

Retail Concepts and Fashion Logistics Performance for Customized Knitted Fashion Products

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ABSTRACT

Mass customization exists today in a variety of areas including automobiles, furniture, food, and clothing. Complete garment knitting is a method of producing knitted fashion garments, ready-made directly in the knitting machine without additional operations such as cutting and sewing. This paper aims first to outline how these concepts can be applied in a retail concept for customized garments, and second evaluate the fashion logistics effects of combining mass customization with complete garment knitting. Research was conducted by a retail concept simulation and two case studies presented in three journal articles and concluded in a doctoral thesis. This paper is based on the results of the thesis. The main findings are a description of two kinds of retail concepts for knitted customized fashion products and how this affects the retail performance ratios. A knitted garment can be customized, produced, and delivered to the customer in three to five hours. Sell-through percentage, lost-sales, and stock-turnover were affected positively, confirming that lead time is an important factor for success in the fashion industry.

Keywords: knitting technology, supply chain management, complete garment knitting, mass customization, fashion

1. Introduction

A major problem for a fashion retailer today is that much of the garments that are sourced and bought must be sold at discounted prices, which results in poor retail performance ratios such as, low sell-through percentage, stock-turnover and high lost-sales. The idea addressed in this article is that a combination of *mass customization (MC)*, *complete garment knitting technology* and *supply chain management* can solve this problem for customized knitted products, and also give

some ideas how to handle the situation with sourcing and production of mass-produced fashion garments in general. You can see an example of this situation in fashion retail stores as H&M, Benetton, Gap and Uniqlo or any other brand what so ever. Signs everywhere showing that price are reduced, and this item will not be sold at full price as the intention probably were from the beginning.

Logistics for fashion products are marked by a climate of uncertainty due to rapid changes

in trends and fluctuating customer demand. Textiles and apparel is characterized by volatile markets and short lifecycles for the products and a high product variety due to Bruce, Daly and Towers, (2004). In this article the authors concludes that there are often a trade-of between production costs, lead-time of supply and a changing customer demand. To master this challenge the company must focus on improved responsiveness and developed relationships with their partners in the supply chain. In recent years the definition of Supply Chain Management (SCM) has taken a wider view of configurations among many researchers. Gattorna (2010) defines SCM as “any combination of processes, functions, activities, relationships and pathways along which products, services, information and financial transactions move in and between enterprises, in both directions.” Gattorna stresses the importance of having the definition embrace everyone in the company for the supply chain to work. This is consistent, and in line with the results Bruce et al. presented in 2004. A supply chain must be align and responsive.

For this reason, it can be an advantage to collaborate in the supply chain and to bring products to market as quickly as possible or retailers may be left holding unsaleable merchandise because items have gone out of fashion. The ideal would be to have an efficient system that could restock garments in one or two days, or even in hours, as they are sold. Such logistics activities require different kinds of sourcing, production, and inventory management than are currently being used.

Fernie and Azuma (2004) state that one direction for the fashion industry may be to reconsider the option of more domestic manufacturing. To use the concept of Quick Response that is inherent to the patterns of consumption in a particular market. For many years the trend in the textile and fashion business has been to source production in low-income countries in order to maximize gross profit margins for the company. This

philosophy can have a negative impact on revenue because of the lead times necessitated by long-range forecasts ahead of sales campaigns. The danger of sourcing to such countries months before the season is an excess of inventory, a greater number of products that must eventually be sold at discounted prices, the risk that customers cannot find what they want in the shop, and ultimately a loss of profit (Mattila, et al., 2002). A study conducted by Mattila, King and Ojala (2002) suggested a relationship between profit, inventory levels and customer service level: “High gross margins and customer service levels with as little inventory as possible” are essential for profitable retail fashion companies.

Christopher et al., argues that a supply chain and logistics system must be integrated in order to reduce lead time. This imposes special requirements on the companies in the supply chain. It is an accepted fact in the industry that the demand for fashion products is difficult to forecast. Fashion markets have been characterized as open systems that are often chaotic (Christopher et al., 2004)

In this paper a solution to this problem is presented when it comes to knitted products for customers who aim for self-designed garments. One of the retail concepts of the future may be MC. It offers a customer the opportunity to be a ‘designer for a day’; the experience of creating a unique product that has never been worn by anyone else. When MC is merged with a second new technology, Internet shopping, it gives customers the opportunity to shop from home at any time they please and have the product delivered directly to their door. This is now possible especially as the problem of obtaining measurements has largely been overcome by graphic instructions and on-line help.

This article is the report of a study and a doctoral thesis in the area of knitting technology and MC and retailing. It was based primarily upon a research project “Knit-on-Demand” at The Swedish School of Textiles, University of Borås in collaboration

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with a knitting manufacturing and retailing company. The aim was to study if it was possible to combine complete garment knitting technology with the concept of MC in a retail setting.

This article attempts to bridge the gap between complete garment knitting technology, fashion logistics, and MC. It poses the following research objectives:

Research Question One (RQ1): *How can knitting technology be applied in a retail concept for customized garments?*

Research Question Two (RQ2): *What are the fashion logistic effects of combining complete garment technology and MC?*

The fashion logistics effects referred to in RQ2 are demand fulfilment time, sell-through, lost sales and stock turn. *Demand fulfilment* time is defined as the time it takes from when customer demand is identified to when the product is in the hand of the customer. It is the time it takes for design, production and transportation of the actual fashion product. *Sell-through factor* is the percentage of products sold at full price, *lost sales* refers to how many customers visit a store but do not purchase anything and *stock turn* is the ratio of inventory compared to sales (Mattila, 1999).

Over the last 50 years the mass production of textiles and fashion garments has largely moved from Europe to countries in Asia and North Africa because of low labor costs (Mattila, 1999). One disadvantage this brings is the long lead times for design, product development, manufacturing, and delivery. By contrast, MC, a concept in which a garment is designed and sold to a consumer before it is manufactured, opens up new possibilities from a fashion logistics perspective. It permits a short lead time from the moment an order is placed to the delivery of the product to the customer. Such expeditious fulfilment increases the likelihood that a garment will be sold at full price.

2. The problem in the fashion industry

Logistics for fashion products are marked by a climate of uncertainty due to rapid changes in trends and fluctuating customer demand. For this reason, it can be an advantage to bring products to market as quickly as possible or retailers may be left holding unsalable merchandise because items have gone out of fashion. The rent for an upscale clothing store in a good location is very high, so it is essential to carry the correct level of inventory. Such a retail shop is too expensive to use as a warehouse; on the other hand, too little stock will result in customers not finding what they want. The ideal would be to have an efficient system that could restock garments in one or two days, or even in hours, as they are sold. Such logistic activities require different kinds of sourcing, production, and inventory management than are currently being used. A supply chain and logistics system must be integrated in order to reduce lead time. This imposes special requirements on the companies in the supply chain. It is an accepted fact in the industry that the demand for fashion products is difficult to forecast. Fashion markets have been characterized as open systems that are often chaotic (Christopher et al., 2004). This philosophy can have a negative impact on revenue because of the lead times necessitated by long-range forecasts ahead of sales campaigns. The danger to source production in low-income countries months before the season is an excess of inventory, a greater number of products that must eventually be sold at discounted prices, the risk that customers cannot find what they want in the shop, and ultimately a loss of profit (Mattila, et al., 2002).

Christopher and Peck (1997) list three dimensions of time-based consumption: *time to market*, or how long it takes a business to recognize a market opportunity, translate it into a product or service, and bring it to the market; *time to serve*, or how long it takes to secure a customer's order and deliver or install the product to the customer's satisfaction; and *time to react*, or how long it

takes to adjust the output of the business in response to volatile demand, that is, how quickly the supply “tap” can be turned on and off. It is of paramount importance to keep time to market as short as possible if one is to fulfil customer demand (Christopher, 2000).

Four critical success factors can be identified for sourcing of seasonal products with a fashion content: forecast accuracy, process lead time, off-shore/local sourcing mix, and up-front/replenishment buying mix (Mattila, 1999). “High gross margins and customer service levels with as little inventory as possible” are essential for profitable retail fashion companies, according to (Mattila, King and Ojala 2002).

The disadvantage with production in Asia is that orders have to be sent in months ahead of retail marketing campaigns. Transportation is also a time and cost factor due to the distance between Asia and Europe. Another problem is that orders must be placed so far ahead of season that when the garments finally arrive they may be out of fashion and must be sold at a reduced price. In the fashion business demand changes rapidly, and having a short time to market is vital if a company is to remain competitive. Production and logistics systems are needed that can put merchandise on the shelf to fulfil customer’s desires at exactly the right time. The supply chain needs to be time-based, customer-oriented, and agile in response to changes in demand (Hoover et al., 2001).

A study of Finnish retailing companies’ shows that the financial performance of traditional retailers with up-front buying is far poorer compared to retailers with in-season replenishment purchasing. (Mattila, King and Ojala 2002). Time is an important factor from demand to fulfilment, that is, from the moment customer request is identified until the customer buys the product. Another problem with textiles and apparel in the marketplace in Asia are environmental concerns with long distances and expensive shipping. Most of the cargo is shipped by sea, but air freight may be used

when time is pressing and goods must reach the market quickly.

3. From craft to customization in the fashion industry

Can knitting technology be applied in a retail concept for customized garments is one of the questions addressed in this article. Today MC has emerged as a combination of craft and mass production. The textile and fashion industry was one of the first to adopt this concept. Tseng and Piller (2003) cite three aspects of apparel that must be capable of modification to be successful in an MC scheme: fit (size and shape), function (adaptability to use), and design (taste and form). Products whose physical dimensions and functional properties can be changed are more suitable for customization than articles in which only color and pattern can be varied. Above all, a garment must fit a customer well. Fralix (2001) points to MC as the future direction of the fashion and apparel industry, but says that garment fit and color selection have tended to restrict its use. In order to produce a customized garment with a perfect fit, the client’s measurements must be determined accurately. At a retail location shop personnel can take customer measurements by hand, body scanning, or video camera (Lee and Chen, 1999). However, on-line shopping presents other challenges. Assuring the correct fit of a garment has been an obstacle for mail-order companies for decades. The same problem exists for MC over the Internet. Attempts have been made to solve this by having customers take their measurement themselves. The client is guided by a configurator on the company’s web site. An example of this procedure has been adopted by the on-line retailer Tailor Store, which sells shirts and other products. The configurator allows a customer to customize a shirt’s color, sleeve length, and other options. Body measurements are entered into the computer, manufacturing is done in a factory in Sri Lanka, and the customer receives the product in 10 to 15 days

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(Estephan and Uppström, 2008; Tailor Store, 2012).

For a business to be engaged in the sale of mass-customized products, the traditional structure of development, production, and distribution needs to be reformulated from a linear to a concurrent or parallel process (Anderson, 1997; Kincade and Regan et al., 2007). Closing the sale with a customer becomes one of the initial steps in a retail transaction, rather than the final one. From that point, streamlining time-consuming manufacturing operations after the point-of-sale is the key to shortening delivery time. Situating the manufacturing process after the point-of sale eliminates or reduces a company's inventory of ready-made garments and may increase its stock-turn percentage.

4. Complete garment knitting technology

Complete garment technology (seamless garment technology) was introduced on flat knitting machines in 1995, having evolved from developments in the 1980s. Since then, the technology has been considered an innovative process and is steadily increasing in fashion manufacturing use around the world (Choi and Powell, 2005; Hunter,

2004). Two stages preceded complete garment technology as illustrated in Figure 1. Cut & sew is a common method of making flat knitted garments (Choi, 2006). In this type of production, the entire garment is ready-made directly in the flat knitting machine. The different parts of the garment are produced in the right shape and knitted together with the trimmings, pockets, and other accessories. This technology makes it possible to eliminate cutting and sewing operations and produce 'on-demand' knitting, which can shorten lead times considerably (Legner, 2003).

Can this technology be applied in a MC concept in a retail environment? If this can be done, what impact will it have on the fashion logistics factors in the company?

When Shima Seiki launched their complete garment concept in 1995, they used the name WholeGarment (Spencer, 2001). Stoll from Germany named their production technology Knit & Wear (Choi and Powell, 2005). Both are brand names and registered trademarks. Since the different terms for making knitted garments with a minimum of post-knit operations can be confusing, we will refer to this flat knitting technology as *complete garment*.

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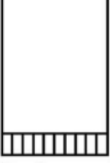



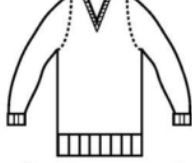





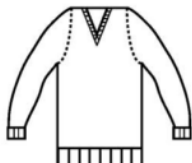
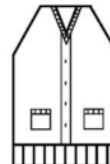



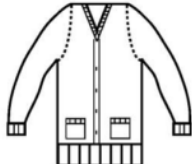
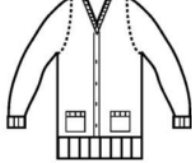
Cut & Sew	 Front panel	 Back panel	 Sleeve	 Sleeve	 Trim	 Ready garment
Fully Fashion	 Front panel	 Back panel	 Sleeve	 Sleeve	 Trim	 Ready garment
Integral knitting	 Front panel	 Back panel	 Sleeve	 Sleeve		 Ready garment
Complete garment	No cutting and no sewing process					 Complete garment

Figure 1. Production methods for flat knitted fashion products.

One of the retail concepts of the future may be MC. It offers a customer the opportunity to be a ‘designer for a day’; the experience of creating a unique product that has never been worn by anyone else.

Historically, the main reason for long lead times has been the presence of several *non-value-adding* activities throughout the supply pipeline. These activities may now be reduced or eliminated entirely, especially in the manufacturing process, without diminishing the total value added to the product. This has been the proven way forward in manufacturing: minimizing processes in order to make a product as efficiently and inexpensively as possible. The implementation of complete garment technology in combination with MC in a supply chain for fashion products may result in measurable benefits:

- Reduction in manufacturing lead times
- Garment custom-knitted close to point-of-sale
- Fast order fulfilment for the customer
- A positive customer shopping experience

If the production system and the supply chain are adapted to this new logistic concept, the time from yarn to finished garment will be greatly improved. The possibilities for complete garment technology, despite some current limitations in structures and patterns, are increasing every year. The question remains: Can MC, in combination with complete garment technology, be applied to all types of garments and products, or are there some garments it is not suitable for? For commercial reasons MC is probably most suitable for products in the middle and upper price range because the mass customization

process often makes them more expensive than mass-produced products. Almost all of the materials commonly used in flat knitting can be employed in making complete garments. Although MC in this research focuses on fashion garments, it can probably be applied to technical textiles made with complete garment knitting technology due to the ability of complete garment machines to produce three-dimensional structures with no waste of material. However, this is an application that remains to be developed and is beyond the scope of the present study.

5. Methodology

The methodology is based on a mixed method design and is the result of three independent and published studies presented in a doctoral thesis at XXX, author, (year), title. The main methods used to gather research material for the thesis have been the qualitative multiple-case study defined by Yin, (2009), quantitative simulations (Banks et al., 2004), and action research (Näslund, 2002).

The study in the article, title (Author, year). The case study presented in the article, “title”, was selected because it represents the only known example of a retail concept combining MC with complete garment

technology (Author, year). The case study in the article, “title,” examines another retail concept combining MC and flat knitting production (Larsson et al., 2012).

The objective was to gather sufficient information about processes, equipment, and lead times to inform the research problem. Interviews were conducted as conversations on-site, by telephone, or through e-mail. The responses were then analyzed. Studies of interaction between customers and store personnel in the retail store were conducted through interviews and participant observations during the co-design process. More information of data sources, measurements and input data for the simulation can be found in the three independent peer-reviewed articles and the thesis this paper is based on.

5.1 The research process and data analysis methods

The data analysis methods applied were (1) triangulation, (2) cross-case synthesis, and (3) value stream mapping. Data triangulation and value stream mapping were used in the analysis of RQ1 and cross-case synthesis of RQ2. The research process and analyze methods in this study consists of the following steps shown in Table 1.

Table 1. Research process and analyse methods.

Formulation of RQ1 and RQ2
Qualitative multiple-case study analysis of three constituent articles in a doctoral thesis
RQ1: Cross-case synthesis
RQ2: Data triangulation, value stream mapping
Answering research questions
Conclusion of the findings

5.1.1. Triangulation

Triangulation is a way of taking more than one approach to answering a research question in order to enhance the strength of the conclusion. The results may be double (or triple) checked, a process also called “cross examination” (Patton, 2002). Data

triangulation has been used for the analysis of RQ2 to compare the results from Articles 1, 2, and 3. Such a multiple approach combining quantitative and qualitative techniques provides a more complete set of findings than could be achieved through the use of a single method. Thus, triangulation is used in order to check the validity of the research data.

5.1.2. Value stream mapping analysis

Value stream mapping is a technique used to identify and eliminate waste in a production flow (Hines and Rich, 1997:46; Womack, 2006:145). In this study it was used for the evaluation of RQ 2 in article 1. The aim was to compare the time it takes to manufacture a complete garment knitted product with a fully-fashioned product. The value stream mapping is adapted for this purpose from the process activity mapping described by Hines & Rich (1997:47). This means that the flow in the manufacturing of a garment was studied and divided into sub-processes and preparation procedures. This was done for the fully-fashioned and complete garment machines separately and activities in each sub-process were noted and boundaries between processes determined. Lead times for each process were collected and the total lead time for complete garment and fully fashion manufacturing calculated. The mapping process was carried out as follows:

1. Process activity mapping
2. Boundaries between processes determined
3. Process times collected
4. Preparation times collected
5. Summary of lead time results
6. Comparison of results

Only processes in the value chain that differ between the two technologies were mapped.

5.1.3. Cross-case synthesis

Cross case synthesis refers to the analysis of two or more cases. The analysis is often easier and the findings more likely to be definitive than having only one case to examine. Although cases are treated separately, synthesizing the data substantiates the findings that seek to respond to the research questions (Yin, 2009). In Articles 1, 2, and 3, the case study method is applied by gathering data through simulation, interviews, and observations. Cross-case synthesis is used to analyze the data in those articles and form the basis for answering RQ1.

5.1.4 Summary of scope, aims and methods

The following Table 2 characterizes the scopes, aims, methods and the empirical sources used in the three articles appended to the thesis. The methods used in the papers have been selected to suit the scope and help answering the research questions in each individual article.

Table 2. Summary of scope, aims and methods in articles.

Article	Scope	Aim	Main methods	Empirical sources
1	Order fulfilment process with customization and production	<i>Develops, describes and simulates the performance</i> of a store and production concept with complete garment technology	Case study, action research, simulation	Knit-on-Demand project
2	Co-design and production process	<i>Describes and evaluates</i> a customization concept and its performance	Case study, interviews, observation, SWOT ^a analysis	Shima Seiki; Factory Boutique Shima
3	Knit-on-Demand research project	<i>Maps</i> Knit-on-Demand supply chain	Case study, value stream mapping	Knit-on-Demand project

^a SWOT (Strengths–Weaknesses–Opportunities–Threats)

6. Results

6.1 Study 1

6.1.1. Purpose and overview

Study 1 presents a design, production, and shop model for the “Knit-on-Demand” concept to show how complete garment knitting technology may be used for customized products (Author, year). A business model with production equipment located in or adjacent to a retail store is presented, shown in Figure 2. Customers are involved in the design process and garments are customized to fulfil actual demand. A lead time simulation of design and production processes in the shop concept is outlined. The method used is based on the

Knit-on- Demand project, whose components are examined in detail with respect to processes, equipment, and lead times. Data source, measurements and input data for the simulations were tested on the equipment for both design and production processes. Production lead time data is based on information from machine equipment companies and our own trials conducted at the Swedish School of Textiles. Data of customers entering store is based on a study at the fashion shop where Knit on Demand shop is to be situated. The results of these tests provided information about lead times for all operations involved in manufacturing the product as shown in table 3. That data formed the basis for the computer simulation that was modelled on customer demand.



Figure 2. Initial model of Knit-on-Demand store (Larsson, 2011).

In the Knit Production Section, an item configured by the customer would be manufactured from yarn to complete garment

in an interval of time that would depend on the material chosen, style, attachments, etc.

Table 3. Design-in-Shop, preparation, and process lead times.

Process	Knitting	Washing		Drying	Steaming	Sewing	Embroidery	Total process time	
Preparation	5	1		1	1	1	2.5	11.5	
Process time	55*	36	14	30	4	5	16	176	154
Total lead time	60	37	15	31	5	6	18,5	187.5	165.5

* Knitting time is triangular, i.e., distributed between 35 and 70 minutes with a mode (most likely value) of 55 minutes, due to varying knitting times for different models and allowance for thread breaks or errors.

6.1.2 Principal findings

The result of the simulation shows that demand fulfilment time would be from 120 and 301 minutes. A client could receive their customized item in 2 to 5 hours. The calculation also assumes no waiting time and no queues in the shop. The efficiency of the knitting machines ranges from 79.1% to 90.0% (average 86.0%) a relatively high degree of utilization. To improve the efficiency of the knitting machines, their set-up time must be minimized. The Knit-on-Demand concept shows an alternative way for American and European knit fashion producers to shift from mass production to MC, rather than outsourcing their manufacturing to low-income countries.

6.2 Study 2

6.2.1. Purpose and overview

The aim was to examine the way complete garment knitting technology has been used for MC of knitted products in Factory Boutique Shimas's design and production concept in Wakayama, Japan (Author, year). Customization rests on collaboration between a customer and a sales assistant. Several options are presented in the choice of style, material, size, trimmings, and color. Swatches of fabric, fashion magazines, and yarn color charts are available in the store to inspire customers to design a product. A

selection of garments of various types and sizes is also on hand to support the client during the customization process. The configuration or co-design phase is a process in which the customer navigates a series of options. The shop assistant writes or draws information on a customization form that later becomes the basis for manufacturing the garment. When structures, patterns, colors, and all other options have been selected, a Computer-Assisted Design (CAD) system simulates the appearance of the completed garment. The manufacturing itself takes place after the client has purchased and paid for the product. Thus, nothing is produced until it has been ordered and paid for, and so the percentage of garments sold at full price (sell-through) is much higher than for a business model where garments are produced in advance of being sold (Mattila, 1999).

6.2.2 Principal findings

The quantitative data in Table 4 indicates that the important fashion logistics factors for success (sell-through, lost sales, and stock turn) may be more positive for Factory Boutique Shima than they are for traditional fashion retailing companies. The data presented shows that the sell-through factor is from 90% to 100%, compared to an average sell-through of 65% to 70% in ordinary fashion retailing (Mattila, King and Ojala, 2002).

Table 2. Critical fashion logistics factors of success.

<i>Success factors</i>	<i>Ordinary fashion retailing</i>	<i>Factory Boutique Shima</i>
Sell-through	65-70%	90% to 100%
Lost sales	20%	Very few lost sales
Stock turn	4 times per year	Very high

The high sell-through percentage is due to the fact that nothing is produced that is not sold. Only customers dissatisfied with their garments will lower this percentage. Lost sales will be minimized because garments are generally customized, thereby increasing a client's likelihood of satisfaction.

A traditional retailing company that turns around its stock four times per year has a great deal of money tied up in inventory, thus negatively affecting its profitability. The stock turnaround for Factory Boutique Shima is much greater because only such raw materials as yarn and trim, but no ready-made garments, are kept in inventory. Complete garment technology also makes it possible to produce a garment faster than by conventional methods. It therefore lends itself to the future development of MC concepts of flat-knitted fashion products. Nevertheless, our analysis also showed limited interest in the market for the customization of coarse-knitted garments. This may be due to the time-consuming, personnel-intensive co-design process, which, if improved, might encourage the spread of the MC concept.

6.3 Study 3

6.3.1 Purpose and overview

The purpose of the third study was to describe the supply chain of the a customization, on-demand concept, conducted by The Swedish School of Textiles in close collaboration with a knitting company, Ivanhoe AB and SOMconcept AB, a retailer of tailored fashion in Stockholm (Larsson, 2012). It examines the customization process, technology systems, and logistics. The

purpose was to map the customization concept in the store and the entire supply chain. A value-stream mapping technique was used to identify waste in the production chain. The study begins with a client entering the store and purchasing a garment, then follows the order back to the customer order decoupling defined in logistics as the point in the value chain where a product is linked to a specific customer order (Olhager, 2012). In this case the order form the basis of a fully-fashioned garment with a cut & sew neck. The study traces the process until the garment is delivered to the customer.

6.3.2 Principal findings

The total value adding time in the production process was 126 minutes for a fully-fashioned garment with neck produced by cut & sew technique. Factoring in set-up and waiting, production lead time was 136.5 minutes. In the knitting production step, the allowance is 100% due to downtime, set-up time, and problems that might occur in manufacturing a garment. The total lead time equaled 179.7 minutes.

Delivery time is one or two days to stores or directly to customers. The total lead time from customer order to delivery varies from one to three weeks. The target is to reduce throughput time in the factory to less than five days, thus decreasing total lead time to one week.

The analysis of the customization process showed that most customers make minor size adjustments to garments, supporting the market need for MC knitwear. Since this was the initiation of a new business concept, it

was not known what the best design, production, or logistic solution would be. The method chosen by the research team, the production manager of the knitting company, and the retail owner offered the best trade-off between design flexibility, manufacturability, and aesthetics.

7. Analysis and discussion

The purpose of this article is to bridge the gap and study the fashion logistics effects of combining complete garment knitting technology, fashion logistics and MC. The research questions in the beginning of this article are answered by evaluating the results of three studies presented in three independent articles. The results of the studies that this article is based on are shown in Table 5.

Table 5. Relationship between the research questions and the articles.

	RQ2	RQ2	RQ2	RQ2	RQ1	RQ1	RQ1	RQ1
Article #	<i>Demand fulfilment time</i>	<i>Sell-through</i>	<i>Lost sales</i>	<i>Stock turn</i>	<i>Manual Co-design</i>	<i>Digital Co-design</i>	<i>Production on the premises</i>	<i>Production further away from the store</i>
1	X	X		X		X	X	
2	X	X	X	X	X		X	
3	X	X	X	X	X			X

7.1 Analysis of research question 1

A cross-case synthesis was performed to analyze data and answer RQ1. The case study method is applied in Articles 1, 2, 4, and 3. It consists of gathering data along with simulations, interviews, and observations. The synthesis was performed as illustrated in Table 6.

RQ 1: How can complete garment knitting technology be applied in a retail concept for customized garments?

A retail concept for customized knitted garments can be applied in two ways: a retail store with knitting machines on the premises (Article) or at a near-by location (Article 2)

can realize such advantages as 1) high sell-through percentage, 2) short lead times, 3) few lost sales, and 4) high stock turn. Much of the clothing we wear today is made in Asia in low-cost manufacturing facilities, resulting in fierce industry competition. One way to stimulate profitability may be to offer prospective customers something new by involving them in the design process. MC may be one answer. A customized garment can be created on-screen or on paper, and if the customer finds the result satisfactory and the garment is bought, production can begin immediately. The customer may even be able to watch the entire process from yarn to ready-made garment. Such a store visit will be a memorable experience, unlike conventional shopping.

Table 6. Cross-case synthesis of data in analysis of RQ 1.

Data (factor) / article	1	2	3
<i>Manufacturing on the premises or near-by</i>	X	X	
<i>Manufacturing further away from the store</i>			X
<i>The use of manual co-design</i>	X		
<i>The use of digital co-design</i>		X	X

A MC concept can also be launched with production facilities off-site, as in the SOMconcept store in Study 3, where the custom-made garment is shipped to the customer by express mail. This kind of collaboration between a retailer and a manufacturer can serve to gain positive effects to both companies.

All studies in this paper involved similar fashion logistics factors, lead time, sell-through, lost sales and stock turn. The shortest lead time in the simulation was 3 hours from design to delivery of a ready-made garment (Article 1). Factory Boutique Shima in Article 2 delivered a garment in 3 to 10 days, compared to 1 to 3 weeks in the Knit-on-Demand project (Article 3). Three weeks is still a relatively short lead time compared to what many mass producers can achieve. The result in Study 3 indicated a high sell-through percentage, few lost sales, and a high stock turn, as in Study 1 and 2. Finally, complete garment technology in combination with MC may require less retail showroom space for finished goods, resulting in savings in areas with high rents.

7.1.1. Manual- or digital co-design?

In MC of knitted products the co-design or interaction process between the company and the customer is an important process. This process in the MC of knitted fashion garments may function either in manual or digital mode. A cross-case analysis was done to analyze data in Articles 1, 2 and 3.

Manual co-design is an interaction between the client and a shop assistant in designing a garment without the aid of a digital tool. This type of co-design offers certain advantages, as has been shown in the case study of

Factory Boutique Shima, which uses a manual procedure described in Article 2. In this collaborative endeavor, the client is given the full attention of one or two shop assistants. Body measurements are taken to assure a perfect fit, and colors, patterns, structures, and attachments are selected in consultation with the store personnel – an interaction that customers perceived as positive. Lampel and Mintzberg (1996) call this “tailored customization”: the company shows the buyer a prototype and then modifies it to the customer’s preferences. A similar dialogue with the customer is termed the “collaborative” approach by Gilmore and Pine (1997).

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The simulations presented in Article 1 indicate the problem inherent in manual co-design is the limited number of customers who can be served at any one time. Perhaps this can be remedied by scheduling appointments, as people are in the habit of doing with their hairdresser or tailor. If the co-design process can be planned in advance, client frustration while waiting to be served can be minimized.

Digital co-design incorporates a digital tool in the interaction between the client and a shop assistant in designing a garment. The interface between the company and the customer is a crucial process in MC. Customer satisfaction depends on obtaining accurate body measurements and getting the computer screen to display the true color of the finished garment.

The MC of complete knitted garments is made more efficient through the use of a co-design configurator. Analysis of the manual and digital customization concepts and the simulations in Article 1 show the strength of

such a tool, which is IT-based (Bourke, 2000; Franke & Piller, 2003; Weston, 1997). More customers can be served via computer co-design than by a manual process, reducing the number of store personnel involved and potentially lowering costs. In addition, a configuration tool enables customization over the Internet, allowing a retailer to engage in e-marketing.

7.2 Analysis of research question 2

One purpose of this article was to bridge the gap and study the fashion logistics effects of

combining complete garment knitting technology, fashion logistics and MC.

RQ 2: *What are the fashion logistic effects of combining complete garment technology and MC?*

The triangulation results presented in Table 7 show that the fashion logistic performance factors in the articles correspond with one another. The reliability of the results in Article 1, however, may be open to discussion because it results from a simulation rather than an actual case with real customers, as in Articles 2 and 3.

Table 7. Triangulation of methods in Research Question One (RQ1).

Art.	Method	Demand fulfilment Time	Sell-through Percentage	Lost sales	Stock turn
1	Simulation, action research	Ready-made product to customer in 3 to 5 hours	High sell-through		
2	Case study with interviews and observations	Ready-made product to customer in 3 to 10 days	High sell-through	Few sales lost	High stock turn
3	Case study, action research, interviews	Ready-made product to customer in 1 to 3 weeks	High sell-through	Few sales lost	High stock turn
Results		Corresponds	Corresponds	Corresponds	Corresponds

7.2.1 Demand fulfilment time

Complete garment technology has been said to reduce manufacturing time and produce a knitted garment faster than by conventional methods (Legner, 2003; Choi, 2006). Only if production is optimized by restricting the number of non-value-added activities can the complete garment machine accelerate the manufacture of a garment. Demand fulfilment time may be subdivided into design time, production time, and transportation time. These consist of value-added and non-value added time. Value-added time is an interval in which a process such as knitting, sewing, or dyeing a garment takes place that adds something of value to

the product. Non-value added time is a period of waiting between value-added processes (Christopher, 2000).

Study 1 presented a business model for mass customized garments using complete garment production equipment located in the retail store. Customers were involved in the design process and garments were customized on-site to fulfil actual demand. A lead time simulation of the design and production stages showed that a customer could have a self- designed garment in 3 to 5 hours.

In Study 2 Factory Boutique Shima, whose operation used such complete garment

technology for customization, was analyzed, although their manufacturing facility was located off the premises. By contrast to our simulation, they delivered a self-designed garment to a customer in 3 to 10 days after it was ordered, depending on production time and shipping destination. In the final SOMconcept example presented in Study 3 (based on cut & sew and fully-fashioned manufacturing techniques) the total lead time from customer order to delivery varied from 1 to 3 weeks.

Our research shows that the fastest fulfilment time is achieved when the production of the garment can start immediately after point-of-sale, as presented in Study 1, and this can be achieved if production equipment is in the store, at a nearby factory, or at another location linked by express delivery services (Study 3). Even a demand fulfilment time of 3 weeks for customized garments is significantly shorter than the average for mass produced products, which in many cases can require a lead time of 40 weeks or more (Lowson, King and Hunter, 1999).

7.2.2 Sell-through percentage

All the three studies shows that a knitted garment may be customized, manufactured to order, and delivered within 3 hours to 3 weeks. As shown in the simulation in Study 1, a delivery time of 3 hours can be achieved if everything is optimized in the customization and manufacturing process, and there is no waiting time in-between. This would revolutionize garment manufacturing, just as same-day dry cleaning revolutionized a related sector of the overall business.

Data presented in the Factory Boutique Shima case shows that the sell-through factor was between 90% and 100%, compared to the average sell-through of 65% to 70% in ordinary fashion retailing. This is an effect of MC more than the use of complete garment knitting machines. The high sell-through percentage indicated in the case studies 2 and 3 can be attributed to the MC concept: production begins almost immediately after

the point-of-sale. Although a high sell-through percentage is not directly visible in the simulation in Study 1, having a set-up that incorporates MC and expeditious manufacturing after a garment is sold may positively influence the sell-through.

7.2.3 Lost sales

Lost sales is a ratio that is difficult to measure because one cannot know whether a customer has any intention of buying (Mattila, 1999). Interviews with store personnel at Factory Boutique Shima during our case in study number 2 indicated that many of the people who visited the store to browse also began to customize a garment, and all those who started to design a product bought it in the end – a very positive outcome for the retailer.

Because the MC concept offers the opportunity to select from a wide array of options, most customers will be able to find something they like. In the SOMconcept example in Study 3, most customers who began to design a garment were pleased with the result because they obtained a garment that conformed to their exact measurements—something that would have been difficult to find in stores that only stocked mass-produced merchandise in standard sizes

7.2.4 Stock turn

An interview conducted with the managing director of Factory Boutique Shima in conjunction with Study 3 indicated that the company's stock turn was "very high" in comparison to ordinary fashion retailing. (A more precise value was not given because of confidentiality issues.) A traditional retailer that turns over its stock four times annually has a great deal invested in inventory, which negatively affects its profitability. The stock turn for a profitable mass customization company like Factory Boutique Shima can be much higher than the average figure cited above. The MC concept needs only relatively low-cost materials: (yarn, buttons, trimmings, and labels) to be kept in

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inventory; the shop has no ready-made garments in stock. Unlike other retail operations, everything the company produces has already been pre-sold. In the case of cut & sew and fully-fashioned production techniques, an inventory of semi-finished products often accumulates between the processes, as unfinished garments await cutting or sewing. This amounts to a great deal of product tied up in the manufacturing process. However, complete garment knitting, by making the entire product in one process, reduces inventory, eliminates much storage space, and affects stock turn positively. According to Lambert and Stock (1993), finished merchandise kept on the shelf is the most expensive form of inventory there is. The true annual cost of carrying inventory is at least 25% of its value (Lambert & Stock, 1993; Christopher & Gattorna, 2005). A high stock turn rate reduces a company's investment in inventory; minimizes its need for warehouse space; lowers interest, insurance, and other related inventory costs; and results in a higher return on invested capital (Mattila, 1999). Our study indicates that MC knitted products manufactured after point-of-sale have a positive impact on a company's stock turn rate, compared with conventional marketing of mass produced-products.

8. Conclusions

The intention of this article is to present three different studies, one simulation and two case studies examining various MC retail concepts in combination with complete garment technique in order to evaluate the performance of the fashion logistics effects. The result showed that MC of knitted products requires specialized production facilities located in the retail store, at a nearby facility, or at a remote location linked by good shipping facilities. If production takes place in the store, it is possible to customize and deliver a garment to the customer in 3 to 5 hours. If the garment is manufactured at another location, the total lead time from customer order to delivery can range from 1 to 3 weeks. Both systems operate within a

relatively short lead time compared with mass-produced products sold at ordinary fashion retailers. A demand fulfilment time of three hours gives advantage for a retailer. Customers who have a hand in the design process tend to anticipate the outcome positively, take ownership of the product in advance, and are less likely to return their purchase, even if it was bought on impulse. A customized garment that is designed, manufactured, and delivered in three to five hours, and that fits perfectly, will be welcomed by most customers, whose satisfaction will result in increased sales. Thus, the concept of MC and the technology of flat knitting may be combined to achieve fashion logistic possibilities far beyond what retailers could offer customers in the past.

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