One-piece fashion, summary of the Knit-on-Demand project

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ABSTRACT

Knit on Demand is a research project at the Swedish School of Textiles in collaboration with Ivanhoe AB and SOMconcept AB. The purpose of the project is to test new production methods for knitwear that could strongly influence the fashion industry's need for agility. In autumn 2009 sales started in Stockholm. The project stands on three legs; design, knitting technology and logistics and the purpose of the paper is to describe the Knit on Demand project from these three perspectives. Designing the garments and the system was the most time consuming part of the project since the products had to be fashionable, manufacturable and preferably not to expensive so a few trade offs hade to be made. Look was however considered essential since fashion always comes first. For knitting a combination of fully fashion and cut and sew are used so that the garments keep some of the fully fashion advantages but remains easily customisable. Logistics becomes a little bit more complicated because of the unique garments but the logistic costs does still not make up more than 3-5 percent of the sales price of a garment. Return rates are below one percent, which is rather interesting to further analysis.

1. INTRODUCTION

There is in the western society abundance of choice and as long as your body fits into the standard sizes you can find any shirt, pants, sweater or jacket you which for. The problem with the abundance of choice is that it also creates an abundance of products in the market, which in the end leads to markdowns or obsolete inventory. An average of 30 percent of all garments are marked down in the end of the season. Obviously very good for the customer but bad for the fashion companies. A solution to the problem with abundance and overstocking is to produce only what the customer wants [1, 2]. That either requires a state of the art forecast tool that is one hundred percent correct, or on-demand production. Since the one hundred percent correct forecast does not really exist the only option left is to produce on demand. In order to test production on demand a project called Knit on Demand was carried out at the Swedish School of Textiles in close collaboration with a knitwear producer; Ivanhoe AB and a retailer of tailored fashion; SOMconcept AB. The original idea was to "*...demonstrate a production method for knitwear that may strongly influence the ability to of the fashion industry to meet new demands for agility in customer relations*" [3].

The result of the project is a business concept where the customers themselves are allowed to, with limitations, design or customise their own knitted garment. The garment is produced at Ivanhoe AB in Gällstad in southern Sweden. Sales started at the SOMconcept in Stockholm in September 2009. Mass customisation, or the ability to produce individualized garments at near mass-production efficiency could be seen as a response to the abundance in the market and a way for the companies to decrease lost sales and to increase the sell though factor. Only a few traditional fashion and apparel companies have however explored and exploited mass customisation, instead new companies have popped up such as Tailor Store AB and SOMconcept AB. Thus it could be suggested that mass customisation is not only a result of the fast fashion industry's short lifecycles and the abundance of products in the market place, it could as well be a response to other dynamics in society such as the "rise of the creative class" [4]. Moreover some customers are looking for experiences when they purchase products and designing an unique garment might be that experience [5, 6]. The price range of the garments is 130 to 160 €.

Besides Knit on Demand there are, to the researchers knowledge, two companies and two research projects in the world that focus on mass customised knitwear. One, Shima Seiki is located in Japan and the other one, Unicatum is located in Kaiserslauten in Germany. Another one in Sweden are at them moment testing the possibilities to produce

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mass customised knitwear. Shima Seki has three stores in Japan that they call "Factory Boutiques". There are also two research projects, one at London College of Fashion and another one at North Carolina State University.

The purpose of this paper is to present a summary of the Knit on Demand project on the topics Design, Technology and Supply Chain Management. The reason for choosing these three topics is that the project is built on the Swedish School of Textiles interdisciplinary structure and that the project members comes from these three backgrounds.

2. MASS CUSTOMISATION

There is not much empirical evidence on mass customised knitwear so learnings about mass customisation have been drawn from other areas, mainly mass customisation of business shirts.

The driving force behind mass production has been economies of scale, necessary for efficient supply chain management but is has a few drawbacks for the customers; one of them is the size issue. If ten people, all wearing the size small are lined up, none of them have the exact same body measurements and if you fit each one with the same jumper, only a few will be satisfied with the fit. In fact, according to a report written by Grimstad et.al. [7], Only one percent of the general population says that they are able to always wear the same size on all garments. The variations in size are actually so wide that a garment marked with "large" for one brand, could be smaller in size than a garment marked with "small" for another brand.

If economies of scale are the key drivers for mass production, economies of scope is the key driver for mass customisation. However, in order to get the mass in mass customisation work, there has to be economies of scale. Economies of scale are visible in the modules that most mass customised products build on. These are pre-engineered modules with fixed interfaces between the body and the sleeves. All of Knit on Demand garments builds on the same base module, which is adjusted to fit the customer's body measurements and design requirements.

Gilmore and Pine [8] defined four faces of mass-customization. Depending on what techniques that are used a company selling mass customised products can offer the customers different grades of customisation; adaptive customization, cosmetic customization, transparent customization or collaborative customisation which is considered to be the highest level of customization, it requires a close dialogue with the customer in which the customer articulates his or her needs. The Knit on Demand project is typical collaborative customisation, the customer designs the garment together with a tailor and makes adjustments on model, colour and fit.

3. METHOD

The method used for the project is inductive approach where a business concept is developed from an idea and the conclusions are drawn from case studies on that project. The researchers have been actively involved in product- and process development. Part of the case study is an analysis of the design, logistics and production processes in the Knit on Demand project. The design processes were analysed in a case studies where the researchers also participated as concept developers. Information and production flows were mapped using the "Value Stream Mapping" technique, which is a method developed in order to find and eliminate waste in production flows [9]. The paper is descriptive in its character.

4. DESIGN

There are several reasons why these people choose to buy a customised garment and these can be divided into two categories; either those who cannot find the right fit because they do not fit into the standard sizes or those who cannot find the right design because they do not fit into the standard trends. A mix of these two is of course possible. The customers with non-standard body measurements are rather easy to satisfy as customers, many of them have never been able to buy garments that fit to their bodies so when they finally find a garment that fits they are generally happy. The first customer of the Knit on Demand sweaters waited over one year for his garment but the store had never had a happier customer ones he got his garment. It must not be forgotten that the garment also has to be fashionable when it is ready. The customer who is willing to spend €150 on a knitted sweater is usually a fashion conscious customer who does not buy the garment only because it customisable but also because it is beautiful. An ugly sweater would not sell no matter how customisable it is - fashion always comes first.

There are two design processes with rather different characteristics related to the Knit on Demand products. The first one; the design *for* mass customisation process where the customisable garments are created and the second one; the design *of* the mass customised garments.

4.1 FIRST DESIGN PROCESS

The aim of the first process is to create a fashion garment that is customisable on the parameters fit and form. The third parameter, usually function is not included since the basic functions of keeping the wearer warm and covering the body does not change. As Tseng and Jao [10] writes one of the technical challenges of mass customisation is to optimize the reusability/commonality of the components and the products. And it is, especially with the trade offs that has to be made between cost, manufacturability and design options. By reusing tools, components, raw materials and designs economies of scale can be utilized, for Knit on Demand this is done by having one base module. The customers have six different models to choose from (Figure 1), 16 different colours, stripes and contrasting fabrics (neck plate) and different buttons.
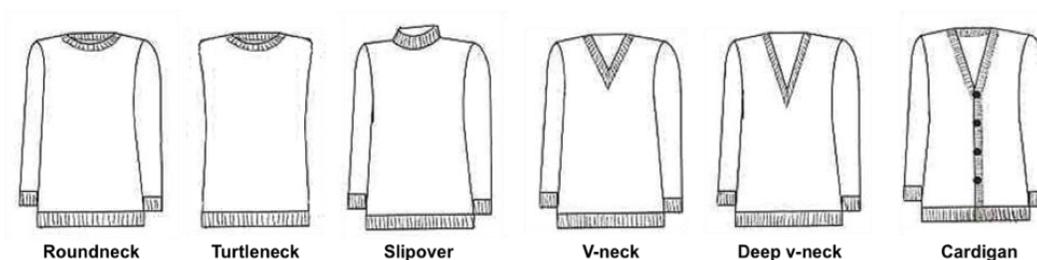
Figure 1. Garment styles

Each garment is made to measure using a system where standard size garments are used as a gauge that the customer tries on. To fit each individual customer material is added or removed from the standard size when the garment is produced.

In Knit on Demand this was done by creating a program in the knitting machine software, which built on the same base module and with easy changes in length and width. This design process is as much an engineering process as a design process.

The design *for* mass customisation is not necessarily a very complex process because the elements are already there and the knitting technician knows how everything fits together but it has to be decided how to do it and that takes a long time since the pros and cons of each method has to be considered. For example; should fully fashion or cut and sew machines be used. Both of them are flat knitting machines but with slightly different end-result. It is also nice if the garment when it is ready looks like a fashion garment. There is a trade off here between design, cost and manufacturability. The fully-fashioned garment is better looking but has slightly slower lead-time from order to delivery than cut and sew.

Usually a fashion designer has an urge to express his- or herself artistically with the garments they design. However that might not always work in mass customisation since somebody else is going to do the last configuration of the garments, somebody who maybe want to express something else with their garments. Perhaps the reason why they buy a customised garment in the first place is that they want to do their own design. It is the designers task to create a toolbox so that the end customer can create an outfit that is easy to customise, easy to produce and goes well together with the customer's over all expression.

In the first design process the design interface for the customer is also built. In the start-up of the project there where ambitious plans for a computerised system that could either go online on to the Internet or be in the store using a touch screen. This was however considered far too expensive and the first calculations showed that one of the computerised configurator would end up costing as much as the entire project budget. In addition no one in the project team knew anything about building such a system. Instead a manual system was designed, a system that very much resembles a traditional tailor except for the knitwear part. In the store there are a number of garments in different models, colours and pattern combinations and there is at least one garment is each size. There are also colour swatches of the different yarns that are available and figure two describes the different design options.
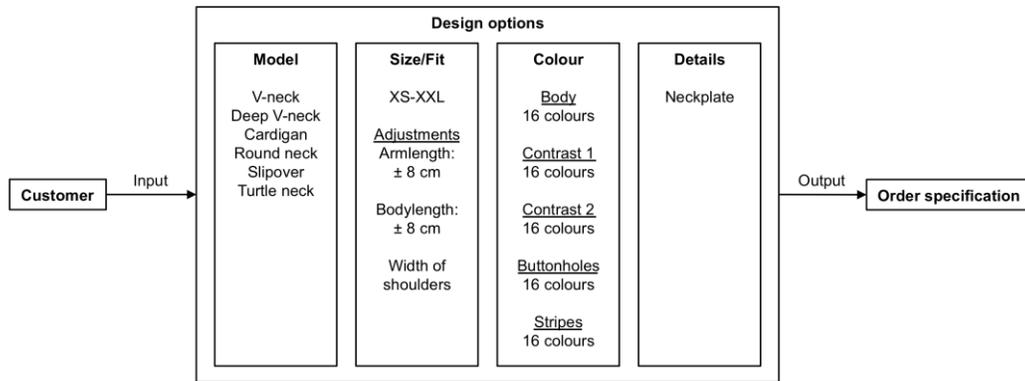
Figure 2. Design options

It is difficult to know how much choice the customer should be given. Some authors [11]claim that too much choice will confuse the customer and others [12-15] claims that the more choice the better as long as it is presented well. The total of possible combinations is around 100 million different combinations including the made to measure part which is, compared to for example Tailor Store AB it is not much; they offer the customers more than 100 billion combinations of their shirts, sizes excluded.

This first design process was by far the most time consuming part of the Knit on Demand project. It took more than three years to set all the requirements for the garments and to get sales started. Also, much time was spent on what could be considered as nitty gritty things like the thickness of the collar down to the millimetre but those things are important for the feeling of the garment.

4.2 SECOND DESIGN PROCESS

The second design process starts with the customer entering the store and decides to buy a customised knitted garment. A tailor guides the customer through the steps of the design process (figure 2), the customer is allowed to change the garment on four parameters: model, fit, colour and details. Within these four parameters there are additional steps so the customer goes through nine design steps in total.

In this design process the customer has a high level of interaction with the tailor and the customer is able to explain what he or she wants. Boyd and Bahn [12] writes that letting the customer explain his or hers demand and from that exhibiting the different design options is the preferred way to communicate with customers when it comes to making choices. The other way would be to show the customer a list of options and let them choose. Customers prefer to state their demands rather than to choose from a list but they tend to be equally satisfied with the end results no matter the method of choosing

Since it is a manual configuration system it means that there is no visual feedback for the customer except for the garments in the store and the swatches of yarn. So the tailor has to make sure the customer understands what the end result will look like. If the image the customer has created of the garment does not resemble enough with the end product the customer might not be satisfied and wants to return the garment. According to Swedish distance shopping laws the customer has no right return a customised garment as long as the garment is made according to the specifications of the customer. However, companies dealing with mass customised garments have very low return rate, less than one percent of the customers wants to return their garments. So the practise is that if the customer is not satisfied the customer receives a new garment for free. The reason why is that it is cheaper to do and keep the old customer happy than to create a new customer. When the customer is satisfied with the design it is specified in a excel document and sent to the manufacturer by e-mail and the order is confirmed by the producer. It takes about 20 minutes for a customer to make up its mind about a sweater, however some customer are very slow and needs up to two hours to decide what to buy, luckily those customer are rare.

5. KNITTING

There are a number of flat knitting techniques available. All of them build on the same foundation, two or four knitting beds in an inverted V-position. The most basic knitting machines; cut and sew machines are capable of knitting panels that later has do be cut into garment pieces. Fully fashion and integral knitting machines are a little bit more

advanced and are able to shape-knit the garment pieces and add pockets thus reducing waste of yarn and cutting time. The most advanced complete garment machines knits the entire garment in one piece, thus totally eliminating the need for cutting and sewing [16, 17]. Figure 4 illustrates the different available knitting technologies.
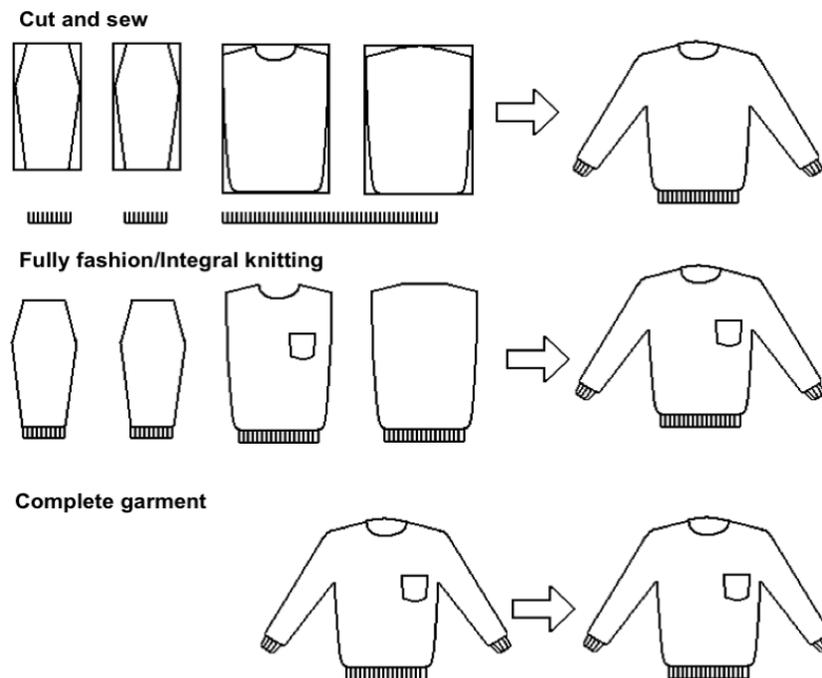

Figure 3. Different knitting technologies

One of the original purposes with the Knit on Demand project was to test and evaluate the complete garment technology so a machine of that type was to be bought. It was however by the knitting company considered too risky to invest in a complete garment machine for one research project and instead the already existing fully fashion and cut and sew machines are used and that works equally well.

In Knit on Demand a combination of fully fashion and cut and sew is used. The arms and bodies are knitted into their final shape directly in the knitting machine. One of the reasons why fully fashion was chosen was that the seams on a fully fashion knitted garment are neater than on a cut and sew garment since there is no need to use an overlock machine, only a single needle machine is needed. When the collar and the front ribbons are added the neck is cut to it final shape and then the collar is mounted using a kettel machine. This requires a very skilled worker and there are only a few left in Sweden who are able to do that job properly. Fully fashion was however not the first option, Cut and sew was long considered the best option because of the flexibility and that simple knitting machines could be used. Moreover, the order to delivery process could be decreased with cut and sew; the idea was to keep knitted panels on stock and when there is an order cut the panels into the right shape and sew them together. Also it does not seem to matter for the customers what kind of knitting technology that is used, a quick walk through the high end stores in Gothenburg showed little relevance between price and knitting technology.

6. LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Supply chains for mass customised products has to answer quickly to diverse customer demand. Mass customizers such as Nike, SOMconcept and Tailor Store have a lead-time promise of about three weeks depending on the available production capacity and these companies offer the customers hundreds of billions of combinations. In literature, such supply chain capabilities are often referred to as agility [18-20]. The agile supply chain reacts to true customer demand rather than relying on the distorted picture of the future created by forecast tools [18]. Not only does it react on true demand, it also benefits from and thrives in a volatile marketplace [21]. The concept agility origins in flexible manufacturing systems that has extended from the production to incorporate the entire organisation [22]. Like the lean concept, agility is characterised by its focus on customer value in all processes and its ability to develop flexible and

responsive processes [19]. The order winners for these processes does not necessarily have to be cost, it might as well be flexibility [22]. These description of an agile supply chain fits the Knit on Demand supply chain very well; it reacts to true costumer demand, it likes different customers with volatile demand and the order winner is not cost but rather availability and customisability. No customers ask for a lower price when they purchase a garment and as long s the supply chain is able to answer to their unique demand they are willing to pay the higher price. Figure 2 illustrates the Knit on Demand supply chain.
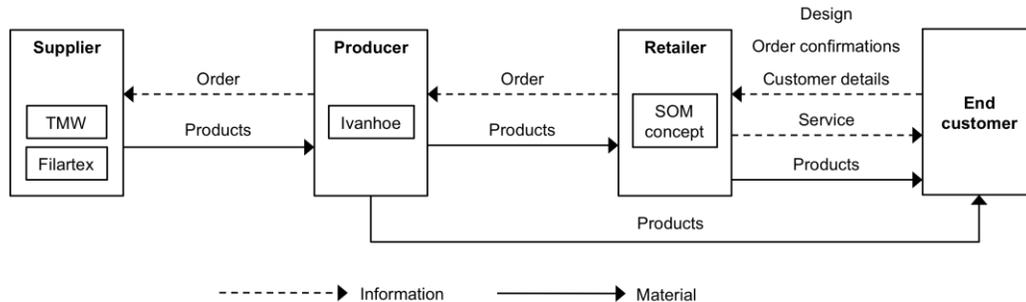

Figure 4. Information and material flow

Since it is a demand driven production flow nothing happens in the system until a customer places an order in the store. The order is then sent to the producer who manufactures the garment and sends it back to the retailer for the end customer to pick it up alternatively sends it directly to the end customer. The Knit on Demand production process has more resemblance with the sample production then with regular production.

The one-piece flow is characteristic for a supply chains for mass customised products. According to Miltenburg [23] the one piece flow is best suited for u-shaped pull production systems paced by takt time. It is suitable for producing medium volumes of many product variants in cells with an even flow of products; it is flexible and has a high quality output and short throughput times. It is also considered to be the one of the most powerful waste reduction tools and decreases the total lead-time of the product since no products are stored between processes [24]. Even though the Knit on Demand production processes are not a picture perfect match to what Miltenburg [23] describes as a one piece flow it has similarities such as high flexibility and high quality of the products. It is difficult to compare the company's regular production with the Knit on Demand production since the design of the value flow differs a lot between them.

Cut and sew has in theory the fastest order to delivery time since panels can be knitted and kept on stock until a customer order comes. Such set up would also create less dependency on available knitting capacity within the promised lead-time since the fabric for the garment is already produced. It is also flexible since any shape can be cut from the panels. Cut and sew does however create more material waste compared to fully fashion and complete garment since the panels are cut into pieces and the pieces of the garments has to be sewn together which requires available sewing capacity.

Before a fully fashion garment can be produced it is programmed in a computerised design system that is connected to the knitting machine. Fully fashion is a little slower from order to delivery since the garment pieces cannot be knitted until there is a customer order. The order to delivery lead-time is about one hour longer so compared to the promised lead-time of three weeks it is not much. But the problem is not lead-times in the knitting machine, it is that there has to available knitting capacity within the promised lead-time. Fully fashion (if correctly utilised) creates no waste of material but the pieces have to sewn together.

Figure 6 illustrates the production Knit on Demand production process with lead times, set-up times and standard allowed minutes (SAM). Standard allowed minute in the time each operation is allowed to take and it differs from the actual lead-time depending on how much set-up time a process is allowed to have.

Fully fashion + Cut and sew

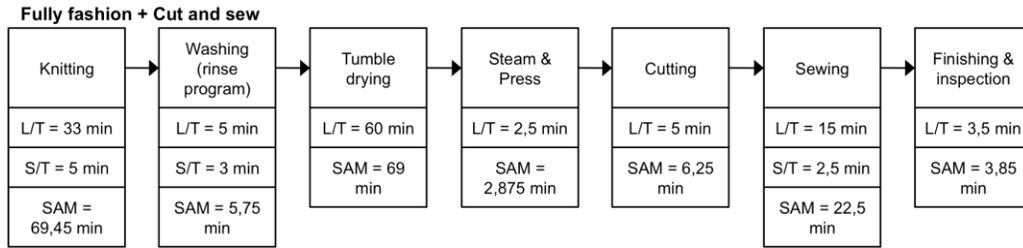| Knitting	Washing (rinse program)	Tumble drying	Steam & Press	Cutting	Sewing	Finishing & inspection
L/T = 33 min	L/T = 5 min	L/T = 60 min	L/T = 2,5 min	L/T = 5 min	L/T = 15 min	L/T = 3,5 min
S/T = 5 min	S/T = 3 min	SAM = 69 min	SAM = 2,875 min	SAM = 6,25 min	S/T = 2,5 min	SAM = 3,85 min
SAM = 69,45 min	SAM = 5,75 min				SAM = 22,5 min	

Figure 5. Process steps with lead-times, set-up times and standard allowed minutes (SAM)

The total value adding time in the production process is 126 minutes. With set up times and waiting times the production lead-time is 136,5 minutes. However when the cost of the garment is calculated the total time is calculated using the Standard Allowed Minute. For example, in the knitting production step the allowance is 100 percent due to downtime, set up time and problems that might occur with each new garment. Using SAM the total lead-time is 179,7 minutes.

Delivery time to the store in Stockholm or directly to the customer is one to two days. Before the customer picks up the garment at the retailer the labels are added and then the customer is notified via phone or e-mail. The cost of shipping is 50 SEK per garment.

The total lead-time from customer order to delivery varies from one to three weeks. The target is to reduce the throughput time in the factory to less than five days, which would decrease the total lead-time to one week. However, in order to reach that the volumes has to increase to at least one garment per day. Then one knitting machine can be dedicated to the customised garments for one day. It has several benefits, one is that the operator gets another sense of focus and learns the personality of that particular knitting machine.

7. CONCLUSION

Knit-on-Demand is not for everybody but it is very much for the people it is for. It operates on a niche market where the order winner is the experience for the customer to design his or hers own unique garment and have it made-to-measure. The number of design options is enough but they need to be pushed in order to satisfy more needs. Once the knitting machine is started manufacturing of mass customised garments is very similar to conventional production except that the knitting machine need more attention so nothing goes wrong, the quality level has to be 100 percent. Logistics is more expensive since the garments are shipped mostly one by one. But the logistic cost does not make out a larger percentage of the sales price than a conventional garment, which is around five percent.

Customers who purchase the garment are generally quite satisfied with the garments. One customer was not very happy when he got his sweater in the wrong colour but other than that all the customers are more than satisfied. One reason is of course that people who buy do not fit into the standard sizes so when they finally find a garment that fit they think it is great.

Mass customisation of knitwear works in reality too, not only in theory. The original purpose:"...*demonstrate a production method for knitwear that may strongly influence the ability to of the fashion industry to meet new demands for agility in customer relations"* is party fulfilled. A functioning business concept has been developed and it is truly agile in customer relations, if it will influence the fashion industry is still to see. It has made some impact although small, the low return rates has interested the distance shopping-industry and one solution regarding sizes is currently being tested.

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