can make their own music or movie using cheap or free music or video editing software.
- The second force is the *democratization of distribution*. Distribution in the online world is free. It does not cost anything to up-load music to Myspace.com or Youtube. It has very recently become cheap to have a store for physical products on the Internet as well. Several companies offer Web shops with secure payment services for as little as 100 euros per month.
- The third force is the *connection of supply and demand*. By different filters that drive the demand down, the tail supply and demand is connected.

The democratization of the means of distribution and connection of supply and demand have been most important for the fashion industry. Pre-Internet, a new company would have a hard time to selling their goods to anyone other than the people in the same town or their closest friends, unless they promoted themselves at a fashion fair or went on a selling trip to the fashion stores, which is very expensive. Instead, in the online age, the designer trades a couple of garments for a few lines of text and a picture in a well renowned blog and suddenly he or she reaches several hundred thousand possible customers that are interested in fashion (Anderson, 2006).

3.10 Knitting

The first examples of knitted fabrics date back to the 15th century AD in Roman Egypt. The first record of knitting in Europe is a painting from 1350 from Northern Italy (Spencer, 2001). Since then, knitting has developed to flat- and circular-bed knitting machines via the framework knitting machine. The first industrial-type knitting machine, "The Stocking Frame," was invented by William Lee of Calverton in 1598 (Wikipedia, 2008). Industrial knitting has developed from cut and sew to complete garment, and Figure 20 illustrates how it has evolved. In cut and sew, knitted panels are cut into shape and sewn together to create a garment. It wastes material and is time consuming in cutting and sewing. Fully Fashion and integral knitting are rather similar, but the main difference between them is that integral knitting makes it possible to knit pockets on the garment. The benefits with Fully Fashion and integral knitting are that little material is wasted and there are no cutting processes after knitting. The complete garment technique is based in flat bed knitting, as are the three other knitting techniques.

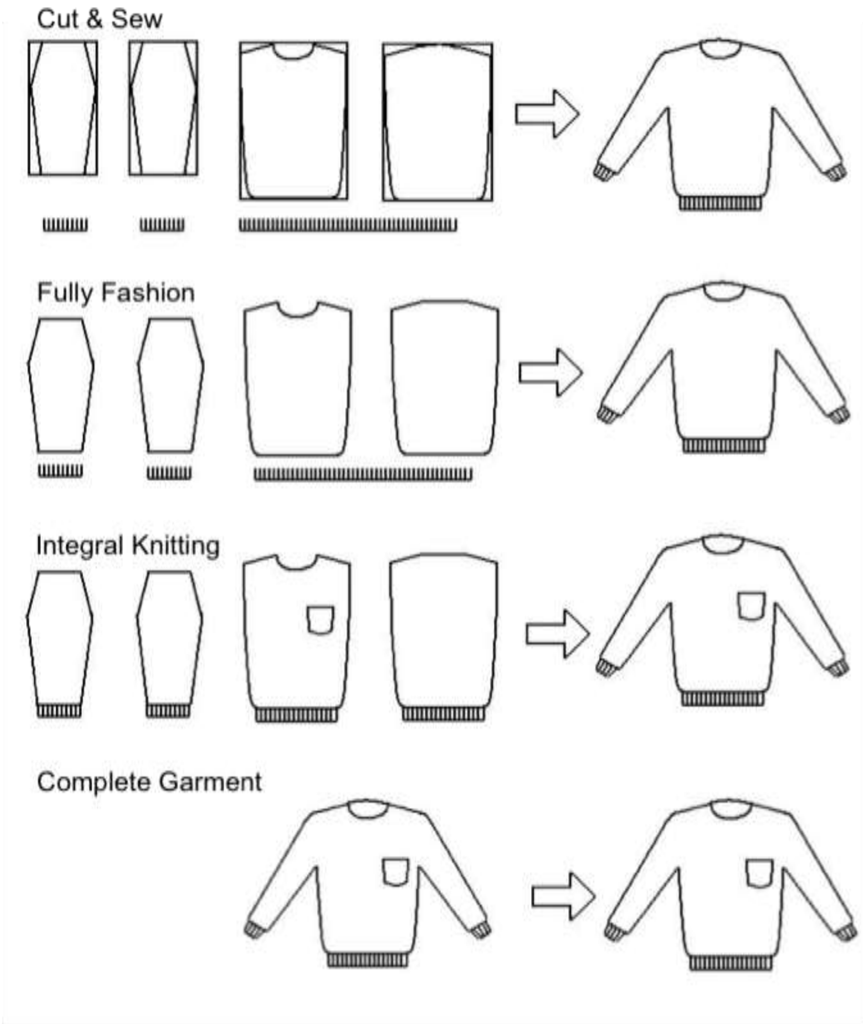

Figure 20. From cut and sew to complete garment

Complete garment knitting technology is a further development of the flatbed knitting technique of knitting the entire garment in one piece, hence the name complete garment. Garments knitted with the complete garment technique have been on the market since 1995 (Hunter, 2004) and it has several benefits compared to older knitting techniques. Figure 1 explains the development of knitting technology from cut and sew to complete garment. There are several benefits of the complete garment technology compared to older techniques.

- Complete Garment technology, integrated with efficient ICT solutions, creates opportunities for instant response to customer demand. When a garment is purchased in the store, a signal is transmitted to the knitting machine which instantly knits another garment with the same specifications and that is later sent to the store.

- Cost savings in materials and handling. The elimination of material cut loss and wasteful post-knitting processes like cutting and sewing are kept to a minimum (Choi & Powell, 2005).

- In a risk management study conducted in the Knit-On-Demand project, it was found that almost all the major risks in the supply chain would decrease significantly if the technology would be used for producing knitwear "on demand" (Andersson, et al., 2007).

- Savings in inventory and shorter lead times. Traditionally, bundle systems are used in apparel manufacturing, often resulting in bundles with semi-finished pieces of garments laying around waiting for the next production step. Since everything is done in one piece there will be no bundles of semi-finished garments and time-to-market and time-to-cash will decrease.

3.11 The most suitable knitting technique

Each of the techniques has its benefits when producing customized garments. Cut and sew, the less advanced knitting technique, offers the most-postponed solution since the shape of the garment is decided after the knitting process. However, cut and sew has the highest waste of material and needs cutting which is time consuming. It also requires an extensive library of templates with different shapes for the different panels. It is not certain whether the benefit from the postponed de-coupling point compensates for the increase in waste compared to other production methods.

Fully Fashion and Integral Knitting offer the possibility of knitting the panels in their final shape. Less material is wasted and no cutting before sewing is needed. The drawback is that everything must be programmed in the knitting machine beforehand. Fully Fashion combined with cut and sew creates the most agile supply chain in terms of offering the customer large variety. Small changes to the garment easily can be made by hand before sewing the garment.

Complete garment technology is the least flexible technique, but on the other hand, the waste of both material and time is held at a minimum and the order fulfilment process is rapid. Complete garment technology offers interesting possibilities for innovative supply chain setups because it is fully automated. A supply chain built around complete garment technology is very agile in terms of responsiveness to changes in quantities. However, it is less flexible than Fully Fashion and cut and sew in terms of offering the customer variety in shapes and measurements.

In terms of production time there are no major differences between the production methods. If only the efficient production time is calculated, production time is approximately three hours no matter what technique is used. The important difference between the techniques is that complete garment offers little possibility to produce waste since the entire garment is produced in one piece.

4. Summary and results from appended papers

This chapter presents the results from the four appended papers. The papers are described in three dimensions: purpose of the paper, an overview of the paper, and the main findings.

Figure 21 illustrates which parts of the textile value chain each paper focuses on in the development of the Knit-on-Demand project.

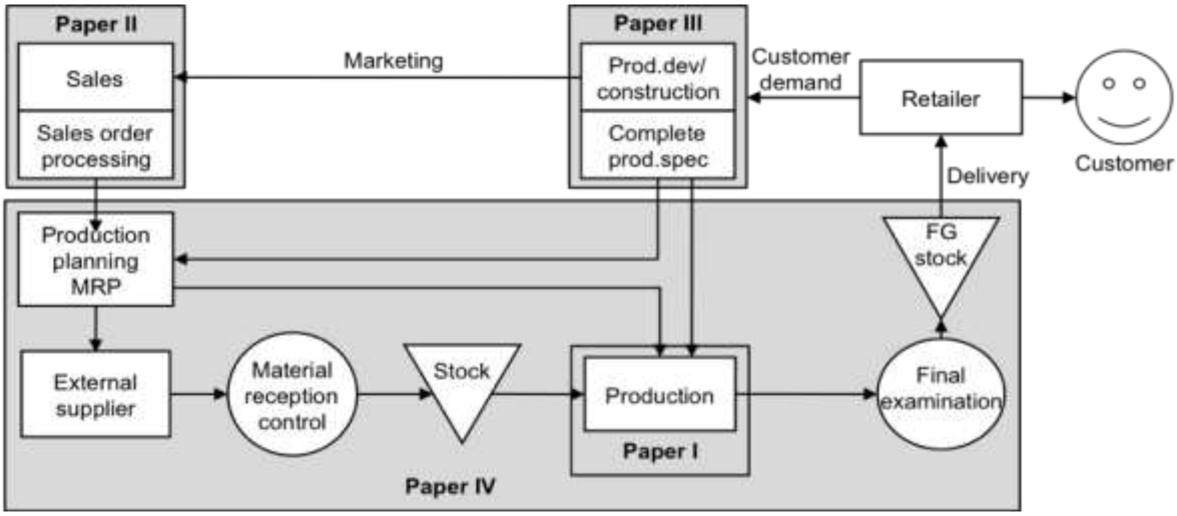

Figure 21. Focus of the appended papers

4.1 How do the papers answer the research questions and do they fulfil the research objectives?

Presented below is the overall research question, the three research questions, and their supporting research objectives. Figure 22 describes how the research question, the research objectives, and the papers are connected.

Overall research question

The aim of the thesis is to contribute to the answer to this question:

What supply chain solution is needed to sell customized knitted garments?

Research questions

The overall research question is rather ambitious, so for the author's convenience it has been broken down into three more specific questions.

1. What logistic and production solutions are needed for the Knit-on-Demand project?
2. How will the garments be designed to fit into the supply chain?
3. What is needed to sell the garments?

Research objectives

In addition to and supporting the research questions are the research objectives. It was necessary to set up research objectives for the development of the different functions of the business concept.

1. Identify, structure, and describe consumer behaviour and needs and build a multiple choice/configuration system in which the customer can design their own garments.

2. Investigate customer requirements from a customized garment and develop a design that is flexible enough to meet the requirements.

3. Analyze production of customized knitted garments, describe what is required from production, and develop a production method that suits both production and the customer.

4. Analyze the requirements of a logistics system that will support the manufacturing of customized knitted garments and set up a solution.

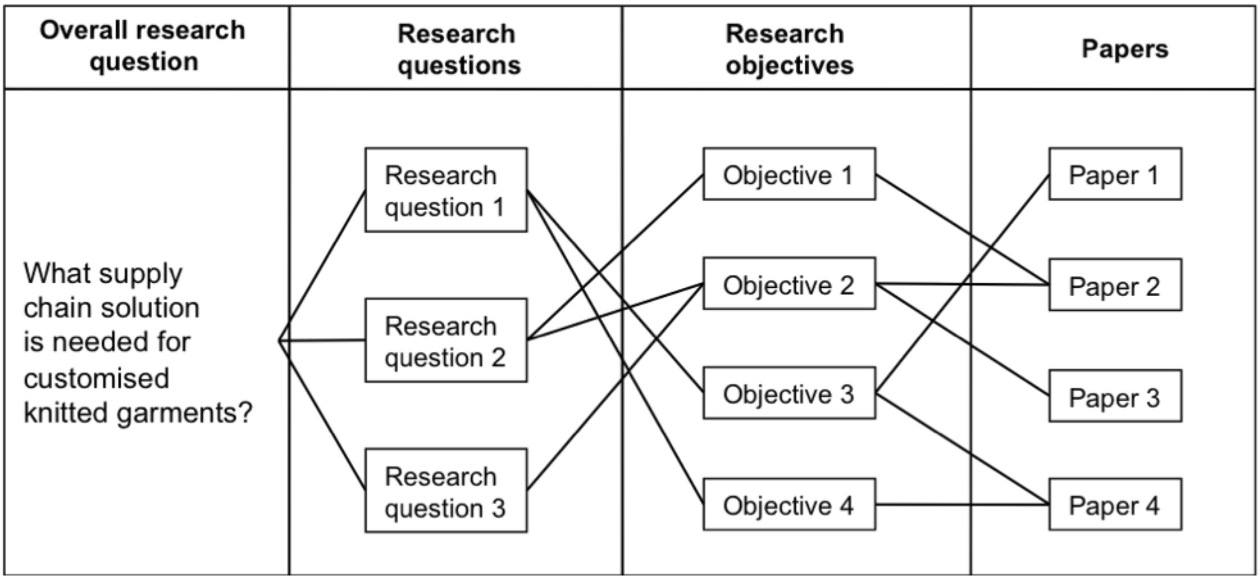

Figure 22. The connection between the research question, the research objectives, and the papers

The connections between the research questions, research objectives, and the papers are spaghetti-like because the thesis treats one project and the papers are relatively interconnected.

4.2 Paper I – Simulations of an agile supply chain

Purpose and overview

Paper I fulfills the third research objective and answers the first research question. It describes the production and sales enviroment using an AutoMod simulation. The purpose of the simulation is to open a small window toward the future through which the demand-driven supply chain can be analysed. The paper presents a simulation of a shop model for customized knitwear, that in combination with complete-garment technology and the concept of mass-customisation creates a demand-driven supply chain for customized knitted garments. Figure 23 illustrates the shop model that is simulated using AutoMod. The customer behaviour data from the model is based in a study at the fashion store where the garments are going to be sold. On average, one customer entered the store every sixth minute during the nine opening hours per day. The data regarding equipment performance is gathered from the equipment suppliers. This paper presents the original idea of the Knit-on-Demand concept.

The model is built on the idea that a customer enters the store and then decides upon a purchase. If the customer decides on a purchase, he or she chooses either to purchase a garment from Designers Place or to design his or her own garment in the Design in Shop part of the store. If the customer chooses to buy a garment from Designers Place, an order is sent to the knitting machine and it knits another one to replenish the one that is sold. If the customer chooses to design a individualized garment, he or she uses a multiple choice system to configure the garment. When the customer is satisfied a message is sent to the knitting machines to produce the garment.

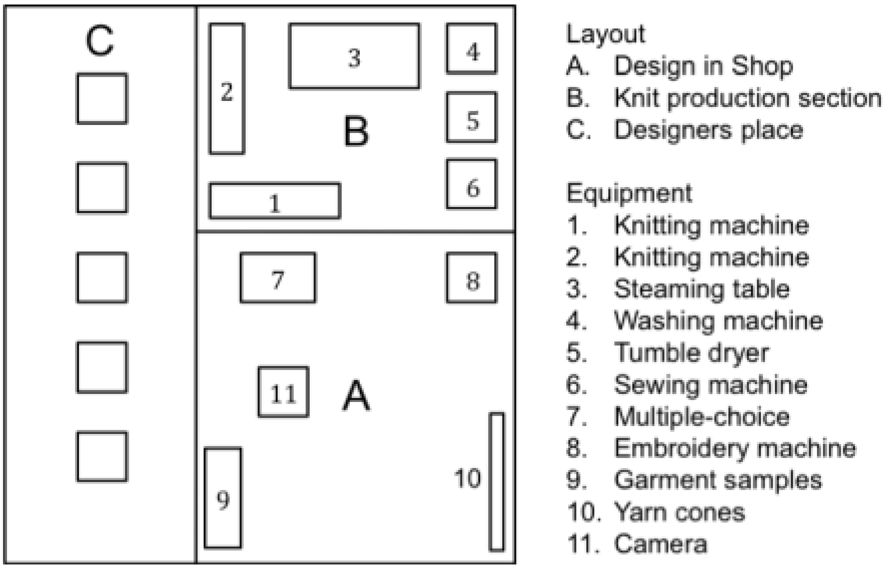

Figure 23. Illustration of the concept store

Main findings

The simulation of the model shows that it is possible to produce and deliver a garment within three hours. Table 1 presents the result of the simulation. Most of the garments' fulfilment time varies between 120 to 300 minutes. Demand fulfilment time for cotton garments is an average of 206 minutes and 191 for woollen garments. The higher fulfilment time for cotton is due to longer finishing process. The most interesting finding is that it is possible to deliver a personally designed garment in approximately three hours.

	Minimum fulfilment time	**Average fulfilment time**	**Maximum fulfilment time**
Cotton	137	206	300
Wool	120	191	301

Table 2. Demand fulfilment time in minutes

4.3 Paper II – A multiple choice system for customized knitted garments

Purpose and overview

The purpose of the paper was to present the development of a multiple choice system for customized knitted garments. The paper answers the third research question and fulfills the first and second research objectives. Multiple choice systems are regarded as the most central functions in a supply chain for mass customizatied products, simply because they are needed for configuration of the products and without them there would be no products sold. Internet-based multiple choice systems are necessary for companies dealing with mass customized products because the customer base in most cities is too small for it to be profitable. On the Internet millions of customers can easily reach the homepage and configure their garments. Multiple choice systems generally consist of three components:

- The *core confiuration tool* presents the choices to the customer and guides the customer through the process of designing the product.
- A *feedback tool* presents the choices the customer has made in the configuration tool. Feedback tools are very often Web-based and consist of an image of the product and the price of the product.
- *Analysis tools* finally translate the customer's choices to a bill of material, production orders, and production schedules.

Figure 24 explains the basic flows of the multiple choice system.

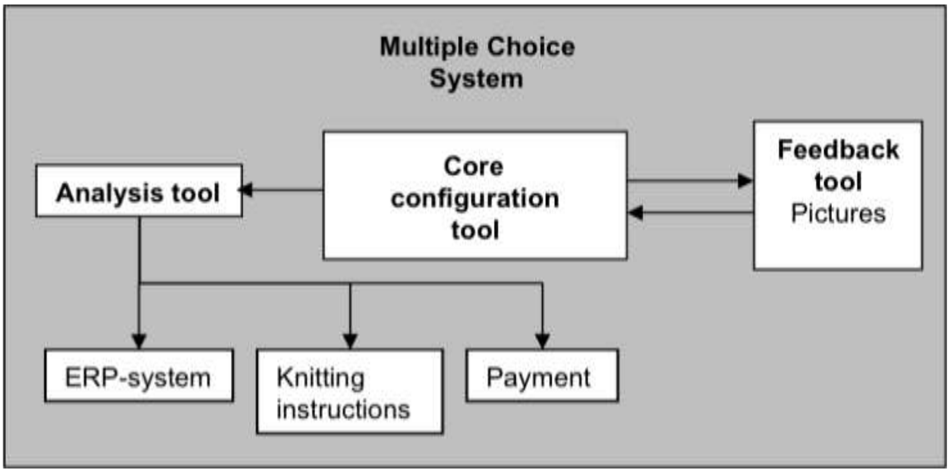

Figure 24. Basic parts and flows of a multiple choice system

Before the development of the multiple choice system, an analysis of the existing systems was conducted. In total, 13 companies were interviewed in the development process. The development of the multiple choice system was done in collaboration with IMDA AB, a supplier of software for the textile industry and InnovationLab, a system developer at the University College of Borås. Developing a multiple choice system that is connected to the knitting machine, the ERP system, and the payment system is a rather ambitious undertaking. It had to be limited to the development of the core configuration system, the feedback tool, and a simple analysis that printed the product specifications on a paper.

Main findings

A multiple choice system is an absolute necessity for the success of the project. Whether the multiple choice system is computer-based or built in the same way as the traditional tailor's system, the purpose is the same: to provide the customer a tool for configuring the garment in an easy and understandable way. If there are many choices they have to be presented in ways that the customer is familiar with or are easy to learn. There are already many systems in use and most of them are constructed in similar ways. Even though the business is not old, a business standard has developed already. It is critical for the success of the system that the image created by the feedback tool is similar to the image that the customer has created in his or her mind. For this reason, customers might need some additional feedback when they are configuring their garment, such as colour swatches and size samples. Early in the development process it also has to be decided if the system should be accesible via the Internet. In this case it was decided the system should be available on the Internet in the future. Internet gives access to niche markets that otherwise could not be reached. In addition to the multiple choice system there should be a tool that can analyse customer behaviour in the system. With such a system it is possible to see what customers browse, what they later buy, and if it is the same. It is also possible to find out on which level in the system most customers drop out of the buying process and improve that part of the system. Another benefit of a multiple choice system is that it limits customers' choices for what is possible to produce.

4.4 Paper III – Design for Mass Customized Knitted Garments

Purpose and overview

The main purpose of the paper was to develop the design for the customized knitted garments that is both appealing to the customer and easy to change without any major changes to the garment. Paper III fulfills the second research objective and answers the second and third research questions. Nine companies were interviewed in the develoment process. The first step toward designing for mass customisation is to define the functional properties of the garment. In this case the functional requirement is a garment on which the customers are able to change color, model, and shape. Step 2 is to choose design parameters, which should be based on their ability to fulfil the functional requirements but still maintain the flexiblility to allow for changes so every customer can have a garment that fits him or her perfectly. The next step is to cluster these parameters into modules from which garments are constructed. Finally, there is the granuality trade-off, or how much variation is managable from the customers' point of view (mass confusion) and from the supply chain's point of view. Figure 25 illustrates an example of the granularity trade-off between Fully Fashion and cut and sew. In Fully Fashion (left) the loops are hung over, therefore creating a slighty thinner look and an more agile feeling, which some customers prefer.

Figure 25. Granularity trade-off between cut and sew and Fully Fashion

Main findings

The design for mass customized garments differs from the design for regular garments because it is not only design for production. It is a design that is going to be changed by a customer that perhaps is not familiar with the design process. Since this is the first time a project of this kind has been undertaken and the notion of mass customisation is quite new, it is difficult to understand customer buying behaviour for these kind of products. The uncertainty makes it difficult to choose the design parameters and functional requirements for the garments. For example, does the customer require Fully Fashion arms on their garment or are they satisfied with cut and sew? Generally customers do not seem to bother. Customers also have different ideas of what designing means. Some customers seem to think they are designing their own garment even if they are only allowed to change a bit of the garment, while others want to change everything. The most rational way to produce is to set boundaries to what is possible to produce at a certain known cost and let the customer choose within a range of pre-engineered modules that allows for changes in size but not in shape. In that way, the system can ensure that the customer does not choose to buy something that cannot be produced with desired qualities or within the acceptable lead-time. This is the major challenge in this part of the project: to ensure quality and lead-time and still keep the design flexible.

4.5 Paper IV – Logistics for Mass Customized Knitted Garments

Purpose and overview

The main purpose of the project is to create a demand chain for customized knitted products. For that purpose this paper has analysed the environment in which the demand chain has to operate and the requirements on the demand chain. Emperical data was gathered from seven interviews and from workshops with the project partners. This paper fulfills the third and fourth research objectives and answers the first research question. The ability to respond rapidly to customer demand is one of the main targets of the project and for that, a quick and agile demand chain is needed. It is usually said that eight days is the limit for delivery. One of the aims of the project is to develop an agile demand-driven supply chain. Agility is defined as “a company’s ability to operate in unpredictable and volatile environments” (SOURCE?). Whether the demand chain’s environment is particularly volatile or unpredictable is still to be determined. However, the industry wide sell-through factor of only 60 percent proves that the environment is somewhat unpredictable. The existing supply chain is rather traditional in its set up and is very unsuitable at the moment for producing customized garments, so some changes have to be made. Figure 26 presents the set up of the original supply chain and the set up of the demand-driven supply chain.

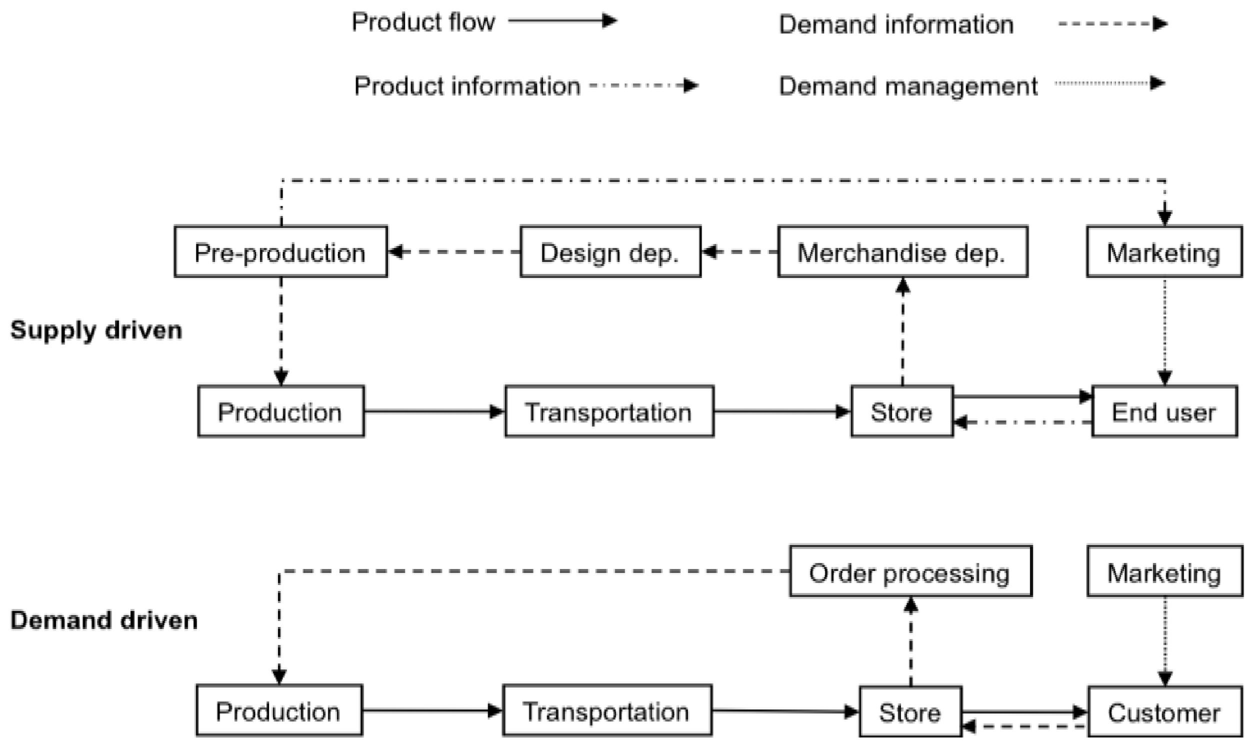

Figure 26. Difference between a traditional supply chain and a demand-driven supply chain

Main findings

A value flow analysis conducted in the case study at Ivanhoe shows that the lead-time from design to delivery is approximately nine months and from design to cash is as much as 11 months. A major proportion of that lead-time is spent in warehouses and factories waiting for something to happen. For example, two months are spent just waiting for goods to come into the warehouse and to be merged before sending it to the customer. Therefore, the supply chain on which the solution for customized garments shall be added is very traditional. That might become a problem when production starts. Yet another issue that might become a problem is that since producing knitwear on demand is very new, not many suppliers of yarns and accessories have set up their supply chains to cope with that new type of business environment with small orders and transparent supply chains. There are a few suppliers of yarns and accessories that do offer vendor-managed inventory solutions and are able to ship small quantities directly from stock. The downside is that the prices are slightly higher and everything might not be available from stock, but as mentioned earlier, it is not the logistics costs that are the problem, but rather the costs of obsolete inventory and stock-outs that are the major problem. Perhaps an increase in logistics cost could result in a decrease in lost sales and an increased sell-through factor. That higher investment is justified by the decrease in inventory cost, risk of obsolete material, and the increase in ability to respond quickly. The major obstacle in the process of shifting from an 11-month, non-responsive supply chain that sells what it is able to produce to a four-hour demand chain that produces what it can sell is to change the mind-set of the involved parties.

4.6 Summary of main findings

The technology to produce customized garments has been available for many years, but it was not until just recently that there has been a demand for customized knitted garments. Theoretically, the shortest response time for knitwear is three hours, but it requires that the knitting machine is located at the same place as the customer. With the production facilities located in Gällstad and the store located in Stockholm, an order fulfilment time of one week is more manageable, and this is also a lead-time with which many customers are satisfied. When it comes to configuring the garment, it is not possible to offer the customer a completely free design of the final product. In order to guarantee quality and lead-time, the modules that build the garment have to be pre-engineered. The multiple choice system guides the customer toward the final purchase decision and helps the customer visualize the final product. It is very important that the image the customer creates in his or her mind resembles the end product. The multiple choice system also limits the customer's wishes for what is possible to produce within a given time frame and at a certain quality. It is rather easy to handle logistically, because in the beginning the flows will be narrow enough to fit the existing supply chain. The logistics costs per garment will be higher than in a mass production supply chain due to the one-piece flow, but the lower risks and increased responsiveness of the supply chain will compensate for that. One of the major issues with producing on-demand is that very few suppliers have channels and systems for demand-driven manufacturing. This means that even if the manufacturing site has the capability to produce on demand, it might be hard to find support upstream. However, the benefit from the reduced risk and the ability to respond faster and more accurately to customer demand makes the concept work well.

Research questions	Connection	Papers
1. What logistic and Production solutions are needed for mass customised knitwear?		1. The simulation shows that it is possible to produce and deliver a garment within three hours if the knitting machine is located at the ratailer.
		2. When selling customized garments it is necesarry with a configuration tool to help the customer with the design. The customer should do most of the design them selves.
2. How will the garments be designed to fit into the supply chain?		3. The garments are module-based with high commonality in order to ensure quality and lead-times. Customers are happy with a limited set of changes.
2. What is needed to sell the garments?		4. In the beginning the garment will fit in the existing flows and no specific solution is needed. The supply chain costs are higher for customised knitwear but the customer is willing to pay the extra price.

Table 3, Results connected to the research question

5. Analysis and discussion

This chapter analyses and discusses the results from the appended papers and answers the research questions. Chapter 5.1 answers the third research question, Chapter 5.2.1, and 5.2.2 answer the first and second research questions and Chapter 5.2.3 partly answers the third research question.

5.1 Customer focus

The beginning and end of every process is the customer. The manufacturing processes start on cue from the customer and end with the delivery of a finished product. It is difficult to know exactly what the customer wants and expects from a new business concept like Knit-on-Demand. Therefore, it is relieving that the customer designs or configures the garments themselves so the company will not have to bother about having the right garment on the shelf. They do have to bother with having the right modules available for the customer and to fulfil the orders within a given timeframe. Eight days is said by many to be the longest preferred waiting time, but as long as the customer knows when it is going to be delivered, up to five weeks is acceptable. The eight-day delivery window is interesting because each interviewee has answered the same, i.e., eight days. The major challenge has been to analyse what the customer wants (order qualifiers), what the customer requires (order winners), and then matching it with what the designer requires, which is generally more than what the customer requires. Figure 27 illustrates the thought about what should be offered to the customer. The largest circle (A) constitutes everything that can possibly be produced using a knitting machine, but this would be too expensive to produce if offered to the customer. Circle B is what would satisfy most customers and is possible to produce at a certain quality. It is this circle that is the target and where we satisfy most of the customers. If the customer is only offered the options in Circle C, they will not be satisfied. One way of limiting customer requirements is to present the choices to them in a multiple-choice system. Everything that is presented to the customer in the multiple-choice system is pre-engineered and the quality and lead-times are guaranteed.

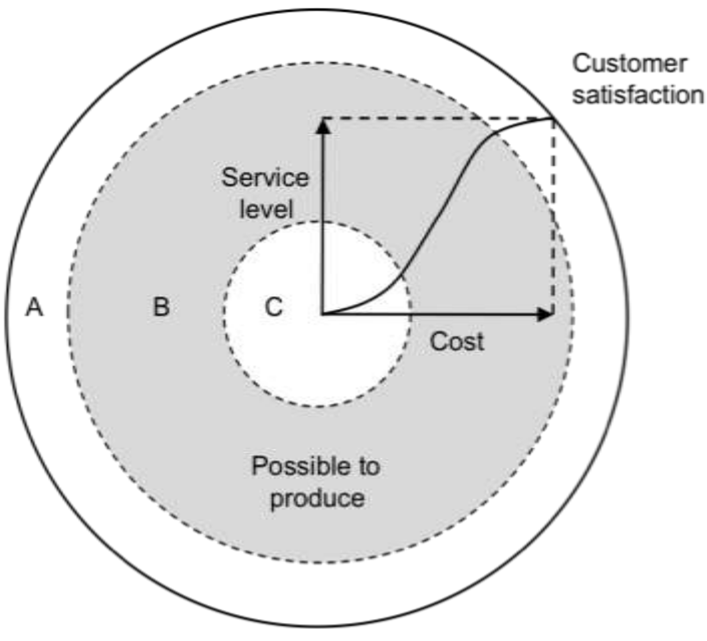

Figure 27. What is possible to produce compared to the cost of service level

5.2 Demand-driven supply chain management

Within demand-driven supply chain management, there are three sub categories that we have focused on in this project—demand-driven logistics, demand-driven manufacturing, and demand-driven design.

5.2.1 Demand-driven logistics

The flows in a demand-driven supply chain do not differ considerably from traditional logistics—the raw material is shipped from the same supplier with the same truck and delivered to the same factory. The major difference is what triggers the order fulfilment activities. In a demand-driven supply chain the trigger is a customer order instead of an order from a production plan. Since the flows in this system will be small in the beginning, approximately five garments per week, they will fit as well into the already existing logistics systems and goods flows as any other product. The flows of customized products are characteristically one-piece flows; therefore, the logistics costs are higher than in a traditional supply chain where products are shipped in large batches. Even though the logistics costs are higher the costs of markdown and lost sales will be lower since the system can answer true demand more effectively. Since it is a new concept it has been rather hard to find suppliers that can offer solutions that fit the project. There is only one known supplier of yarns that keeps all the colours of the season in stock. Demand-driven supply chains require a level of traceability of the goods, both for the producing company and for the customer because the garments are unique and a loss of a garment would require the whole process to start again. In a traditional supply chain, a new garment would be taken off the shelf and sent to the customer. The customers also might want to know the garment's whereabouts through the order fulfilment process.

5.2.2 Demand-driven manufacturing

Manufacturing customized garments requires more from the production processes than traditional garments. Due to the one-piece flow, there is no room for mistakes of any kind. It is simply not affordable to produce an extra garment if the first one is wrong. One danger with producing customized garments in a factory for mass production is that the customized products might disturb the production of mass products and cause delays. Therefore demand-driven manufacturing requires more from the production system in terms of information and material handling. There is little need to invest in advanced ICT tools to make the production work, but the current material and information flows are not efficient enough to handle any large-scale production quantities. From the simulation (Paper I) it can be found that it is possible to sell, produce, and deliver in approximately three hours. On average, it takes 15 minutes longer between cotton and wool because cotton requires a longer finishing process. The three hours it takes to produce a garment is not very long considering that the customers are willing to wait 7-8 days for delivery (Paper IV).

5.2.3 Demand-driven design

The design of customized garments differs from the design of regular garments since it is divided into two design processes—the company's design process and the customer's design process. First the company has to decide what type of garments to sell, the basic design of the garment, and the design parameters, i.e., what parts of the garment the customer is allowed to configure themselves and to what extent. When the design parameters are set, the customer can be allowed to do his or her part of the design and configure the garment to fit his or her needs. The designer of the garment has to take an engineer's approach when designing the garment, since it has to flexible enough in its construction to allow for changes. The design has to work in the logistics system and the production system and also be sellable. To find the balance between these three "musts" is difficult.

There is a difference between designing a garment and configuring a garment in the customer design process. When a garment is designed the person who designs is free and can cut and sew however he or she likes. Such a free process is hard to turn into a production process, since it is not known how much time each step takes beforehand and how much fabric is used. When a customer designs a mass-customized garment it is more of a configuring process where he or she chooses between a set of pre-engineered modules that can be fitted together easily and perhaps be changed within fixed boundaries such as length and width.

Different knitting machine types allow for different customisation options. Cut and sew is the most flexible type of production since everything is cut by hand. However, it does create waste. Fully Fashion creates less waste but is less flexible since the shape of the panels is knitted directly in the knitting machine. Fully Fashion also looks better and has a more agile feeling. The best way is to combine the two knitting techniques, using Fully Fashion for the body and the arms and cut and sew for the neck. In this way, a standard body can be fitted with any kind of neck. Figure 28 illustrates how it will be produced.

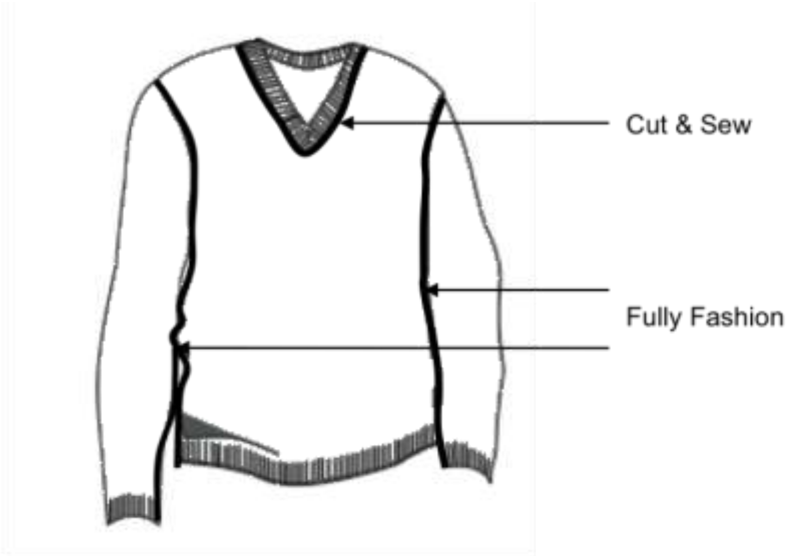

Figure 28. cut and sew combined with Fully Fashion

5.2.4 Effects of demand-driven supply chain management

One of the major problems with today’s fashion manufacturing is the overproduction by approximately 50 percent; more than 30 percent of the costs in the supply chain can be allocated to overproduction. Fashion companies overproduce to hedge for uncertainties in the market and it is cheaper to keep one extra on stock than to miss one customer. Approximately 40 percent of the costs in the supply chain are due to low service level, i.e., not having the right products in stock. The sell-through factor, service level, and lost sales can be affected when producing on-demand. Figure 29 describes how the logistics costs in a supply chain are affected. If the products were produced on-demand, nothing that is not sold is produced so the costs of markdowns would disappear. Also, when the customers are allowed to configure the garment the service level should increase, lowering the costs of lost sales (X). Moreover, if the garments were sold on the Internet there would be no store and since the store is responsible for approximately 70 percent of the handling costs in the supply chain these could be decreased (Y) as well. It is a rather bold statement that the costs of markdowns would disappear, as is claiming that the handling costs would be decreased 70 percent. However, it is likely that on-demand methods will affect the supply chain.

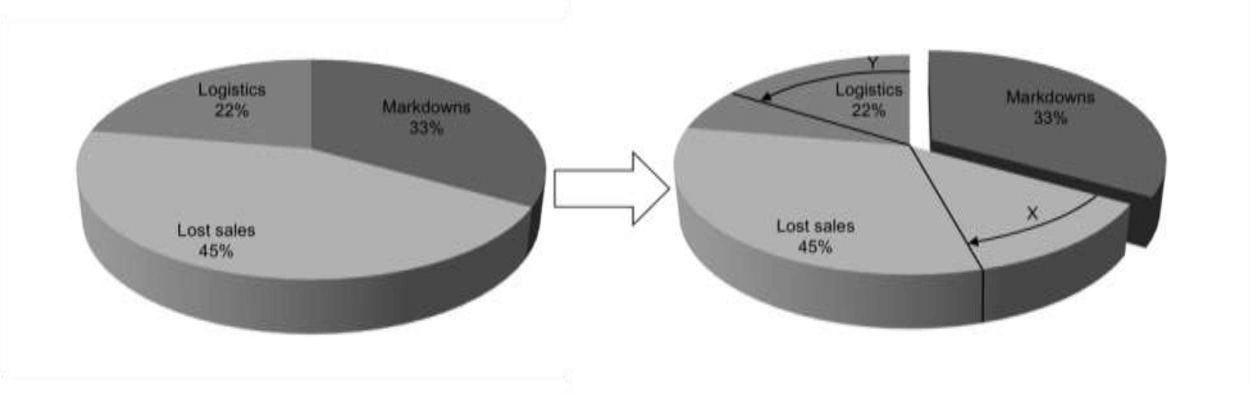

Figure 29. Effects of on-demand business on supply chain costs

In a traditional supply chain most of the design work is done a few times every year, while in the fast fashion supply chains it is continuous. In this demand-driven supply chain the lion's share of the work is put into building the system such as engineering the design parameters, building the multiple choice system, and finding the best logistics solution.

6. Conclusion

Seen from the customer's perspective, he or she will be able to buy a garment that fits better to his or her preferences whether it is a different fit, model, or colour. For this the customer is willing to spend extra money. It is important that the variety of the garments are presented to customers in an easy and understandable way, otherwise customers might be confused and walk out of the store empty handed. The order winner is the ability for the customer to design an unique garment.

Seen from a company's point of view, the problems in the supply chain are not production costs or logistics costs. The problems are the clothes that are marked down at the end of the selling season since they have accumulated costs through their shelf life and the customers that do not purchase anything because the product they want is not available in the store. And these costs are not only in terms of floor space—it is also the costs of handling, folding, and carrying the clothes back and forth to the dressing room. These costs can be reduced if garments are produced on-demand and if the customer is given the opportunity to customize his or her garment. The project can affect the key performance indicators, i.e., sell-through factor, lost sales factor, and the service level. The sell-through factor will increase, the service level will increase and lost sales will decrease because the supply chain will be better in answering true customer demand. In the beginning it is not necessary with a specific logistic or production solution for the customised garments, the volumes are low enough to fit into the existing supply chain. It will however be more costly to produce garments on demand but if the commonality is held to a maximum it is possible to keep the production and logistic costs down.

Seen from a larger perspective, it is not the garments we purchase that are the problem, but instead it is the garments we do not purchase that are the problem because they are wasted. If only the garments that people wanted to pay full price for were produced, there would be less wasted farm land that could be used for growing food and fuel. There would also be less fertilisers, pesticides, and transports which could slow the pollution of the earth.

7. Further research

When this thesis is presented production and sales of the garments have just begun. The first task is to make sure the supply chain is functioning well and serves its purpose. Once the supply chain is up and running the next step in the research process is to analyse the concept's effects on the supply chain. It is concluded in the thesis that on-demand business might help to decrease logistics costs and lost sales and increase the sell-through factor and service level. Whether his is true or not is still to investigate. One further challenge is to develop the design options for the customer. In the beginning the customer will be quite limited in his or her choices but it is interesting to analyse how complex a configuration of a garment can be and still be produced at a reasonable price.

On-demand business also has other opportunities and a number of hypotheses were stated in the project proposal that were sent to the Knowledge Foundation. It is believed that on-demand business opens up for. In addition to the hypotheses a number of research question can be stated:

- **Improved external and internal integration**
  Mass customised garments need more attention in each step of the fulfilment process and each garment is unique. Therefore high integration between the customer, retailer, producer and supplier seams to be necessary for the success of businesses within mass customisation. There are several methods to increase both internal and external integration and many solutions include different ICT-tools. There are already different systems available both at the retailer and at the producer that allow for increased integration from POS to supplier, the next challenge is to connect at least a few of these systems. Vertical integration and production close to the POS is often considered a success factor. The garments are produced locally in Gällstad at a higher cost a then a regular garment, it is good for the enviroment and good for the development of the textile industry.
  Research questions:

  > *Would it be meaningful to develop a structured information system, e.g., by means of XML mark-up and Web communication?*
  >
  > *Is the total cost of a local complete-garment facility feasible, and under what conditions?*
  >
  > *How can transparency of crucial costs, such as logistics costs, downtime costs, and risk costs be ensured?*

- **Reduction of inventories and lead times**
  One of the targets when the project started was to come up with a solution that offer customers a ready made garment in three hours. However the technology required was considered too expensive. Some of the results in the project however do however suggest that it is possible to produce and deliver within three hours using existing machinery. If a Lean approach could be used the lead-times could be reduced and a more responsive supply chain is created.
  Research question:

  > *Are the flows of information associated with the knitting technology and the supporting logistics system adequate and can they be simplified?*

- **Increased precision in the control of flows**
  Mass customised garments require high precision in the control of the flows otherwise

garments and orders might be mixed up as volumes grow.
Research question:

Is there a potential for misunderstanding essential information?

- **Realizing the importance of time and quality**
  The order winner is opportunity for the customer to design an unique garment, thus each garment is only produced in one sample. It becomes very clear for the producer if there is something wrong with fit, colour or function of the garment. Traditionally the producer is seldomly notified if the customer does not like the colour or if the size is incorrect but in on-demand business the producer will have the notification immediately.
  Research question:

  Will fashion enterprises adopt (and by what reasons) the quality concepts needed to support logistics development (such as Lean Manufacturing, TQM, Six Sigma)?

8. References

Allwood, M. J., Ellebäck-Laursen, S., Maldivo de Rodrígues, C. & Bocken, N. (2006). *Well Dressed?* University of Cambridge, Institute for Manufacturing, Cambridge, UK.

Andersson, R., Ottosson, T. & Larsson, J. (2007). A Case Study: A quality approach to managing supply chain risks, *QMOD*, Helsingborg 19 June (also paper in conference proceedings).

Anderson, C. (2006). *The Long Tail Economy, Why the Future of Business is Selling Less of More,* Hyperion Books, New York.

Amaro, G., Hendry, L. & Kingsman, B. (1999). Competitive advantage, customization and a new taxomony for non make-to-stock companies, *International Journal of Operations & Production Managament*, *19* (4). 349-371.

Banks, J., Carson, J. S., Nelson, B. L. & Nicol, D. (2004) *Discrete event simulation.* Prentice-Hall, New Jersey, USA.

Bruce, M. & Daly, L. (2006). Buyer behaviour for fast fashion, *Journal of Fashion Marketing and Management*, *10* (3), 329-344.

Cerruti, C. & Harrison, A. (2006). Agile supply chain management in the fashion business, *Supply Chain Practice 8* (1).

Choi, W. & Powell, N.B. (2005). Three Dimensional Seamless Garment Knitting on V-Bed Flat Knitting Machines, *Journal of Textile and Apparel Technology and Management, 4* (3), 1-33.

Christopher, M. C. (2000). The Agile Supply Chain, Competing in Volatile Markets, *International Marketing Management,* 29 pp. 37-44.

Christopher, M. C., Lowson, R. & Peck, H. (2004). Creating Agile Supply Chains in the Fashion Industry, *International Journal of Retail and Distribution Management,31* (8), 367-376.

Christopher, M. & Towill, D. (2001). An Integrated Model for the Design of Agile Supply Chains. *International Journal of Physical Distribution & Logistics Management,31* (4), 235-246.

Configurator Database. (2008) *Explore the World of Configurators!*, Available <http://www.configurator-database.com> 2008-11-13.

Ellinger, A.E. (2000). Improving Marketing/Logistics Cross Functional Collaboration on the Supply Chain, *Industrial Marketing Management* 29, pp. 85-96.

Fisher, M. L. (2007). What is the right supply-chain for your product? *Harvard Business Review*, March-April 1997.

Footlocker.com. (2008). *Footlocker.com.* (Electronic resource), Available <http://www.footlocker.com> 2008-04-15.

Franke, N. & Piller, F. (2002). Configuration Toolkit for Mass Customization, Lehrstuhls für Allgemeine und Industrielle Betriebswirtchaftlehre der Technische Universität München.

Frohlich T. M. & Westbrook, R. (2001). Arcs of integration: an international study of supply chain strategies, *Journal of Operations Management*, 19, pp.185-200.

German, K. (2008). Top 10 dot-com Flops, *Cnet.com.* Available on-line http://www.cnet.com/4520-11136_1-6278387-1.html, 2008-04-30.

Ghemawat, P. (2003). *Zara: Fast Fashion*, Video. Harvard Business Publishing, Boston.

Ghemawat, P. & Nueno, J. L. (2003). *Zara: Fast Fashion*, Harvard Business School Publishing, April 1, 2003, Boston.

Gilmore, J. H. & Pine J. B. (1997). The Four Faces of Mass Customization, *Harvard Business Review,* January-February 1997.

Gilmore, J. H. & Pine, J. B. (2007). *Authenticity: What Consumers Really Want,* Harvard Business School Publishing, Boston, USA.

Habit. (2008). Köpfest hos kedjorna, *Habit Marknadsnummer 2008,* Mentor Communications AB, Stockholm Sweden. In Swedish.

Habit. (2007). Modemarknaden, *Habit Modemarknaden 2006,* Mentor Comminications AB, Stockholm Sweden. In Swedish.

Harrison, A. & van Hoek, R. (2008). *Logistics Management and Strategy, Competing through the Supply Chain.* 3rd ed. Pearson Education Limited, Essex, England.

Hunter, B. (2004). Complete Garments, Evolution or Revolution? *Knitting International 111* (1321), 20-22.

Jüttner, U., Christopher, M. & Baker, S. (2007). Demand chain management – integrating marketing and supply chain management, *Industrial Marketing Management*, 36, 377-392.

Kleiby, P (2007) Lecture at "*Detaljhandelslogistikens dag 2007*" 26th of Nov 2007.

Lindahl, B. (2008). Kortlivat, *SvD Näringsliv,* 39, pp 5-11. Okt 2008. In Swedish.

Liker, J. K. (2004). *The Toyota Way*, McGraw-Hill, New York.

Luximon, A., Goonetilleke, R. & Tsui, K. (2003). Footwear Fit Configuration, *The Customer Centric Enterprise,* Springer-Verlag Berlin, Heidelberg.

Mattila, H. (2004). *Fashion Logistics and Brand Management,* Tampere University of Technology, Fibre and Material Science.

Mattsson, S-A. & Jonsson, P. (2003). *Produktionslogistik*, Studentlitteratur, Lund, Sweden. In Swedish.

Mason-Jones, R. & Towill, D. R. (1999). Total cycle time compression and the agile supply chain, *International Journal of Production Economics,* 62, pp. 61-73.

Mason-Jones, R., Naylor, B. & Towill R.D. (2000). Lean or Agile? Matching your supply chain to the marketplace, *International Journal of Production Research,38* (17), 4061-4070.

Pine, J. B. (1993). *Mass Customization, the New Frontier in Business Competition*, Harvard Business School Press.

Pålsson Syll, L. (2008). Vilfredo Pareto, *The Swedish National Encyclopedia.* Retrieved on-line http://www.ne.se, 2008-04-02.

Shima Seiki. (2008). *Factory Boutique*, Electronic resource http://www.shimaseiki.co.jp.
DATE?

Spencer, D. J. (2001). *Knitting Technology, a comprehensive handbook and practical guide,* Woodhead Publishing, Cambridge England.

Statistics Sweden. (2007). Use of Computers and the Internet by Private Persons in 2007, *Statistics Sweden,* http://www.scb.se, Data accessed 2008-01-10.

Tailor Store AB. (2008). *Tailor made shirts online,* Available http://www.tailorstore.com, 2008-06-29.

Wikipedia. (2008). *Knitting*, Available on http://en.wikipedia.org/wiki/knitting, 2009-01-28.

Yin, R. K. (2003) *Application of case study research,* Sage Publications, London

Åhlström, P. & Westbrook, R. (1999). Implications of mass customization for operations management, *International Journal of Operations and Productions Management 19* (3), 262-274.