Knit on Demand - mass customisation of knitted fashion products

Jonas larsson is a PhD candidate in fashion logistics with speciality in supply and demand chain management for mass customised knitwear.

Pia Mouwitz is a fashion designer, lecturer and deputy education coordinator of the fashion programmes at the Swedish School of Textiles. Educated in design and textile technology; practical experience of design and product development within the apparel industry. Designer in the research project Knit on demand.

Joel Peterson is a lecturer in knitting technology and fashion logistics and a PhD candidate at the Swedish School of Textiles at the University of Borås. He holds a BSc and a MSc in textile technology. His research interests are in knitting technology, mass customisation, smart textiles and fashion logistics.

Jonas Larsson
jonas.kj.larsson@hb.se

Pia Mouwitz
pia.mouwitz@hb.se

Joel Peterson
joel.peterson@hb.se

University of Borås
The Swedish School of Textiles, Borås, Sweden

Abstract

Today's fashion market is characterised by short life cycles, low predictability and high impulse purchasing. Many fashion companies are responding to this by constantly introducing new collections. Zara, which is considered to be the leader of fast fashion are introducing as many as 211 new models per week. One of the drawbacks of Zara's and others´ methods is the resulting over-production; many garments have to be sold to reduced price or are thrown away. An average of one third of the collections is considered waste. It costs money for the fashion companies; it reduces the sell-through factor and wastes natural resources. Knit on Demand is a research project at the Swedish School of Textiles that aims to reduce the waste and increase the sell-through factor and service level. A local producer of knitwear and a retailer of tailored fashion in Stockholm also participate in the project. The purpose of the project is to test new methods of supply chain management and to analyse whether mass customisation is applicable on knitwear. There are several benefits with mass customised garments: the customer receives a garment that is better suited to his or her needs, the producer does not have to make garments on forecast, and the environment and natural resources are spared because only what is bought by the end consumer is produced and shipped.

Key Words: mass customisation, knitting technology, fashion design and fashion logistics

1. Introduction

The fashion market is characterised by short life cycles, low predictability and high impulse purchasing Christopher et.al, 2004, Cerruti & Harrison, 2006, Ghemawat & Nueno, 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 challenge, if not impossible to sell all these garments at full price, and often companies are overstocked and left with piles of unsold products at the end of the season. These garments have to be marked down and sold to reduced price or are liquidated. The sell-through factor, which indicates how many of the total SKUs that are sold at full price, is in fashion about 65 percent (Mattila, 2004). One of the reasons is the long lead-time, which in turn is caused by sourcing and production in countries far away. It is not unusual that lead-times from design to delivery in the store are 8-10 months. Fashion companies, by offering the customers a vast amount of choices, have created a new shopping behaviour amongst their customers. Customers now want more fashion even quicker and such demands cannot be responded to with traditional supply-chain management.

Knit On Demand is a research project financed by the Knowledge Foundation in Sweden and carried out at the Swedish School of Textiles. The objectives of the project are to demonstrate production methods 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. This leads to e.g. improved decision support in outsourcing and offshoring strategies and may contribute to increased local fashion production. Three industrial partners have participated in the project, Ivanhoe, a producer of knitwear, Total Logistik, a third party logistics provider that early on had to leave

the project due to new owner constellations and SOMconcept which was not in the original line up of companies but have joined later. SOMconcept is a retailer of tailored fashion in Stockholm and is one of the pioneers in customised fashion in Sweden.

2. Methodology

The aim of this paper is to present the research project Knit on demand and the development of the project to its present state. The paper takes its starting point in the theories on mass customisation and is built on case studies done during the course of the project. In order to get the sales of customised knitted garment started, the researchers themselves had to take an active role in developing the business concept. The methods used for collecting empirical data were interviews, inspiration journeys and workshops. Learning from these activities were combined with theoretical frameworks for developing and applying a solution.

3. Mass customisation

Fralix (2001) points out that mass customisation is a future direction for the fashion and apparel industry, but garment fit and colour selection have so far limited its use. Tseng and Jiao (2001) defined mass customisation as technologies and systems that can deliver products, which meet an individual customer's needs with nearly the same efficiency as that of mass production. There are business concepts for fashion products, shoes, and other items that combine modern manufacturing technologies with mass customisation. An example of this is the Finnish left® foot company, where the customer's feet are scanned in the shop, and this information is used to manufacture shoes with a perfect fit that are home delivered to the customer within three weeks (Sievänen and Peltonen 2006). Another example is the Internet-based German company Spreadshirt, which sells T-shirts with customers' individually, designed prints. The customer can choose between standard options of T-shirts, and then Spreadshirt produces the customer's self-design on the garment with modern digital printing technology (Reichwald and Piller 2006). This shows some examples of how fashion products can be customised. There are also examples of knitted fashion products, most of them T-shirts, that show that customisation of knitted fashion garments can be done.

Mass customisation is a response to customers´ demand for higher variety, more authenticity and a better shopping experience (Gilmore & Pine, 2007, Luximon et.al, 2003). An apparel related example is running shoes: in the beginning of the seventies there were about five different running shoes to choose from, in 1988, that number had increased to 285 (Luximon et.al, 2003) and in 2008 one single on-line retailer offered more then 550 running shoes (Footlocker, 2008). In addition to these 550 running shoes the company offers almost 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 may become unmanageable, for the company, and it also confuses the customer. Figure 1 illustrates the correlation between variety and customer satisfaction, at a certain point variety becomes too large for the customer to handle.
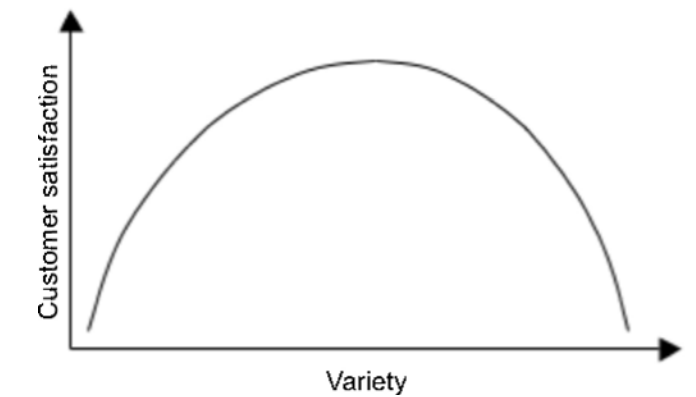

Figure 1. Variety vs. customer satisfaction.

In a survey conducted at the universities of Columbia and Stanford was 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 were offered the standard six choices (blueberry, raspberry, strawberry etc.) 30 percent of the customers made a purchase and when they were offered 24 types only three percent purchased the jam. But 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 variation confuses the customer. However, if the variety is presented in an understandable way, variety is beneficial for an organisation (Anderson, 2006). The Swedish shirt manufacturer Tailor Store AB verifies Anderson's statement by offering their customers 43 000 trillion different combination in an understandable way (Tailor Store AB, 2000)

Mass customised products can by definition only be made to order, they can be designed to order, engineered to order or assembled to order. It is a company's ability to offer customised products that creates its competitive advantage within its segment. According to Amaro et. al. (1999) the decision to produce to order is strategic; most companies that offer mass-customised products only offer customised products. One of the reasons for this may be that traditional supply chain management cannot mix customised products and mass products. Since the market for mass customised goods is marginal, companies offering this type of products 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 probably is NikeID that 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 customised goods spanning from muesli to drums (Configurator-Database, 2008).

There are several degrees of customisation; Gilmore and Pine (1997) have identified four distinct approaches to mass customisation, which are represented in figure 2.
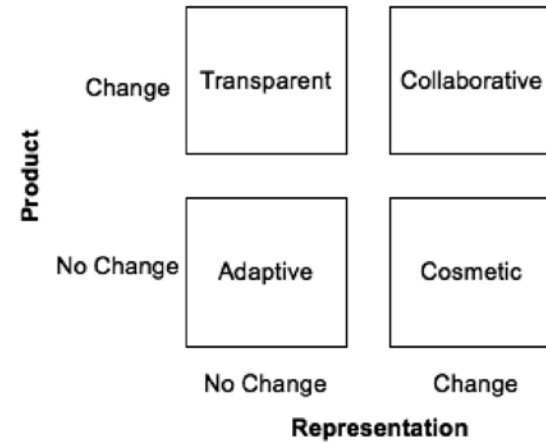

Figure 2. Four faces of Mass Customisation (Gilmore & Pine, 1997).

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

Adaptive Customisation
One customisable standard is offered and the customers can alter the products themselves. Nike ID lets the customer alter the colours of the shoes and the customer can add his name 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 "customised". Eyeglasses 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 is able to guide the customer through the purchase.

There are the following drawbacks of customisation, according to Åhlström and Westbrook (1999):
- Increased material costs
- Increased manufacturing costs
- Less on-time deliveries

Pine et al. (1993) writes that one of the reasons Toyota failed, when they persuaded mass customisation, was that, they remained in the structures of continuous improvement. Managers did not realize that the problems were caused by failure to transform the organisation from an organisation of continuous improvement to an organisation that could also handle mass customisation.

There have been some criticism on the upcoming trend of mass-customisation; critics mainly ask why it has not been done earlier since most of the tools have been available. The reason for that might be a shift in how people are shopping. Gilmore and Pine (2007) write that customers look for authenticity and experiences when they are shopping. Oneway of adding 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 that it is a unique design. And it sometimes is, a Swedish on-line retailer of customised shirts offers more than 43 000 trillion different combinations, sizes excluded (Tailor Store AB, 2008).

Whether the design is unique or not is in the eye of the beholder, most customers probably experience that they are designing their own garment but a few would like even more freedom.
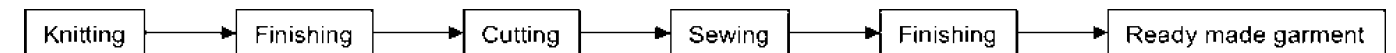
4. The production of flat knitted products

The flat knitting machine has a linear needle bed that makes it possible to produce flat knitted rectangular panels for products like cardigans, sweaters, skirts, scarves, and other garments. Flat knitting machines traditionally produce knit panels with a fixed edge and a welt at the bottom of the panel, coarse structures, and then such patterns such as rib, jacquard, stripes or cables across the panel. The manufacturing from yarn to ready-made garment can be done in several ways in flat knitting, depending on production methods and the type of machinery used by the company. The production from yarn to ready-made garment consists of several processes, as shown in figure 3. It starts with the knitting process, where yarns from yarn cones are knitted to panels in the flat knitting machine. The panels are often steamed in the finishing process after knitting. In the cutting process the panels are cut to the right shape and size, according to design and quality requirements. The panels are joined together into a garment in the sewing process. To achieve the correct quality, the garment is often passed through a finishing process, such as steaming or washing. The traditional manufacturing of coarse flat knitted garments consists of several time-consuming processes after knitting.

Figure 3.

Figure 3. Production process of flat knitted garments.

The manufacturing of flat knitted garments can be divided into the four different production methods, as shown in figure 4: cut & sew, fully fashioned, integral knitting, and complete garment.
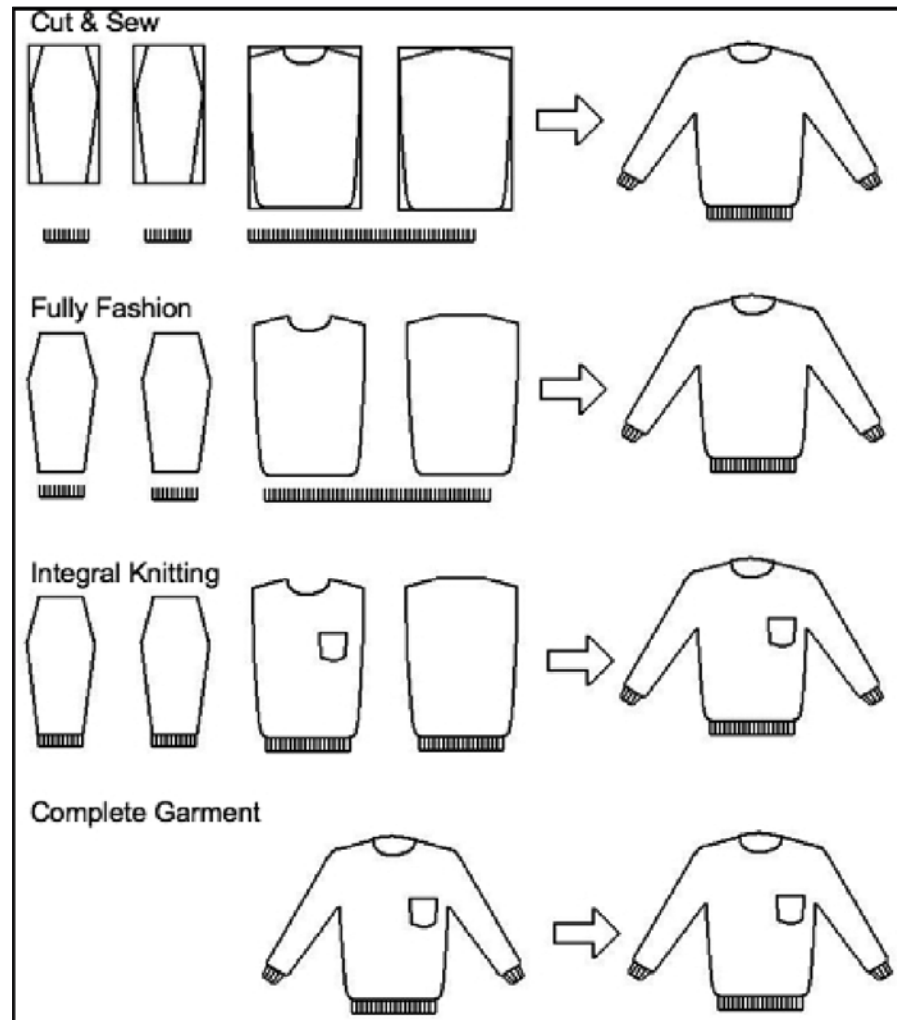

Figure 4. Production methods for flat knitted fashion garments.

Cut & sew is the conventional and most common method for producing flat knitted garments. Panels for front, back, and sleeves are knitted in a rectangular form and then cut into shape in the cutting process. Next the panels are sewn together with separately knitted trimmings and pockets to complete the garment. Both cutting and sewing are post-knit processes that take place away from the knitting machine. With cut & sew, up to 30% of the original fabric may be wasted as cut-loss. The advantage of this type of production is that it can be done in all flat-knitting machines, including old models without computer processing systems. The disadvantages are the labour intensive post-knitting processes such as cutting and sewing, which makes this production suitable in countries with low labour costs, such as Eastern Europe and China. Another disadvantage is material waste in the cutting process. A large fraction of the knitted material is cut-loss, when the right form of the panels is formed in the cutting machine.

Fully fashioned, or shaped knitting, is a method of production, where the front, back, and sleeve pieces are knitted in the right shape directly in the knitting machine. The cutting process is at a minimum or totally eliminated, but some post-knit cutting can still be necessary. Trimmings and pockets are knitted separately and sewn together with the rest of the knitted pieces to complete the garment. The benefit of this production method, compared with the cut & sew method, is that cutting is eliminated or kept to a minimum, and that the material consumption is much lower, due to lower cut-loss. Both material and labour costs are lower than with the cut & sew production method.

Integral knitting means that trimmings, pockets, buttonholes, and other accessories are directly knitted in the fully-fashioned produced panels. With this technique there are fewer post-knit processes such as cutting and sewing. Compared with cut & sew and fully fashioned production methods, savings may be made in both cutting and sewing post-knit processes. Quality and appearance of the completed garment can be improved by this method of integrating accessories directly in the panels in the knitting process. Also, by this production method, cut-loss is kept to a minimum.

Complete garment production means that the entire garment is ready-made directly in the flat knitting machine. The different parts of the garment are knitted in the right shape and knitted together with the trimmings, pockets, and other accessories. As shown in figure 4, the advantages with this technique are many. There is no waste of material such as cut-loss in the cutting process and no expensive post-knit processes such as sewing or cutting. Depending on the style of the garment, some additional cutting and sewing of labels and trimmings may still be necessary. All yarn in the garment comes from the same yarn cones, which enables higher quality and reduces problems with yarn from different dye lots. Due to the seamless technology, the garment could both fit perfectly and be comfortable to wear. This technology makes it possible to reduce processes in the manufacturing of the garment and produce "on-demand" knitting, which can shorten production lead time considerably.

5. Knit on demand – from demand to delivery

5.1 Development of the concept

The research team represent the Swedish School of Textiles together with Ivanhoe AB in Gällstad, a producer of knitwear and SOMconcept, a tailored fashion retailer situated in a top retail location in Stockholm that focuses on tailored fashion and smaller exclusive brands. Production is located in Gällstad in southern Sweden, which has relatively high labour costs compared to the countries were clothes typically are produced. The company producing the garments is relatively small with about twenty employees. It focuses mainly on active wear like golf- and ski clothes. This project focuses on a business concept where the customer is allowed to design his own garment, choose his fit, colour and model and place 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, so it is more a configuration of pre-engineered modules. Figure 5 is an illustration of the original idea of how a store for customised knitwear would be set up. The original idea was to have a complete garment machine in the store and to connect it to the design systems in the computer where the customer configures or "designs" the garment. However, the business risk of investment in a complete-garment knitting machine was at the end unacceptable for the partners and the best solution was to have the retail store at SOMconcept in Stockholm and the production of the garments at Ivanhoe in Gällstad. This changed the project plan with regard to knitwear production resources, but the collaboration with the partners to develop the concept continued.
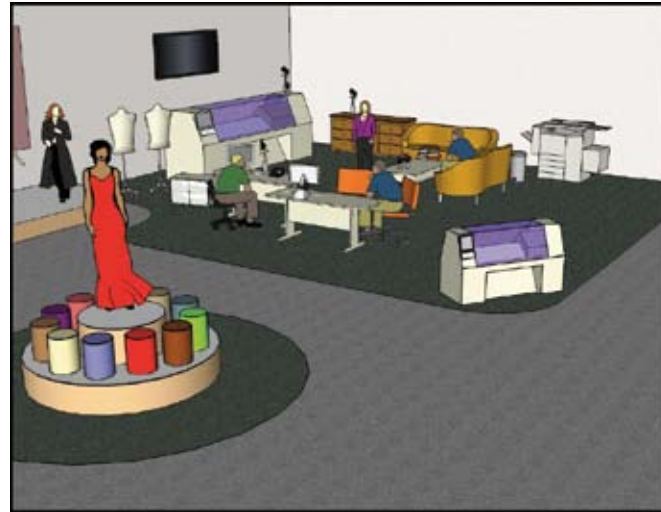

Figure 5. Design in Shop.

Development of the concept of the project, design of the garment, production and logistics 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 of the customised garments were developed together with the two project partners Ivanhoe AB and SOMconcept. Several workshops have been held, where the development of the concept has evolved. Figure 6 explains the role of each participant in the development of the concept.
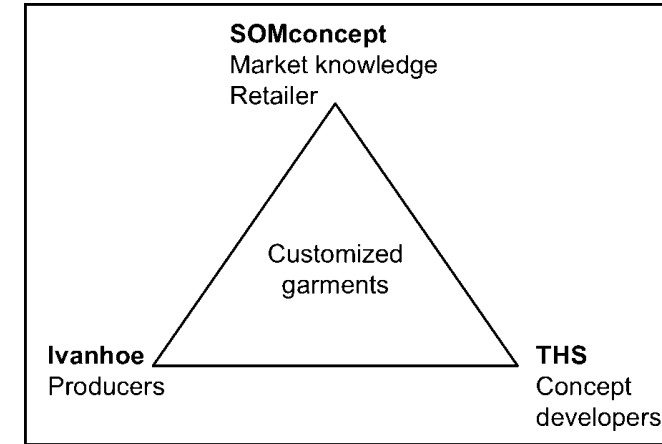

Figure 6. Participants in the development of the concept.

5.2 The logistics behind the scene

The logistics goods- and information flow from supplier to customer can be divided into two flows: product flow and demand information flow. Figure 7 shows the demand chain where the customer comes in to the retail store, in Knit on Demand represented by SOMconcept, and manufacturing represented by Ivanhoe. The yarn suppliers are chosen upon their ability to keep all the season´s colours in stock the entire season and they also provide Vendor-managed inventory solutions, if volumes are sufficient. It is also possible to order special colours but to a higher price for the customer. The lead-time for yarns differs between one and two weeks. As the supplier has a wide range of yarn on stock at all times the agility of the demand chain is assured. There is however a cost associated with agility and if the customer wishes something outside the normal range, he or she will have to pay a higher price.
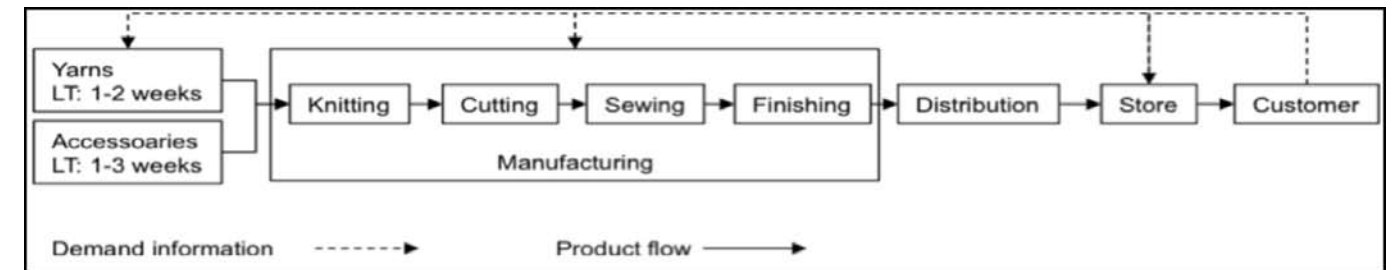

Figure 7.

Figure 7. A demand chain for knitted customised garments.

The knitted garments are made to order and the customer is allowed to (with limitations) customise their garments. The design possibilities have been limited for the customer to change colour, model and pattern. In total five different models (see figure 8) in seven different colours are offered.

Each garment is made to measure using a system where standard size garments are used as a gauge. In order to fit each customer material is added or removed from the standard size when the garment is produced. The forecasted volumes are quite small in comparison to the producing companies' volumes of regular garments.

The retail price of the garment will be about 1600 SEK. It is from the retailer's point of view better to offer one price for all the models even if the profit margin is higher on a round neck then on a cardigan since less effort in manufacturing is needed for the round-neck.

Figure 8. Model range, the v-neck is available with two collar depths.

5.3 Garment manufacturing

Two production technologies were available for producing the garment, Cut & Sew and Fully Fashion. The advantage with fully fashion is that less material is wasted since no material has to be removed after knitting (see figure 9). On the other hand, it can be difficult to knit exactly the right shape of the garment part and this requires longer set-up time in the machine. In order to ensure quality it has been decided to use Cut & Sew technology.
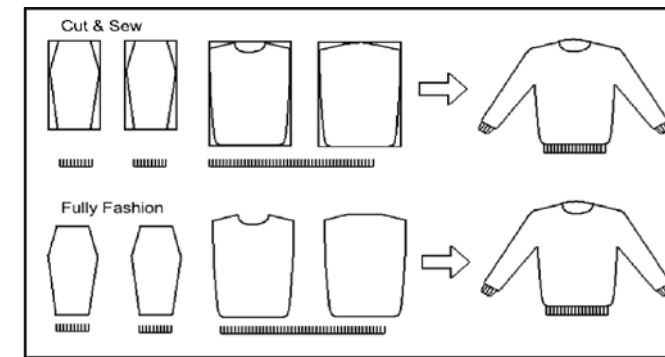

Figure 9. Difference between Cut & Sew and Fully Fashion.

Cut & Sew and Fully Fashion have slightly different logistics solutions. If Cut & Sew is used panels of fabric can be knitted in advance of the customer order point and be kept on stock, which is not possible with Fully Fashion since everything is knitted to order and each panel is knitted to fit one specific customer. From a logistic point of view a Fully Fashion situation would be most beneficial since it minimizes inventory- and handling costs. However, Cut & Sew has its advantages and in this case the Cut & Sew technique has been used due to the following reasons:

- Quality
Washing is carried out before cutting the panels into knittable shapes so when the garment is sewn together it already has the final shape. Since the garments is unique in size it is not possible to sell it to another customer and therefore it was decided that the method that guarantees the highest quality is to be chosen.

- Production
As the panels are cut from a larger piece of fabric it is easier to get the shape right. If Fully Fashion would be used the shape has to be changed in the knitting machine, an equally time-consuming manoeuvre but less safe from a quality perspective. There is no mentionable difference in lead time between Cut & Sew and Fully Fashion, the time-consuming steps are not in production but in the intermediary steps such as trend spotting, forecasting, inventory and long shipment lead-times.

When customers are asked how long they are prepared to wait for delivery they often state around eight days. However, customers seem to be willing to wait longer when they order mass customised products. Whichever is the case, mass customisation of knitwear imposes a challenge on production and logistics. First of all, yarns and accessories have to be kept on stock since their leadtimes are more then eight days. In order to keep the stock at an appropriate level seven colours are available in one yarn quality; the yarn to be used is extra-fine combed merino wool. Secondly, the information flow needs to work flawlessly since there is only one chance to produce each garment. If the garment needs to be changed or if another one has to be produced, most of the profit is lost. It is possible to produce and deliver with shorter lead-times than eight days but eight or nine days is the best lead-time from the producers´ point of view. It gives them the opportunity to schedule one day per week on which the garment will be produced and distributed.

6. Main findings

The technology to produce customised garments has been available for many years, but only recently there has been a demand for individualized knitted garments. The theoretically 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, this is also a lead-time that many customers are satisfied with. When it comes to configuration of 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 the garment is built up from have to be pre-engineered in some way. The multiple-choice system guides the customer towards the final purchase decision and helps the customer visualize the final product. It is very important that the image that the customer creates in his or her mind resembles the end product. The multiple-choice system also limits the customer's wishes to what is possible to produce within a given timeframe and at a certain quality. Regarding the logistics of the project it is rather easy to handle; in the beginning the flows will be narrow enough to fit the existing supply chain. The logistic costs per garment will be higher than in a supply chain of mass products, 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; it means that even if the manufacturing site has the capability to produce on demand, it might be hard to find support up-stream. However, the benefits from reduced risk and the ability to respond faster and more accurately to customer demand make the concept work well.

7. Conclutions

The problem is not the garments customers buy and pay full price for, the problems is the garments that the customer does not buy. Those garments have travelled around the globe for no reason more than taking up valuable shelf space at the retailer. It is the redundant garments that the Knit-on-Demand concept removes from the supply chain. It is however slightly more expensive to produce on demand; production control and order handling does take more time than in traditional production. If the customer can order a garment that suits his or her needs perfectly, either the lead-time or the price is not the order winner. The order winner is the ability to customise the garment. The major benefits for the customer when producing on demand is that the customer receives a garment that better suits his or her needs. Benefit for the company are that they do not have to produce on forecast and overproduction can be held at a minimum. The benefits for the world are that only the garments that are needed are produced. This reduces the emission of pollutants and the use of natural resources.

8. References

Amaro, G., Hendry, L. & Kingsman, B. (1999), Competitive advantage, customization and a new taxonomy for non make-to-stock companies, *International Journal of Operations & Production Management*. Vol. 19, No. 4, pp. 349-371.

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

Cerruti, C. & Harrison, A., (2006), Agile supply chain management in the fashion business, *Supply Chain Practice* Vol. 8, No. 1.

Christopher, M. (2000), The Agile Supply Chain: Competing in Volatile Markets, *Industrial marketing Management*, Vol. 29, No.1, 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*, Vol. 3l, No. 8, pp. 367-376.

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

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

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

Fralix, M.T. (2001), From Mass Production to Mass Customisation, *Journal of Textile And Apparel, Technology and Management*, Vol. 1, No.2, pp. 3-4.

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.

Lindahl, B., (2008), Kortlivat, *SvD Näringsliv*, No 39, pp. 5-11 Okt 2008, in Swedish.

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.

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

Reichwald, R. & Piller, F. (2006), *Interaktive Wertschöpfung*. Wiesbaden: Gabler Verlag. pp. 51-53.

Sievänen, M. & Peltonen, L. (2006), Mass customising footwear: the left® foot company case, *International Journal of Mass Customization*. Vol. 1, No 4, pp: 480-491.

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

Toffler, A. (1984), T*he Third Wave*, New York: Bantam Books.

Tseng, M. & Jiao, J., (2001), Mass Customisation, In: Salvendy, G. (ed.) *Handbook of Industrial Engineering, Technology and Operation Management*, (Chapter 25), New York: Wiley.

Åhlström, P. & Westbrook, R., (1999), Implications of mass customization for operations management *International Journal of Operations and Productions Management* Vol. 19, No 3, 1999 pp. 262-274.