



Feasibility of Fashion Remanufacturing

Organizing fashion value chains for circularity through remanufacturing (including redesign)

Authors: Rudrajeet Pal, Jonas Larsson, Håkan Torstensson, Mirja Scott

Executive summary

In recent years the increased awareness of the need for conservation of resources and environmental sustainability has brought a focus on the potential for a circular economy in textiles and fashion. Commissioned by the Region of Västra Götaland, a number of investigations were carried out during 2015-2019, related to redesign, reuse and recycling of textile materials and products, at the Swedish School of Textiles and Science Park Borås. These projects addressed measures and strategies that were considered essential for this purpose, i.e. collection and sorting, design for longevity and recyclability, remanufacturing, and a possible shift of selling offers from products to services and service systems, throughout with an aim to assess the feasibility of each such approach, technically and economically. The findings were consequently presented in a series of five reports, which are collected in this publication. It comprises the following titles:

1. Planning a Swedish Collection and Sorting Plant for Used Textiles – a feasibility study; and, as an annex, Collection and Legislation for Used Textiles and Clothing (commissioned by TEKO)
2. Feasibility of Conditional Design - organizing a circular textile value chain by design principles
3. **Feasibility of Fashion Remanufacturing - organizing fashion value chains for circularity through remanufacturing (including redesign)**
4. Feasibility of Servitization - transforming fashion value chains to circularity through service innovation

The objectives of the reports, where feasibility is a keyword, is to develop structures for circular processes in the textile industry, in order to create new business opportunities and use less planetary resources. The focus is to design for longevity, through conditional design, redesign and remanufacturing and service innovation, and to ensure that the resulting circular processes are technically, organizationally and economically feasible.

Planning a Swedish Collection and Sorting Plant for Used Textiles – a feasibility study

In the first report, the feasibility of collection and sorting of used textiles is assessed. The assessment was based on a model for the different flow directions in collection and sorting – collection by charity organizations, stores, municipalities etc. or directly from users, and sorting into export channels, second-hand stores, recycling and redesign facilities or even destruction by incineration. It was evident that realistic conditions, at that time (2015) at least, did not permit a profitable, fully commercial sorting facility. There was a need for further value-adding features, which must be developed in order to ensure the feasibility of such a centralized facility. Critical success factors, as proposed, are the following.

Voluntary and subsidized work is essential for economic feasibility, and must be supported by legislation, occupational measures or general practice. 2. Increased prime quality in incoming material will raise the income level of sold fractions. There are ways to achieve this, of which one is to convince consumers of providing less used material for collection – perhaps at the cost of shorter firsthand use. Another possibility is a sharing agreement with the charities, which carry out the first-tier sorting. It involves also measures to enable consumers to make more educated decisions. A certification system may also be helpful to achieve better quality. New actors should be encouraged to join the market. 3. Increased productivity in the

sorting centre. 4. Increased value of output can otherwise be achieved by innovative sorting, cleaning, redesign and remanufacturing methods and development of new products. 5. Automated sorting may become increasingly appealing, as new sensors and devices for image-processing, identification, robotics and affordable control units become available. Technology development is needed regarding inexpensive sensors for identifying toxic additives in textiles and for fibre contents. 6. New business models, for example streamlined selling/purchasing by agents, who also provide training, packing etc., web services for used textiles brokerage, or financial recalculation of sustainability values, may become established. 7. Provision of parallel technical and administrative services, such as making a test bed available for new development projects, may as well be an opportunity.

Collection and Legislation for Used Textiles and Clothing

In addition to the report on collection and sorting a meta-analysis of the present situation of the used clothing network in six countries is presented in the second report. The analysis for each country comprises the total consumption of clothing, the collection structure, actors and volumes, a map of the reused clothing network, legislation, taxation, and revenue in the value chain.

The presence of large unified sorting centres increases the volume of used textiles in the market. Used textiles collection, in all the countries, is mainly arranged via traditional collection points like charities, textile banks, door-to-door etc. In-store collection and over-the-counter collections has increased collections in recent years. Sorting of the collected items typically takes place in domestic sorting plants with clearly defined sorting criteria. On an average ~10% of the sorted clothes are re-used in the native country of consumption while nearly 80% is exported to Africa and Asia.

Legislation around used clothing has been observed to be either mandatory or voluntary. In France, a mandatory Extended Producer Responsibility (EPR) scheme has been introduced since 2008, while the other countries have a voluntary EPR. However, certain bodies exist, responsible for setting out directives, guidelines and frameworks for their voluntary members. Taxation on used clothes is mainly in the form of VAT, however the charities are mostly exempted. Waste fees for post-consumer textile waste or landfill taxes exist in almost all the six countries.

Feasibility of Conditional Design - organizing a circular textile value chain by design principles

Conditional design is a concept that involves defining systematically the design elements that are relevant to apply in the design process for both longevity and recyclability. The report on conditional design focuses on the feasibility of service innovation, while intending to answer the following issues, having also in mind to maintain or increase the attractiveness of the products: 1) Can the design/construction phase decisively influence the characteristics of the product, so that the prerequisites for circular, sustainable flows will be significantly improved? 2) Which are then the key critical factors? 3) What is the future for different scenarios? 4) What is in that case a feasible way out for the concrete implementation of a strategy that positively affects the entire textile value chain?

It implies several actions, which can be carried out within a relatively short time frame. They include applying design principles of mono-material choices, modular design and redirecting the design of garments as a process that goes on during the life of the product (i.e. incremental design). It is however clear that it will take considerable time to form the conditional design processes into a mainstream principle for large volumes. The development and implementation of such principles will nevertheless have the impact of creating new innovation products and create new interesting business models, resulting in a growing small and local industry sector. Regional assets can be instrumental in the movement towards circularity, such as an educational centre for the implementation of design actions for synthesizing in value chains, development of media and communication addressing design for circularity in consumers' minds, or the establishment of an arena and facilities for realizing new ideas within the sector.

Critical success factors for design in relation to circularity are thus the following, 1) education of designers and design managers in all issues concerning the implications of design in achieving longevity and circularity, 2) development of a classification system covering design conditions for circularity, to enable the identification of the products already at the design phase; the recognition of the products in sorting phases enables automatic sorting for specific recycling processes, 3) further development of sorting (automatic) systems, 4) further R&D activities in all aspects of recycling processes, 5) further development of incremental design approaches and associated business models, aiming at longevity, and 6) development of an arena with the aim to inspire and educate designers to really demonstrate design's power to synthesize, i.e. identify problems – generate ideas – test the ideas – realize the ideas.

Feasibility of Fashion Remanufacturing - organizing fashion value chains for circularity through remanufacturing (including redesign)

Remanufacturing is practiced only at a very small scale in the fashion industry, despite the increasing need for a development towards dematerialization, higher revalue addition, ways to generate a high profit margin, and at the same time create more employment. A net positive environmental impact however, can only be made through remanufacturing at a larger scale. Yet, research investigations on this matter are insufficient, and knowledge of the practices regarding new value chain models, the associated processes and designers' approach to the product development process is still limited.

The report, based on three participatory action projects, aims to investigate how remanufacturing can be made feasible industrially, for sustainable competitiveness in the fashion industry, through detailed observation of a fairly large and successfully operating remanufacturing business. Key decision elements in different fashion remanufacturing value chain models, the associated critical success factors and the feasibility of fashion remanufacturing are addressed here. Three different fashion remanufacturing models were selected and analysed, namely scaled remanufacturing, distributed redesign and PSS (product service system) redesign-as-a-service. The study identifies the key decision making variables in each of these models, the critical success factors and also in connection assessing the feasibility of each model by constructing various scenarios. It is noted that there is currently no certification system or standard for remanufactured fashion products, which challenges their legitimacy.

Critical success factors for scaled fashion remanufacturing comprise the fraction of input materials obtained for remanufacturing (now very small), yield of remanufacturing processes (now low), remanufacturing process costs (now requiring subsidized workforce and zero cost of material), remanufacturing lead times (needing new tools and technologies) and market price of the remanufactured items. The future potential for scaling up fashion remanufacturing is likely dependent on growing from a redesign studio concept towards a mini-factory. To fuel such mini-factory key requirements comprise the supply of good quality material in considerable volume, high productivity and flexible remanufacturing systems and high demand and price propositions for the remanufactured products. Fashion remanufacturers should also consider collaborating with other collecting organizations, e.g. fashion retailers, acquiring more prime material input, creating a branding strategy and identifying 'new' customer segments, creating innovative design ideas, targeting more and innovative sales channels and, in order to synchronize the supply and demand, also extra resources, 'new' technologies (for disassembly, pattern development and cutting, manufacturing), and flexible remanufacturing systems.

The critical success factors for distributed fashion redesign comprise material cost (which may vary widely), material usage, redesign process cost and lead time, and subsidies obtainable. The future potential for establishing distributed fashion redesign is likely dependent on creating a strong inter-connected network of suppliers and value-adders regionally. Educational efforts are needed, also primarily in circular product development and design, circular production processes, and in circular local flows and establishment of collaborative networks. The critical success factors for PSS redesign-as-a-service are identified as direct process costs, overhead costs, customers' willingness to pay, and PSS lead time. The future potential here is in developing both the technical solution and improving the customer satisfaction in a larger retail setting, for example by direct-to-garment printing or fun features for customers, like artwork, 3D visualizations, customization features, etc.

Feasibility of Servitization - transforming fashion value chains to circularity through service innovation

Servitization is a growing phenomenon to improve resource efficiency, leading to positive effects for the environmental and for society. It stands for the innovation of an organization's capabilities and processes to create mutual value through a shift from selling products to selling product service systems. In this context, product-service systems are one of the most effective instruments to attain a resource-efficient circular economy. It combines design principles, technology considerations, and marketing strategies into a business model for extending the useful life of a garment. In particular, the economic implications and feasibility will be assessed for such a business model, taking into account crucial factors, such as logistics flow, quality factors, key performance indicators (societal, environmental, economic), life-cycle discussions and the required competence-building. Servitization combines design principles, technology considerations, and marketing strategies into a business model for extending the useful life of a garment. This report demonstrates an economic feasibility assessment, by examining two examples of servitization for circularity in the apparel and fashion industry, and outlining potential business models, along with prospects for future research. Core elements for decision-making and the economic implications and feasibility of extending the useful life of a garment through servitization are identified here. Decision variables are typically choice of partnerships and scenarios, related to distribution channels,

cost structures and revenue streams for creating additional value through extended producer responsibility, and how the servitization offer is marketed and communicated to customers. Critical success factors comprise direct service costs, partnership scenarios and the customers' willingness to pay, in the redesign-as-a-service scenario also direct process costs, overhead costs, customers' willingness to pay and PSS lead time.

Borås, 15 December 2019

The authors

Foreword

During 2014-2015 we carried out, on behalf of the Västra Götaland region (VGR), a pi-lot study regarding the potential for re-design, as well as a feasibility study titled Re:de-sign – planning a Swedish collection and sorting plant for used textiles. When the project was ex-panded in 2016 to a three-year project Re:Textile (<http://retextile.se/>), it was decided to con-tinue the series with three new studies as a logical consequence of the results obtained in previous work.

Three areas were defined as follows:

1. Re:Textile - Feasibility of conditional design (finalized in Feb 2017), 2. The feasibility of redesign manufacturing, and 3. The feasibility of service innovations.

This report is a deliverable towards the second feasibility study on redesign manufacturing, aimed at its partial fulfillment, where the potential for industrial models for remanufacturing (including redesign) are investigated in fashion context.

We are grateful to VGR for the opportunity to carry out these studies based on the directions set in the current project proposal. The trend towards circularity is fast, and pre-conditions for the feasibility of project ideas are changing rapidly. The report takes this into consideration and has been designed to allow feasibility to be measured with varia-ble parameters in the models.

Special thanks to the entire crew of Case 1, Case 2 (Lindex and associated project partners), and Case 3 (Monki and associated project partners), who has been wonderful in accommo-dating us in conducting the investigation at their facilities over a long period and in supporting with all possible information required to realize this study.

In addition, we would like to thank our Textile Management students Armaghan Chizarifard and Yassaman Samie for conducting Case 1 research, Sophie-Marie Ertelt, Ecaterina Guzun, and Mirja Scott for conducting Case 3 research, and colleagues Anna-Karin Reis (ex. Marketplace Borås) and Adrian Zethraeus (Science Park Borås) for conducting Case 2 research.

Relevant Links:

For Case 2: <http://retextile.se/portfolio-item/lindex-redesign-projekt/>

Main document for Case 3:

<http://hb.diva-portal.org/smash/record.jsf?pid=diva2%3A1262696&dsid=3777>

The report is written in English to cater to a wider readership.

Rudrajeet Pal, Associate Professor, Textile Management

Jonas Larsson, Assistant Professor, Textile Management

Håkan Torstensson, Senior Professor, Textile Management

Mirja Scott, M.Sc. Researcher, Textile Management

Abstract

Despite the increasing need of remanufacturing in fashion industry for leading towards dematerialization, higher revalue addition, possibility to generate highest profit margin, along with create more employment in the industry, it is still practiced on a very small scale. A net-positive environmental impact however, can only be made through remanufacturing with higher scale. However research investigations on this matter are insufficient and knowledge of the practices on new value chain models, associated processes, and designers' approach to the product development process is still limited.

The general aim of this study is to investigate how remanufacturing can be made feasible industrially for sustainable competitiveness in the fashion industry.

This feasibility study was conducted by Re:Textile group in collaboration with several Swedish players, e.g. fashion branded retailers, local textile and apparel manufacturers, and charities. 3 participatory action projects were developed between 2017-2018 in order to elucidate the different possibilities of organizing remanufacturing in fashion industry context, and check the viability of these options. 3 different fashion remanufacturing models were considered to be interesting via literature review, and were planned for further exploration. These were: scaled remanufacturing, distributed rede-sign and PSS redesign-as-a-service. The study identifies the key decision making variables in each of these models, the critical success factors and also in connection assessing the feasibility of each model by constructing various scenarios.

Table of contents

| | |
|--|-----------|
| 1. Introduction | 12 |
| 1.1. Background and Motivation | 12 |
| 1.2. Key Questions Raised | 14 |
| 2. State-of-art on remanufacturing | 14 |
| 2.1. Remanufacturing in a wider context of CLSCs | 14 |
| 2.2. What is Remanufacturing? | 15 |
| 2.2.1. Difference between remanufacturing and other recovery options | 16 |
| 2.2.2. Remanufacturing process: A decision perspective | 17 |
| 2.2.3. Remanufactured products and design for remanufacturing | 18 |
| 2.3. Remanufacturing opportunities and challenges | 18 |
| 2.4. What is Fashion Remanufacturing: A state-of-art review | 19 |
| 2.4.1. Levelled quality and quantity of remanufacturing products | 21 |
| 2.4.2. Efficient remanufacturing process planning | 21 |
| 2.4.3. New business models | 21 |
| 3. Research methodology | 23 |
| 3.1. Data collection and analysis | 23 |
| 4. Case I – Scaled fashion remanufacturing | 25 |
| 4.1. Case description | 25 |
| 4.2. Description of remanufactured fashion products | 25 |
| 4.2.1. Remanufactured Product-Process Structure and Property Matrix | 25 |
| 4.3. Basic remanufacturing design and construction principles | 28 |
| 4.3.1. Full-disassembly/Full-reassembly | 28 |
| 4.3.2. Semi-disassembly/Semi-reassembly | 29 |
| 4.3.3. No-disassembly/Minor value adding | 30 |
| 4.4. Remanufacturing process description | 30 |
| 4.4.1. Fully-disassembly/Fully-Reassembly | 33 |
| 4.4.2. Semi-disassembly/Semi-Reassembly | 35 |
| 4.4.3. No disassembly/Minor value addition | 36 |
| 5. Case 2 - Distributed redesign | 38 |
| 5.1. Case description | 38 |
| 5.2. Description of redesigned fashion products | 39 |
| 5.3. Basic redesign and construction principles | 40 |
| 5.3.1. Denim jeans development | 40 |
| 5.3.2. Kimono development | 41 |
| 5.3.3. Bag development | 41 |
| 5.4. Redesign process description | 42 |
| 5.4.1. Denim jeans | 42 |
| 5.4.2. Kimono | 43 |
| 5.4.3. Bag | 46 |

| | |
|--|-----------|
| 6. Case 3 – PSS redesign-as-a-service | 48 |
| 6.1. Case description | 48 |
| 6.2. Description of PSS redesign-as-a-service products | 49 |
| 6.3. Basic PSS redesign-as-a-service and construction principles | 50 |
| 6.3.1. Blueprint | 50 |
| 6.4. PSS redesign process description | 51 |
| 7. Economic feasibility, a projection | 58 |
| 7.1. Model description | 58 |
| 7.2. Financial model for Case 1 | 58 |
| 7.3. Financial model for Case 2 | 65 |
| 7.3.1. Costs and price of the product | 65 |
| 7.3.2. Scenario-based feasibility assessment | 66 |
| 7.4. Financial model for Case 3 | 68 |
| 7.4.1. Costs and price of the redesign-as-a-service | 68 |
| 8. Remanufacturing fashion business models | 71 |
| 8.1. Business Model Canvas – Case 1 | 71 |
| 8.2. Business Model Canvas – Case 2 | 79 |
| 8.3. Business Model Canvas – Case 3 | 84 |
| 9. Legitimacy issues in fashion remanufacturing | 86 |
| 10. Analytical conclusion | 88 |
| 10.1. Key decision variables | 88 |
| 10.2. Critical success factors | 89 |
| 10.3. Feasibility assessment | 91 |
| 11. Future considerations and recommendations | 92 |
| 11.1. Scaled fashion remanufacturing | 92 |
| 11.2. Distributed redesign | 92 |
| 11.3. PSS redesign-as-a-service | 92 |
| 12. References | 93 |

1. Introduction

1.1. Background and Motivation

The fashion apparel industry by nature is a global industry with significant contribution towards world economic growth accounting for ~2 percent of the world's Gross Domestic Product (GDP). The global apparel industry over the last decade has experienced an unprecedented rate of growth (over 50 %) (Pulse of the Fashion Industry, 2017). This growth has led to a rapid increase of textile and apparel consumption and also of household waste (WRAP, 2014).

At the current trajectory of production and consumption of fashion apparel and footwear, it can be projected that the current global consumption amount of 62 million tons (in 2015) will increase by another 63% to 102 million tons by 2030. Niinimäki and Hassi (2011) recognize the rapidly changing fashion cycles besides unsustainable consumption habits of textile and apparel consumers to be the main cause. Unsustainable consumption and rapid disposal of clothes are the outcomes of cheap industrial mass production. In this respect, fast fashion leads retailers to sell large volumes of products at a low price range, thus resulting in higher frequency of fashion products being purchased by the consumers (DEFRA, 2007). 2000 onwards there has been an "explosive expansion" in fast fashion, led by the brands like H&M and Zara, resulting in nearly doubling the sales of clothing from \$1 trillion in 2002 to \$1.8 trillion in 2015 (projected to rise to \$2.1 trillion by 2025), doubling of clothing production from 2000 to 2014, while about 60% more clothing are being bought on an average with about half the lifespan as it was 15 years ago (Greenpeace, 2016)¹. In other words, the disposal and accumulation of clothing is a result of planned obsolescence, placed at the core of fashion (Hawley, 2008). Dissanayake and Sinha (2015) argue that fast changing trends of fashion products have resulted in high consumption rates and shortened lifespan for fashion products and thus increasing the volumes of postconsumer textile waste.

Consequently, the potential for harming the environment has raised as well (Dissanayake and Sinha, 2012). Given that the natural resources of the planet are already burdened, the projected rise in clothing consumption will increase the water consumption, energy emissions, and waste creation by 50%, 63%, and 62% respectively by 2030 (Pulse of the Fashion Industry, 2017).

Today, humankind produces 2.1 billion tons of waste per year. In terms of annual ecological footprint, the world's population already produces more than 1.6 times what the earth can absorb in the same timeframe. Assuming today's current solid waste during production and at end-of-use, the industry's waste will increase by about 60% between 2015 and 2030, with an additional new 57 million tons of waste generated annually. This brings the total level of fashion waste in 2030 to 148 million tonsequivalent to annual waste of 17.5 kg per capita across the planet. The vast majority of clothing waste ends up in landfills or is incinerated; globally, only 20% of clothing is collected for reuse or recycling.²

¹ <http://www.greenpeace.org/international/Global/international/briefings/toxics/2016/Fact-Sheet-Timeout-for-fast-fashion.pdf>

² Pulse of the Fashion Industry, 2017 Global Fashion Agenda & Boston Consulting Group. https://www.copenhagenfashionsummit.com/wp-content/uploads/2017/05/Pulse-of-the-Fashion-Industry_2017.pdf (Accessed June: 2017)

Increased volume of household textile waste and decreased quality of the thrown-away fabrics highlight the need for innovative yet efficient managing system aimed towards higher value recovery. While new fashion products are continuously purchased and useable clothing's are discarded, a strategy like fashion remanufacturing can aid the material recirculation with enhanced value being generated in this problematic landscape (Birtwistle and Moore, 2007; Dissanayake and Sinha, 2015). This highlights the importance of exploring alternative solutions (operations, business models and structures) for remanufacturing. The importance of fashion remanufacturing is highlighted in the literature as it extends the product lifecycle and maximizes the resources, energy and labor efficiency in production (Dissanayake and Sinha, 2015). Consequently remanufacturing results in minimization of soil contamination and air pollution caused by the dumped or incinerated textile waste, hence in the context of circular economy can deliver lower eco-costs of pollution. As can be noticed in other industries where remanufacturing has been embraced successfully, a rough assessment of resource impact of remanufacturing shows that it approximately uses 85% less energy than manufacturing (Steinhilper, 1998) and saves in excess of 800,000 tons CO₂ emissions per annum (Charter and Gray, 2008). The environmental benefits however are not only limited to this, the reduced material depletion places lesser demand for virgin materials such as virgin fibers and therefore the reduced demand for harmful chemicals like those used in dyeing and finishing of textiles have a great environmental advantage as well (Dissanayake and Sinha, 2015, Vogtlander et al. 2017). This is a key issue, as global shortage of raw material sooner or later will bring aggravate with higher imbalance between production and consumption rates and cycles.

Woolridge et al (2006) asserts that for every kilogram of cotton which is replaced by second hand clothing almost 65kWh energy is saved. Similarly, for each kilogram of polyester replaced by used polyester, 90kWh energy is saved. In addition to these benefits, Allwood et al. (2006) suggest that second hand clothes upgraded to a certain extent through remanufacturing, i.e. by replacing few panels of a dress with new fabrics etc., may provide a new look, aesthetics and customer value through such 'fashion upgrade'. This has encouraged many fashion designers to have a remanufacturing approach in their start-up businesses as a new opportunity. However, this business opportunity has been practiced mostly in niche market or on a small scale, therefore, the environmental benefits are insignificant.

Several challenges currently hinder fashion remanufacturing in reaching an industrial scale and in reaping the real benefits (Pal, 2016; Dissanayake and Sinha, 2015; Sinha et al., 2009). These are related to:

- **Product development principles:** Conventional garments are non-modular in design, unlike mobile phones or computers, making its dis- and re-assembly processes unproductive, less efficient and time-consuming. Further variability in type, style and composition limits repeatability of remanufacturing processes.
- **Quality:** In a throwaway society, garments are increasingly short life-cycled and can hardly survive the rigors of single lifetime.
- **Reverse logistics implementation:** Variability in both the volume and condition of the collected used clothes is extreme, in terms of quality and condition, cleanliness, making the process of remanufacturing difficult to formalize, optimize and scaleup.

- Skillset: Remanufacturing skills and knowledge are hard to find.
- Consumers, market and pricing: Price sensitivity of the fashion apparel consumers is high, hence for remanufactured products the sales volumes are still low due to their high price points generally coming due to lack of awareness of consumers. Further retailing of remanufactured clothes is difficult as this may conflict with the mainstream sales, marketing and pricing strategies of the retailers.

1.2. Key Questions Raised

As mentioned above, despite the existing elements, potential benefits and increasing need of remanufacturing in fashion industry for leading towards dematerialization, higher revalue addition, possibility to generate highest profit margin, along with create more employment in the industry, it is still practiced on a very small scale. A net-positive environmental impact however, can only be made through remanufacturing of greater volumes. However research investigations on this matter are insufficient and knowledge of the practices particularly on reverse logistics processes and designers' approach to the product development process is still limited (Dissanayake and Sinha, 2015).

Given this motivation, the purpose of this study is to make a feasibility analysis on fashion remanufacturing through detailed observation of a fairly large and successfully operating remanufacturing business. The key questions raised in this investigation are as follows:

How can remanufacturing be made feasible industrially for sustainable competitiveness in the fashion industry?

- a) What are the key decision elements in different fashion remanufacturing value chain models?
- b) Considering these decision elements, what are the critical success factors in fashion remanufacturing value chain?
- c) Based on these success factors, how is fashion remanufacturing made feasible?

2. State-of-art on remanufacturing

2.1. Remanufacturing in a wider context of CLSCs

Reverse logistics and closed-loop supply chain have attracted attention among both academia and practitioners in recent years due to the environmental, social, and economic issues of linear pattern of consumption (Govindan et al., 2015). Closed-loop supply chain is a new logistics system opposed to conventional open-loop supply chain which solely considers forward supply chain design and management activities, and refers to the entire lifecycle of the product and its circulation within the society for as long as possible, with the maximum product longevity coupled with the maximum efficient utilization of water, energy, chemicals and other resources through the entire life cycle along with the minimum waste production and least environmental damage and pollution (Ferguson, 2009, Sinha et al., 2016). It typically includes four types of recovery options: reuse, remanufacture, recycle and business returns. Additionally, other options for prolonging product lifecycle are restoration, refurbishing, and cannibalization. Most commonly these terms are differentiated in meaning, e.g. reconditioning, remanufacturing and cannibalization refer to high-efficiency recovery of the product as a whole, in parts or components (Gallo et al., 2012).

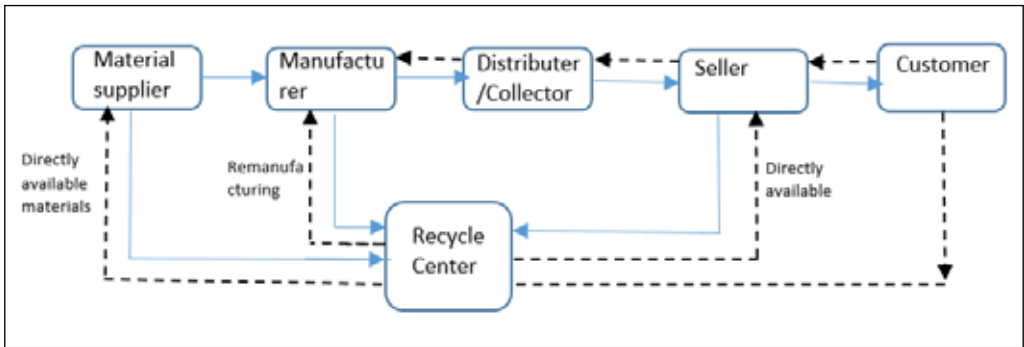


Figure 2.1. Closed loop supply chain network structure (Adapted from Wen-hui et al. 2011).

The concept of remanufacturing in closed-loop supply chain is a logistics process that integrates forward and reverse logistics flow by circulating the product acquired from the customer and moving it respectively to collectors/sellers, manufacturers, dealers, and back again to customers (Wen-hui et al., 2011). This way remanufacturing has become a critical element of circular economy, where products are developed, manufactured, used and recovered to prevent any sort of waste and reduce the extraction of raw materials; in Europe alone thus the remanufacturing industry is estimated to generate billions of euros yearly with significant environmental benefits (Kurilova-Palisaitiene et al., 2018).

2.2. What is Remanufacturing?

Literature reviewed reveals various definitions of remanufacturing however uncertainty over the definition creates confusion in conducting a concrete framework towards remanufacturing (Charter and Gray, 2008). To give an instance, it appears to be difficult to create a business model for remanufacturing in absence of clear understanding of the differentiation between remanufacturing and recycling. The recycling process is at the lowest level of recovery efficiency, it allows recovery of only raw materials but not the added value of production cycle (Gallo et al., 2012). Compared to that, remanufacturing retains higher original value of the product. According to Nasr and Thurston (2006), *'remanufacturing is typically a more efficient means of material recirculation than recycling. Remanufacturing retains more of the energy associated with the original conversion of raw materials to finished product'*. On a similar note, Sundin (2004) defines remanufacturing as an industrial process to restore the core part of products through passing several stages, e.g. inspection, disassembly, part replacement/refurbishment, cleaning, reassembly, and testing to ensure it meets the desired product standards. Often these series of manufacturing stages are applied to the end-of-use part or product in order to return it to like-new or even better performance.

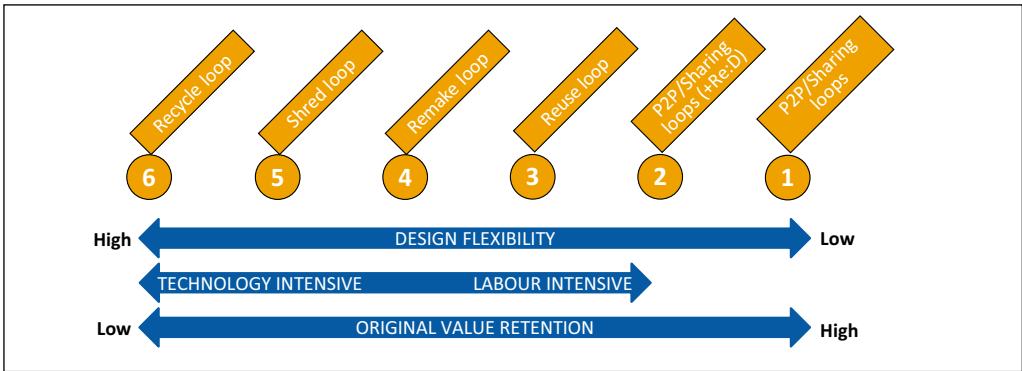


Figure 2.2. Key considerations in various closed loops. (Authors' viewpoint)

Remanufacturing is an important part of reverse logistics which recaptures and adds to the use value of the product (Charter and Gray, 2008). Based on the EU waste hierarchy (Palm, 2011) the preferred value recovery treatments are, i.e. prevention, reuse, materials recovery, energy recovery and landfill (in a decreasing order of preference as per EU directive). By considering the narrow capacity of waste treatment and impending resource scarcity challenge, remanufacturing is an advanced form of recycling that can result in improvement of environmental perception and corporate reputation and bring in financial benefits to the business (Wen-hui et al., 2011). Moreover, remanufacturing process is by far less expensive than production of a new product since many components of the used products are still functioning thus avoiding the need to procure them from suppliers (Ferguson, 2009). By replacing the use of virgin materials, remanufacturing can be recognized as one of the best methods for sustainable production and managing wastes (Krystofik et al., 2015). Wen-hui et al. (2011) state that the quality of a remanufactured product and its performance is not less than that of a new product, by considering the fact that it has lower costs, shorter production cycle and processing time, and lesser negative impacts on the environment compared to the production of new products.

However, majority of the original equipment manufacturers (OEMs) focus on production of new products and without dedicating much thought and resources to explore the potential of remanufacturing business opportunities. This can be largely attributed to the lack of adequate experience and infrastructure for the reverse logistics system especially for the collection process (Ferguson, 2009). Additionally due to globalization and new geographical map of production, most of the OEMs outsource and offshore their manufacturing thus it is often difficult to set up remanufacturing operation (due to lack of adequate manufacturing skills), unless they outsource their remanufacturing to lowest cost contract manufacturers which also means twice the cost of shipping, cost of collection and transportation of the remanufactured products to the markets where they will be sold (Ferguson, 2009). It is worth mentioning that unfamiliarity of remanufacturing operations by both parties results in less motivation towards their collaboration (Hermansson and Sundin, 2005).

2.2.1. Difference between remanufacturing and other recovery options

The concept of 're' is also associated with other recovery options such as refurbishment, reconditioning and repair; although they share various commonalities in the process with remanufacturing, they are fundamentally different in terms of warranty, final product performance and positioning in the material flow loop (Gallo et al., 2012; Charter and Gray, 2008).

On the same note, reconditioning returns a product functionally to almost same as new product condition but unlike remanufacturing, it might not necessarily provide warranty and the process might not include disassembly and cleaning of all parts of the products (Charter and Gray, 2008). Moreover, it can be said that remanufacturing is a process, a set of linked activities, rather than a single step aimed at restoring the performance of a product however repair or reuse are simply defined as an activity (Gallo et al., 2012).

2.2.2. Remanufacturing process: A decision perspective

The processes of remanufacturing and reverse logistics activities can be classified into collection, disassembly, inspection, sorting, cleaning, reprocessing, reassembly, checking, testing and redistribution (Charter and Gray, 2008; Sundin, 2004; Wen-hui et al., 2011). Although the market for remanufactured products seems promising, there is huge uncertainty in the entire remanufacturing reverse supply chain in terms of quantities and timing of returns, recovery time, cost, products quality and market demand (Ferguson, 2009). As a consequence, there is a lack of control over remanufacturing reverse supply chain and remanufacturers are faced with difficulties in decisionmaking and planning of production, inventory, demand, organizational model and network design (Gallo et al., 2012). Such lack of fixed product and process criteria for remanufacturing leads to development of rules of thumb-based heuristic model by some firms. To give an example, strategic decisions such as remanufactured products' price range, markets and distribution channels where they can be sold, are largely dependent upon the rules of thumb, which may otherwise increase the risk of product cannibalization (Ferguson, 2009). The price of remanufactured products has to be certain percentage lesser than the price of new products in the market (Valenta, 2004). If the products have more than 50% of the market share then it is not appropriate for remanufacturing since there is a higher possibility of cannibalization of the firm's new products (Ferguson, 2009). Yet another example is the disassembly stage which has a direct impact on the final product's quality and has a fixed point in upstream of the entire process. This part of remanufacturing process is highly time demanding and labor-intensive, and is also subjected to higher human error (Gallo et al., 2012). This makes disassembly a highly uncertain in terms of level, sequence and method for optimum disassembly (Mok et al., 1997; Priyono et al., 2013) – thus decision regarding these aspects being largely subjected to bounded rationality of the remanufacturers. Also note that the sequence of activities such as inspection, cleaning or testing that determines the quality standard of the remanufactured process and product depends upon the characteristics of the product, level of cleaning required, and the technology available for treatment – and in many cases is dependent on the remanufacturer's skills and experience. Over time, this demands a standardized quality inspection system. These suggest that heuristic-based decision-making perspective plays a vital role in the remanufacturing process. A concise model of key factors required for assessing the feasibility of remanufacturing is proposed in Goodall et al. (2014). Such decision making is required at all levels: strategic, tactical and operational, and impacts triple-bottom line sustainability. Economically, it is important to create higher remanufacturing value for the product and for the business, and at the same time ensure lower process costs. A large number of factors, related to product design, quality and process efficiency affects the cost. The environmental impacts of remanufacturing are related to prolonging the product lifetime; whilst environmental directives and legislations provide different incentives to many industrial sectors to conduct remanufacturing activities. Finally the social benefits of remanufacturing can be evaluated to be related to both human and societal aspects, that concerns additional job creation, improving skillsets in particular industry sectors, etc.

2.2.3. Remanufactured products and design for remanufacturing

Design for remanufacturing (DfRem) is the most effective approach to identify and prevent inefficiencies in remanufacturing, e.g. for identifying materials and forms appropriate for repetitive remanufacturing. By integrating the design processes, DfRem can aid a particular challenging stage of the remanufacturing process for instance, disassembly where products need to be design to be disassembled to separate components. For example, DfRem may result in creation of innovative solutions for the complex and critical stages of the remanufacturing process e.g. disassembly (Charter and Gray, 2008). Any product that can be manufactured by considering that the design of the product plays a significant role in optimization of the remanufacturing process can lead to development of value added business models (Charter and Gray, 2008).

To enable redesign and recycling at the end of the products' life, remanufacturing is guided by an assessment of product or component value over time and this value may vary depending on the market and material demand and supply, legislation and technological improvements (Charter and Gray, 2008). Effective application of remanufacturing, DfRem further needs to become an integral part of the product development process (Nasr and Thurston, 2006). In the reverse supply chain DfRem is also facilitated by proper design of the reverse logistics to guarantee the adequate return of used products (Nasr and Thurston, 2006). There are also the four most common properties for remanufactured products and components named as ease of access, ease of identification, wear resistance and ease of handling (Sundin, 2004). Sundin (2004) also points that DfRem boosts the decision making on EU waste management hierarchy to higher up alternative treatments over options such as recycling.

2.3. Remanufacturing opportunities and challenges

Opportunities

Implementation of remanufacturing as one of the most environmentally and economically efficient option of recovery treatment would offer multidimensional benefits to firms.

1. It helps to meet their social, environmental and legal responsibilities as well as reduce the risk of costly environmental regulatory restrictions and government mandated producer disposal fees (Ferguson, 2009; Rubio and Corominas, 2008).
2. Properly designed environmental legislations however would improve innovation capabilities and competitive advantages which will reduce remanufacturing costs, negative impacts on environment and increase the value of products to the customer (Porter and Linde, 1995). Innovative policies can optimize the value within used products and introduce new business opportunities to OEMs and third-party companies in reverse supply chain (Gallo et al. 2012). Thus, retailers and brands can share the risk of cannibalizing the sales of new products by collaborating with third parties (collectors and remanufacturers) (Ferguson, 2009).
3. Provide opportunity of accessing to a new market segment and customers who demand for environmentally friendly products and prefer a remanufactured product over a new product (Atasu et al., 2008; Ferguson, 2009). Eventually remanufacturers have the opportunity to sell its products via different channels, either in cooperation or in competition with the manufacturer (Wang et al., 2014). Higher the acceptance of remanufactured products is, the more the remanufacturer will be competitive with the manufacturers.

Goodall et al. (2014) provides a detailed review of the key remanufacturing techniques and tools, and how they influence triple bottom line sustainability.

Challenges

A recent study (Kurilova-Palisaitiene et al., 2018) based on a thorough literature review provides a three-level model of remanufacturing challenges. These refer to: (i) Industry level challenges related to legislation and environmental regulations, customer preferences, and technological changes, (ii) System level challenges from closed product life-cycle system perspective, e.g. those related to remanufacturing business model, marketing, material and information flows, demand-supply, company identity etc., and (iii) Process level challenges referring to those related to operations, process upgradation, costs, product cores, etc.

When it comes to decision making, remanufacturing mainly faces challenges that stems from uncertainty associated with product returns and lack of information (Goodall et al., 2014). Uncertainty in quantities and timing of returns, recovery time, cost, products quality and market demand (Ferguson, 2009) results in lack of control over remanufacturing reverse logistics and remanufacturers are faced with difficulties in decision-making and planning of production, inventory, demand, organizational model and network design management (Gallo et al., 2012).

Another key challenge is related to product cannibalization which refers to the reduction in demand of firm's new products as a result of the presence of remanufactured products in the same market (Wen-hui et al., 2011). Strategic decisions such as remanufactured products' price range, limits on the markets and distribution channels where they can be sold, and where the firm had less than 50% market share tend to reduce the risk of product cannibalization (Ferguson, 2009).

2.4. What is Fashion Remanufacturing: A state-of-art review

Remanufacturing fashion is a new and emerging phenomenon which aims at remaking of used clothes through various redesign possibilities so that they at least equals to newly manufactured garments in terms of quality. Dissanayake and Sinha (2015) defines it as fashion clothing that is constructed by using reclaimed fabrics, which can be either post-industrial or post-consumer waste, or a combination of both. Amongst other differences (see Dissanayake and Sinha 2015), what differentiates remanufactured fashion from that of upcycling is the focus towards process industrialization to reach certain degrees of business scalability. Other differences lie in terms of the design goal or strategy, the process approach, product end use or function, the material input and the need for a warranty.

The concept of fashion remanufacturing became more popular at the beginning of 21st century among sustainability oriented fashion designers. They applied this concept in order to develop sustainable collections out of post-consumer textile and clothing waste (Niinimäki and Hassi, 2011; Gwilt and Rissanen, 2011). Ever since then, this has been recognized as a new business opportunity. In general, extant literature highlights the process of remanufacturing garments, into two main processes of: (i) reverse logistics and (ii) product development. Reverse logistics process starts with retrieving the discarded garments from a number of sources, such as charities, consumers, retailers, waste collectors and sorting facilities, second-hand retailers and wholesalers, etc. This continues further with the sorting of the collected items on the basis of a number of criteria, like fabric type, color, and product category, e.g. trousers, dresses, etc. (Dissanayake and Sinha, 2015). Followed by an optional cleaning stage the sorted items are ready for remanufacturing – this is when the product development process initiates. The reverse logistics process also includes the final distribution, marketing and retailing of the remanufactured items.

Dissanayake and Sinha (2015) highlight a generic five step process underlying fashion remanufacturing product development, these are:

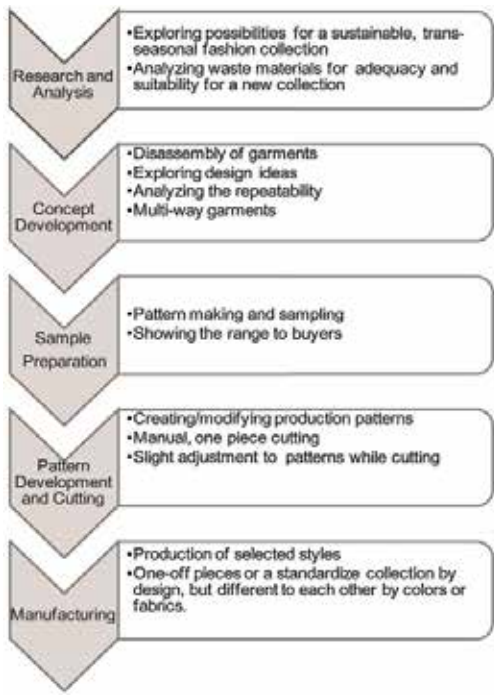
| | |
|---|--|
| <p>Steps</p> <ol style="list-style-type: none">1. research and analysis of trends, and most importantly material analysis.2. concept development, starting with manual disassembly of the garments by unpicking the seam threads or cutting along the seams of the garment. Generally disassembling has been reported as a time-consuming, unproductive and low value adding step demanding low skilled labor, thus often being outsourced by the fashion remanufacturers. This is followed by design development often using either draping techniques (for partially disassembled garments) or pattern cutting (for full disassembled garments), and are restricted by the dimensions of the input fabrics, their types, prints and colors.3. Sample preparation is reported commonly for remanufacturers to develop a sample collection for their potential retail buyers during the selling-in period.4. Pattern development and cutting follows as the next steps. Production patterns are created from the orders place and by slight amendments in those generated at the design step. One ply cutting operation is performed manually from the flat fabrics. Adjustments are made during cutting due to fabric restrictions.5. Final garment manufacturing (assembly) is performed as an individual/whole garment system resulting in low production efficiency. Repeatability is negligible except that of the design. |  <p>Research and Analysis</p> <ul style="list-style-type: none">•Exploring possibilities for a sustainable, trans-seasonal fashion collection•Analyzing waste materials for adequacy and suitability for a new collection <p>Concept Development</p> <ul style="list-style-type: none">•Disassembly of garments•Exploring design ideas•Analyzing the repeatability•Multi-way garments <p>Sample Preparation</p> <ul style="list-style-type: none">•Pattern making and sampling•Showing the range to buyers <p>Pattern Development and Cutting</p> <ul style="list-style-type: none">•Creating/modifying production patterns•Manual, one piece cutting•Slight adjustment to patterns while cutting <p>Manufacturing</p> <ul style="list-style-type: none">•Production of selected styles•One-off pieces or a standardize collection by design, but different to each other by colors or fabrics. <p>(From Dissanayake and Sinha, 2015)</p> |
|---|--|

Table 2.1. Generic steps underlying fashion remanufacturing product development.

The above mentioned stages in fashion remanufacturing process have several key issues that require careful consideration in order to achieve higher process efficiency and quality levels. It has been highlighted that commercial success of remanufacturing in fashion is highly dependent on the following:

- Reducing the high variability of the quality and quantity of incoming materials and finished products.
- Efficient process planning to reduce unpredictability, and
- higher revenue generation by exploring new business model options.

2.4.1. Levelled quality and quantity of remanufacturing products

The popularity of remanufactured fashion is increasing however it has not been successful to perform on mass markets. In order to achieve a standard level in remanufactured fashion products and to scale up the production, factors such as the quality of the discarded garment as well as the disassembly expertise are recognized as integral elements (Dissanayake and Sinha, 2012; 2015). From retailers point, a remanufactured product can only guarantee the design and not the required quality level of fabrics. Therefore, retailers are still unprepared to introduce a high priced, non-standard fashion into their stores. One way to deal with this is to have more “second hand” clothes that are otherwise at per the quality of a first-hand garment, such as directly from consumers’ latent wardrobe, or retailers’ deadstock.

One problematic aspect in terms of remanufacturing is that a remanufacturer does not have a full control over the reverse supply chain. Also, maintaining full control over the supply chain can be costly. Therefore, their production relies on the collected material from the general waste stream. This leads to uncertainty in the quality and quantity of the collected and recovered waste. This pinpoints the importance of collaborations between fashion remanufacturers and textiles recyclers (sorter and collectors) to ensure efficient reverse flow of material. A remanufacturing process network in which a firm operates such as with textile recyclers, textile waste collectors, technology providers (pattern cutting and management software companies) together with local craft entrepreneurs as well as the manufacturing facilities and suppliers of large retailers are required to guarantee the required standards and volumes in the reverse supply chain. This will lead to minimum waste dumping, value addition through utilization of craftsmanship while existing technology can also be applied for fashion remanufacturing purposes.

2.4.2. Efficient remanufacturing process planning

Generally disassembly and pattern cutting are manual operations in the remanufacturing process and are costly, unproductive and time-consuming and also increase the material consumption (Dissanayake and Sinha, 2015). Technology uptake can be vital to increase efficiency and creating volume. Possible technologies could be, e.g. using leather cutting machines, combined with patternmaking software, for cutting irregular shaped single ply, using an inbuilt projector camera for placing the digital patterns effectively in an irregular shaped material and also make timely modifications to the patterns.

Designers’ skills and technical capabilities also have a crucial role in increasing fashion remanufacturing production efficiency and volume. Design for remanufacturing is faced with obstacles such as material restrictions, lack of technology applications and lack of technical redesign skills coupled with uncertain market demand. Application of innovative design and product development approaches helps to remove the complexity of redesign process as technical know-how together with tacit knowledge are considered to be the critical success factors in the design process efficiency.

2.4.3. New business models

Fashion remanufacturing can be used as marketing point as it is based on sustainable production method. For this the marketing strategy should address new customer value propositions, e.g. products that are transseasonal, premium and sustainable. The retailing of remanufactured products at a cheap price is a wrong strategy since it can cause rebound effect. Rather, sufficient marketing strategies are required for efficient interaction between

mass market products and the remanufactured fashion products. Also, the target customers are those groups of people who are appreciative of sustainable fashion and eager to pay higher price to support sustainable production. Further fashion remanufacturing can benefit a number of other entities involved with the used clothing network, such as textile waste collectors and sorters. This can boost the domestic used clothing market and help the remanufacturing firm to be independent from overseas markets. In other words, the existence of a fashion remanufacturing firm will result in increasing visibility of other businesses while they operate as a whole. Additionally the local market will develop further which can facilitate developing innovations and technologies and thus increased production efficiency (Dissanayake and Sinha, 2015).

In this context, redesign and upcycling options have been explored as a process of servitization. The concept of servitization, defined as the ability to better create mutual value through a shift from selling products to selling product service systems (Baines et al., 2009) is also described as having the potential to improve resource efficiency and decrease the environmental impact. This, as previous research by Tukker and Tischner (2006) points out, makes it a feasible solution for the highly resource inefficient global textilefashion industry (Pal 2016). It is also indicated that servitization could generate an improved revenue stream thus creating a competitive advantage increasing firm value. The true value of servitization in the fashion remanufacturing activities could therefore be felt by redesigning or upcycling a product that is already on the consumer market in order to reduce the dependency of natural resources, i.e. purchase of new ones – a phenomenon Tukker and Tischner (2006) describes as extending the value of tangible products through intangible services. Such redesigning or upcycling can explore the concept of designing larger business systems to support the products, thus aiming towards more participatory and usercentered design methods. In Pulse of the Fashion Industry (2017) mass customization services provided at the retail as well as use stage of a garment life cycle are included in the list of the most critical innovation solutions on the textile agenda. Within this framework, Chapman (2005) advances yet an additional role a designer needs to embrace, one that presents the customers with products that trigger an emotional response at the onset, but also contribute towards a continuous emotional stimulation, prolonging thus the use life-cycle of the product.

3. Research methodology

This feasibility study is conducted by Re:Textile group in collaboration with several Swedish players, e.g. fashion branded retailers, local textile and apparel manufacturers, and charities. The aim was to develop 3 participatory action projects in order to elucidate the different possibilities of organizing remanufacturing in fashion industry context, and check the viability of these options. 3 different fashion remanufacturing models were considered to be interesting via literature review, and were planned for further exploration. This way the choice of the cases (based on the action projects) were considered to serve as rich sources of interesting, informative evidences full of extremes that is valuable for showing the opportunities for fashion remanufacturing. These three models are depicted in Table 3.1.

| Fashion Remanufacturing types | Business case example (in this study) | Target focus, projects |
|--------------------------------------|--|--|
| Scaled remanufacturing | Case 1 (Name not disclosed) | Scalability of apparel remanufacturing operation |
| Distributed redesign | Lindex | Distributed manufacturing supply chain |
| PSS redesign-as-a-service | Monki | Product-service customization |

Table. 3.1. Fashion remanufacturing models studied here.

3.1. Data collection and analysis

Data for case 1 was collected in a number of ways during 2017, primarily through on-site observations. Two researchers cumulatively spent six weeks of time in the remanufacturing studios of case 1 where they observed all the product development and reverse logistics stages and activities constituting the remanufacturing processes. These observations were documented in a variety of formats, audio, visual and textual. Interviews were conducted with key personnel involved, such as designers, seamstresses and pattern makers. The semi-structured interviews were conducted with the lead designer (originator) of studio who had the best and most complete information of all the process stages. Apart from a complete overview, the lead designer also possessed the creative vision and the foresight related to current situation and future requirements connected to advancing the concept of fashion remanufacturing. Several informal discussions were made with the seamstresses and pattern makers who worked on the remanufacturing floor, apart from those with the designer. These interviews/discussions were kept informal as these respondents only had knowledge of limited number of activities, i.e. of what they are associated with, were less knowledgeable and vision of the entire process. Furthermore, they had limited decisionmaking power as their work was mostly “blue-collar” in nature. Notes were taken during these discussions. In addition, visually information was captured by taking photographs and videos of activities, operations, inventories, production planning charts, etc. These served as a rich source of evidential data while formulating and depicting the process flowcharts. Finally several sources of texts and images were also gathered from the studios, e.g. monthly sales data, product development and construction diagrams and details, plant layout, etc.

For result formulation as per the study objective, multiple data were aggregated and was utilized collectively. In order to develop the visual representation of the products and processes, first-hand observations of the remanufacturing processes served to a large extent, which then was rechecked through the informal interviews and verbal communication with the respondents in an iterative manner. The iterative approach serves as a good way to develop such models and knowhow in an explorative manner considering the fact that formalized approaches are less available in this context yet. Result of the study was aggregated through analysis of audio interviews, visual recordings like photos and videos, and texts created from interview transcriptions and informal notes.

For case 2, Re:Textile and Lindex jointly facilitated the project such that Re:Textile created the platform for project implementation for experimenting with a distributed redesign setup for Lindex. The project was conducted over 45 weeks, starting in 2017. Re:Textile researchers and Lindex started with jointly developing a project blueprint, that initiated the identification of the right garments/styles that should be reworked. The process of identifying suitable models for rework was very timeconsuming based on locating the low stockturn products and balancing it with inventory level. One challenge was that once the correct models had been identified and booked there was a risk that they were not yet available when the redesign started well because they might have been pushed out to the stores.

This was followed by experimentation to develop new product development steps and clear instructions to convert the leftover items to new products, as specified under case study 2. Simultaneously the redesign manufacturing steps for each product were finalized in conversation with the local manufacturing partners in the project. The researchers during this process “walked the process” to describe and map the process flows, used techniques, lead times, calculation of material usage and costs, and in addition develop clear logistics and marketing campaigns to make the redesigned products being commercially available in the store at the end of the experimental project.

Finally for case 3 with Monki together with Re:Textile researchers started generating the project idea, i.e. the objective, perspective and context, from 2017 onwards. For example, during this stage, the type of product to be experimented with, i.e. denims, was decided. The first testing on the actual printer started in February 2018, which was followed by development of a PSS blueprint that was analyzed from the service provider’s perspective. The experimental research of employing mass customization by making use of the fast directto-garment printing process took place at the beginning of April 2018. Overall, the PSS and its components were developed in the following steps: (i) setup of the PSS instore, (ii) development of requirements for changed role of the store assistant to facilitate the co-design process, (iii) product design by combining sustain-able design specifications with mass customization process, i.e. choice of 100% cotton jeans only, (iv) development of a product configurator with enhanced user interface, (v) Testing of the in-store PSS by performing factorial experiments and several pre-testing pilot-runs in the Re:Textile laboratory, and finally (vi) Evaluating the feasibility of the in-store PSS, by finding out the customers’ willingness to pay for such services.

4. Case I – Scaled fashion remanufacturing

4.1. Case description

This study is conducted in collaboration with the remanufacturing studio (Case 1) of one of the largest charities in Sweden, which serves an appropriate case to investigate the key research questions raised here. Case 1 started its work approximately 15 years ago; however, it was only in the year 2016 that the brand introduced its own store and its new design concept – the same year it was nominated for the “miljöstrategipriset” (Environmental Strategy Prize). This new born brand still is a part of the charity. Within its work, Case 1 provides traineeships and job integration for disadvantaged and long-term unemployed individuals to create fashionable and modern set of fashion collection out of used clothes and textiles, thus to extend the lifespan of more than 2.5 tons of textiles every year. It operates three studios all based in Stockholm in which fashion items as well as accessories are being produced out of used textiles and clothing. While the fashion items are produced in one of the studios, the other two mainly produces accessories such as bags and computer cases. This sustainability-oriented brand serves the mission of increasing quality and longevity of products through its redesign approach.

The fashion and clothing items designed by Case 1 are hardly categorized based on the season as the style, design and the pattern of the garments may remain the same with slight changes during the whole year. Nevertheless, the material, fabrics and color palette varies depending on the weather. Moreover, Remake fashion is characterized as unisex, uni-size and free style garments. The remanufactured products are categorized on the basis of their “level of remanufacturing”, e.g. “sewn from scratch” products such as bomber jacket, pants, long garments, puffs; “cut apart + add and put-together” products such as 2-piece shirts, sleeveless trench coats; and the “minor-value adding” through repair, recoloring, rebranding and refreshing products, such as denim jackets, jeans, cloth bags etc. These products have different levels of production complexities, in terms of e.g. input volume and its acquisition challenges, manual labor intensity and skill requirements, and disassembly/reassembly levels. This makes Case 1’s fashion remanufacturing processes and their planning an interesting case from a multi-criteria-based decision-making perspective, with no ‘one-size’ approach ‘fit-for-all’. For example, in its current collection Case 1 has many products that are sewn from scratch from the material that are made from meters of fabric formed by sewing patches of cut fabrics, or materials donated by meter or other large pieces of fabric, or simply by cutting and joining multiple garments. This highlights the need for various resources and capabilities, key design elements, decision criteria and even business models suitable for differentiated fashion remanufacturing processes to underpin their feasibility.

4.2. Description of remanufactured fashion products

4.2.1. Remanufactured Product-Process Structure and Property Matrix

6 product types are produced in Case 1, categorized along Hayes and Wheelright (1984)’s model of product-process matrix. Remanufactured products’ structure primarily defined on the basis of production volume, as in fashion remanufacturing standardization can be hardly achieved due to lack of repeatability of the base material being derived from different used clothes’ parts. On the other hand, the remanufacturing process structure is determined at Case 1 by the level of remanufacturing, i.e. degree/level of disassembly and reassembly of the product. See Figure 4.1.

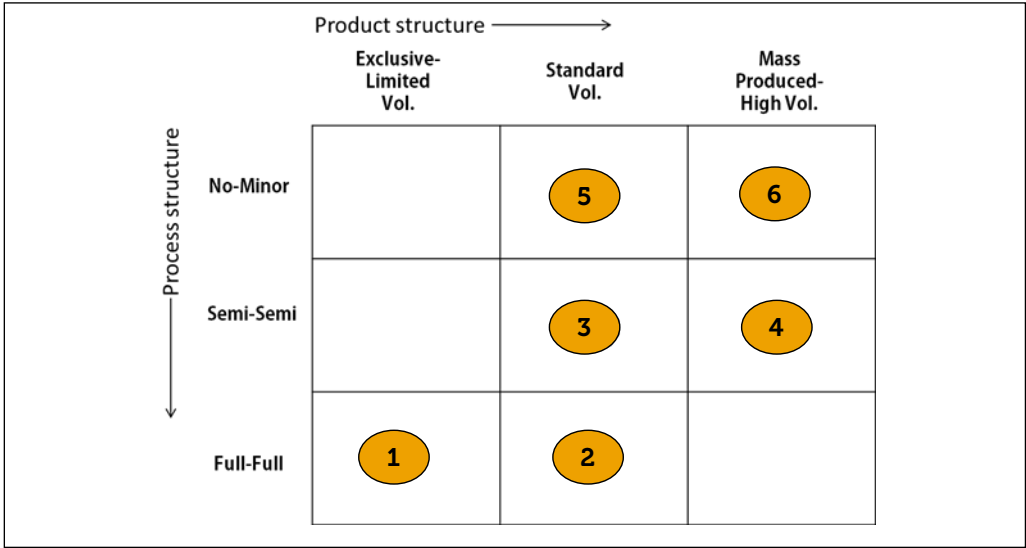


Figure 4.1. Remanufactured product mapping at Case 1.

Production volume is categorized in Case 1 is categorized into:

1. Mass production, which refers to yearly production volume $V \geq 100$ pieces (items),
2. Standard production, where $10 \leq V < 100$, and
3. Limited production, where refers to the $V < 10$.

While 3 main categories for processes are:

- Full disassembly – Full reassembly (Total steps ≥ 8)
- Semi disassembly – Semi reassembly ($5 \leq \text{Total steps} < 8$)
- No disassembly – Minor reassembly ($4 \leq \text{Total steps}$)

Level of Disassembly: indicates the extent that the input material (i.e. second hand garment) should go through disassembly operations in order to be ready for remanufacturing and redesign. There are three distinct levels of disassembly distinguished from Remake's production:

1. Full Disassembly, which refers to when an old garment is totally opened up and unseamed and turned to a flat fabric. In many cases the smaller pieces of fully disassembled garments are sewn together to make a wider and longer piece of fabric, called "snake".
2. Semi Disassembly, which refers to when an old garment depending on the design and pattern of the new garment is disassembled. Disassembly in this level is not operated fully and is rather limited to a few major or minor cuts.
3. No Disassembly is when an old garment remains as it is. No cutting or disassembly is applied on the input material and remanufacturing is conducted through value adding recoupling activities.

Level of Reassembly: refers to the stage when the final remanufacturing is conducted for the production of the final product. Similar to disassembly process, there are three reassembly levels distinguished from Remake's production:

1. Full Reassembly, is when the entire new garment is produced out of flat fabric or "snake". In other words, the new garment's pattern is fully cut and tailored from the fully disassembled and unseamed old garments joined in a "snake".

2. Semi Reassembly, refers when a new garment is produced out of semi disassembled old garments. Depending on the design and style of the new garment, the old garments which have already been cut into major pieces are seamed to each other and made into a new garment.
3. Minor Value adding, is when the new garment is produced by operating value adding activities such as dyeing the old garment, stitching, beading, embroidering and patching. In this production process the old garment as already mentioned, does not undergo any disassembly process.

Apart from the 6 product groups above, the DIY products (e.g. stitched patches, puffs, etc.) form the seventh, which is often fully disassembled but the final assembly and finishing is done by the consumer themselves. Therefore, the processes of reassembly are not carried out at the Remake studio and DIY product kits are packaged halfway. This makes them fully disassembled but packaged into minor value added reassembly.

It is to note that, full disassembly and reassembly are highly time-consuming hence producing high volumes of such products are not feasible at limited remanufacturing skill availability and capacities. Further, the exclusivity of the remanufactured fashion products is achieved through unique design/style patterns (as repeatability of color combinations, fabrics, etc. is not achievable hence always 'unique'). Thus semi disassembly or minor reworks are not considered to render exclusive products. Further quicker remanufacturing time for semi-semi and no-minor products provides opportunities to scale up the volume (unless there is unavailability of input materials). However, input material is not a major constraining factor in the remanufacturing process as the design specificity to disassembled material is low.

Table 4.1 further categorizes these seven product groups in terms of supply and operational capacity requirements as per Dissanayake and Sinha (2015). This mapping is along: ease of sourcing input material, technical skills required, and the time demanded to produce. The "input material" indicates the difficulty level in sourcing the desirable input material for each product group from a variety of sources. The input material is mainly in the form of second hand garments which are sourced by Case 1 from sorting plant and also sometimes include donations from fashion retailers. Depending on the factors such as fabric material, size or style, the degree of how easy or difficult it is to acquire the input material (Iv) could vary. Case 1 defines this into three ranges – Easy ($Iv > 100$ kgs), Semi Easy ($10 < Iv < 100$ kgs) and Hard ($10 \leq Iv$). It should be noted that that a lot of input materials goes back to the sorting plant after the first Quality Check (QC). The next variable is related to the degree of skill required for conducting the remanufacturing operations, particularly the most crucial disassembly-reassembly stages. In Case 1's facility this is normally decided in terms of the experience gained by the workers in terms of weeks of training received (T). The workers are evaluated as: highly skilled ($T \geq 8$), moderately skilled ($4 \leq T < 8$) and poorly skilled ($1 \leq T < 4$). Note that, not necessarily all the trainees manage to develop same level of skills over a given time; however trainees mostly are proven to gain relatively high level of sewing and cutting skills over a period of two months. The last variable "time demand" (lead time, LD) indicates how time-consuming the remanufacturing processes are for each product group. This is categorized as High ($LD > 2$ days), Intermediate ($1 \leq LD < 2$), and Low ($LD \leq 1$).

| From Product-Process matrix | Product Group | Ease of sourcing (in kgs/month) | Skill requirement (in weeks) | Time demanded (in days) | Product e.g. |
|---------------------------------|---------------|---------------------------------|------------------------------|-------------------------------|---|
| Fully-Fully+Limited Vol. | 1 | Easy ($I_v \geq 100$) | High ($T \geq 8$) | High ($LD > 2$) | Bomber jacket, coat, computer case, puffs, etc. |
| Fully-Fully+Stan. Vol. | 2 | Easy ($I_v \geq 100$) | Moderate ($4 \leq T < 8$) | High ($LD > 2$) | Short shirt, trousers, Wide knitted sweater |
| Semi-Semi+Stan. Vol. | 3 | Hard ($10 \leq I_v$) | Low ($1 \leq T < 4$) | Low ($LD < 1$) | Knitted jumper, work-jacket, knitted cap, long college-jumper |
| | a | | | | |
| Semi-Semi+Mass | b | Easy ($I_v \geq 100$) | Moderate ($4 \leq T < 8$) | High ($LD > 2$) | Big shirt, Mega long shirt, narrow shirt, kimono jacket |
| | 4 | | | | |
| No-Minor+Stan. Vol. | 5 | Easy ($I_v \geq 100$) | Low ($1 \leq T < 4$) | High ($LD > 2$) | Mended denim jackets, Patched denim jeans |
| No-Minor+Mass | 6 | Easy ($I_v \geq 100$) | Moderate ($4 \leq T < 8$) | Low-Moderate ($1 < LD < 2$) | T-shirt and college jumpers with patches |
| DIY | 7 | Easy ($I_v \geq 100$) | Moderate ($4 \leq T < 8$) | Moderate ($1 < LD < 2$) | Stitched patches, puffs, etc. |

Table 4.1. Key requirements related to the diverse remanufacturing product groups.

Figure 4.2 maps the product groups in accordance to the variables identified above.

| Variables & Features | Ease of sourcing | Production Process | | | | Production Volume |
|----------------------|------------------|------------------------|----------------------|----------------------|------------------|-------------------|
| | | Remake skills required | Level of Disassembly | Level of Re-assembly | Lead time Demand | |
| | | | | | Fixed Workforce | |
| Degree | Hand | High | Full | Full | High | Mass |
| | 3a | 1 | 1 2 7 | 1 2 | 1 2 3b 5 | 4 6 |
| | Semi-Easy | Moderate | Semi | Semi | Moderate | Standard |
| | | 2 3b 4 6 7 | 3a 3b 4 | 2 3b 4 7 | 6 7 | 2 3a 3b 5 |
| | Easy | Low | No | Minor | Low | Limited |
| | 1 2 3b 4 5 6 7 | 3a 5 | 5 6 | 5 6 | 3a 4 | 1 |

Figure 4.2. Product group mapping over property matrix.

4.3. Basic remanufacturing design and construction principles

The figures 4.3-4.5 below show representative product design and development for each product group.

4.3.1. Full-disassembly/Full-reassembly

Group 2 products, e.g. trousers are fully disassembled and then fully reassembled, and are of standard volume. A pictorial representation of the construction process is depicted below.

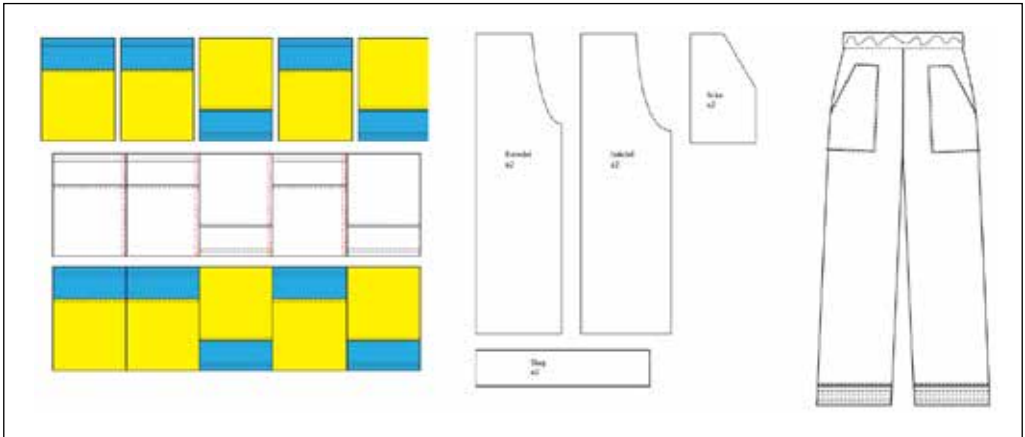


Figure 4.3. Full-disassembly/Full-reassembly.

4.3.2. Semi-disassembly/Semi-reassembly

Group 3 products, e.g. narrow shirts are semi disassembled and then semi reassembled, and is of standard volume. A pictorial representation of the construction process is depicted below.

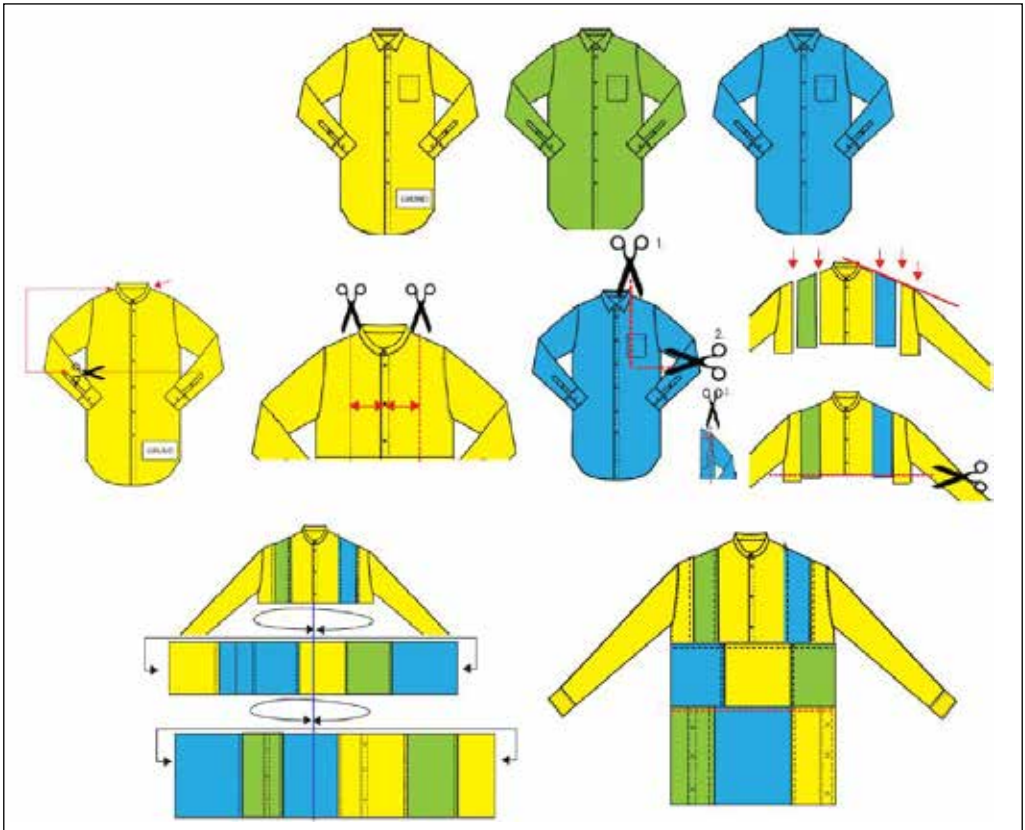


Figure 4.4. Semi-disassembly/Semi-reassembly

4.3.3. No-disassembly/Minor value adding

Group 6 products, e.g. patched denim jacket are not disassembled and minor value is added. A pictorial representation of the construction process is depicted below.



Figure 4.5. No-disassembly/Minor value adding.

4.4. Remanufacturing process description³

The generic remanufacturing process starts with supply of input material (used clothes) from Case 1's sorting facility or donated garments obtained from fashion retailers. This is based upon a monthly demand order planning evaluated on the basis of the previous month's sales report from the store. In fact the sales report is available on a weekly basis based on which the material is collected (picked up) by Case 1's remake professionals from the sorted piles of used clothes that would otherwise be sold at Case 1's own second-hand stores. In case of continuous availability of the required input materials the items are directly sent to the preparation stage, where all the used clothes are washed and inspected before being approved of entering the remanufacturing value chain. In case the input material is hard to find, there is an intermediate storage to pile up adequate stock before it is sent for washing and inspection. Cleaning and inspection are thus mandatory for every input material entering the remanufacturing value chain at Case 1's remake facility. The weekly sales status also serves as an input information to determine how many and which items from the storage sections would be disassembled and reassembled.

After the garment is washed and has passed the inspection stage, it is ready for the first stage of disassembly and raw material preparation. At this stage the decision to be taken is whether the garment will undergo full, semi or no disassembly, and is based upon its match with

³ Note that cost calculation for this scaled remanufacturing set-up is done separately under Economic Feasibility study (in Chapter 8) unlike that of Cases 2 and 3 that are experimental in nature.

the requirements in the remanufactured products. Typically this decision is taken only by the most experienced designer in the team. The creative decision-making is solely intuitive and is based upon creativity and the ability to judge the suitability of the material for future redesigns that comes through years of experience with remaking of garments. This mental visualization of the foreseeable remanufactured products helps in segregating the raw materials in different shelves of the sorting section, as for example in Figure 4.6. Apart from the design aspects, technical parameters such as fabric quality, stock repeatability, etc. are taken into consideration.

| SORTING SECTION | | STORAGE SECTION |
|---|--|---|
| Shelf 1 Hat, zipper, Raw material for patches, Blue/Black/White short shirt, Knitwear pieces... | Shelf 2 Jeans shirts, Large shorts between 27-28 cm, Black cotton long garments, Blue patten long garment, Jackets to fix, White linen and silk long garments... | Patch pieces Piles of cut pieces Overlocked pieces Snakes Cut pattern ... |
| Shelf 3 Dark jeans shirts, Gray shirts, Dark blue shirts... | Shelf 4 White shirts, Light blue throughout shirts, Whole black shirts, Work jackets, Black/Gray pants... | |
| Shelf 5 Sweaters, Jeans jackets, Flat fabrics, Jackets... | | |

Figure 4.6. Sorting and storage sections’ arrangement.

The three differentiated disassembly processes vary depending upon the level of disassembly – generally including 6, 3 and 1 step respectively for full, semi and no disassembly. For full disassembly, following single ply manual cutting, mix and match is important first to pile compatible pieces (decided through creative heuristics) based on several characteristics, e.g. color, pattern, size and quality, and then to sew these pieces with overlock stitches. Finally flat fabrics or snakes are formed. In case of semi disassembly, the process starts with making packages of a base garments and 2-3 additional garments that would be used to make the remanufactured garment. This is followed by mix-and-match to foresee the remanufactured product design, followed by manual single piece cutting and a careful matching between the base and additional garment parts.

Intermediate inventories are maintained in a storage section (Figure 4.6) in the form of patches, piles, overlocked pieces, cut patterns and snakes - mainly for high flow raw materials in various semi-processed forms. For low flow materials the storage is before the preparation and disassembly processes.

Following disassembly, reassembly processes can be including upto four steps. Obvious for the fully disassembled products, are the steps of matching between the snakes and the designed paper patterns followed by single ply manual cutting, sewing and finishing/packing. While for semi-disassembled products sewing and finishing/packing are key. The sewing stage for semi disassembled products can be complicated and can be upto 3 steps (depending upon the final garment), which includes sewing of the top part of the garment to the middle and subsequently the bottom part. For not disassembled products, minor sewing of patches and embroideries is followed by finishing/packing.

The current state of the value stream mapping is provided to depict a better picture of the present working units and production stages of the three different product categories at remake facility. As also illustrated in Figure 4.7, Case 1's store submits weekly reports as well as monthly demand planning to remake facilities. Accordingly, the production plan is developed. As mentioned earlier, the input material are often supplied from two sources, the main supplier is Case 1's sorting plant, while donations are also received from the retailers directly. The input material flow can be classified into either high or low. Low flow input material are the material that due to their good quality, color or design pattern are considered to be worth saving, however, they may not necessarily match the design criteria of the ongoing collection. Therefore those materials end up at the remake facility's storage section for future usage. The high flow refers to the flow of materials which are constantly in use. Therefore, they are directly transferred to the preparation stage in order to become ready to feed the production lines as raw material. The input material depending on the final product is placed in one of the three production processes.

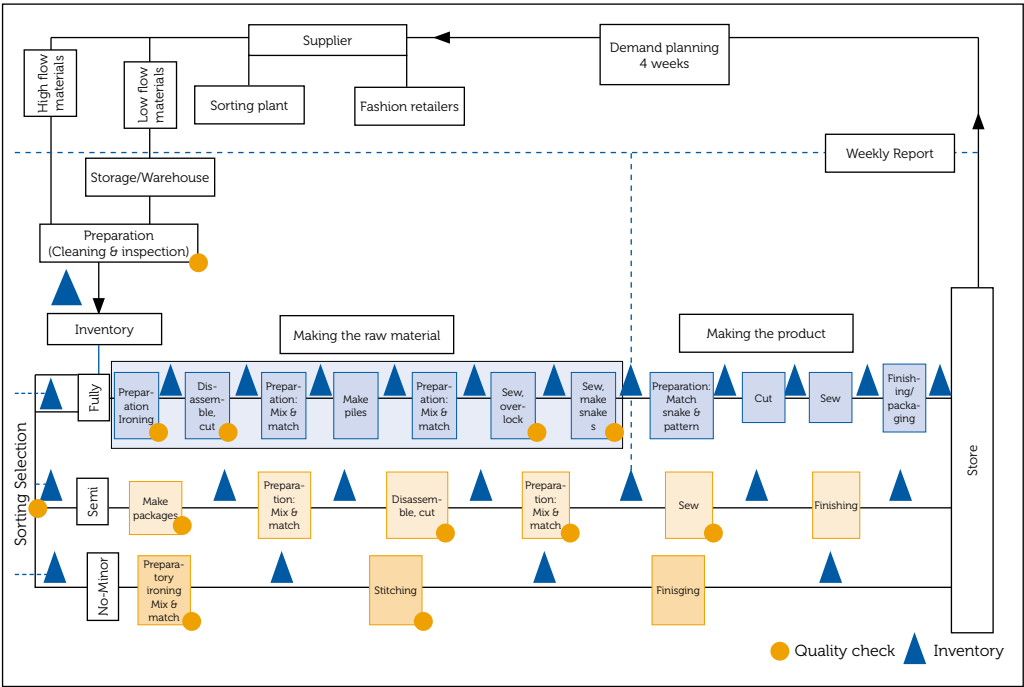


Figure 4.7. Generic remanufacturing process description.

The three categories are detailed below. In order to conduct a value stream mapping, four product examples from the three categories are chosen. In this manner, a pair of trousers is chosen from category 2, i.e. Fully-disassembly/Fully-reassembly, a 50/50 shirt is chosen from category 4 - Semi-disassembly/Semi-reassembly and two examples, patched t-shirt and patched denim jacket, are chosen from product categories 5 and 6 respectively, falling under No-disassembly/minor value adding.

4.4.1. Fully-disassembly/Fully-Reassembly

A pair of trouser is produced out of fully disassembled pairs of jeans. To make 1 pair of trousers, 5 old pairs of trousers are needed. Out of 1 pair of jeans approximately 12 cut pieces are sustained. The pieces can be cut in different sizes; however, there are two main standard sizes: 27×16.5 cm² and 27×10 cm². In this respect, the 12 cut pieces often include 7 pieces of 27×16.5 cm² (big pieces) and 5 pieces of 27×10 cm² (small pieces). For each pair of remanufactured trouser the input of 5×12 pieces are needed.

However, the preparation of raw material, or in this case a bigger piece of flat fabric, called "snake", is not done separately for each product, but rather meters of fabric are prepared first and later the products are produced out of them. Therefore, in the value stream mapping it can be seen that inventories are kept in various forms, i.e. up to 300 cut pieces (roughly 175 big pieces and 125 small pieces @7:5 ratio) as well as 3 snakes (each of dimension ~40×605 cm²). The production of a pair of trouser in brief is as follow:

Old yet qualified pair of jeans are first sorted and selected by the designer of the studio. Next, they are ironed and prepared to be cut. As already mentioned there are two main sizes that the old pairs of jeans are cut into. The cutting operator uses rectangle patterns in different sizes to ease the cutting process. Next, the cut pieces are left on the cutting table in piles. The supervisor mix and matches the cut pieces based on their color, texture, fabric weight, etc. After that, the mix and matched pieces are tied together by a rubber band and left aside for the next person to over lock the pieces together and make a bigger flat fabric out of cut pieces. At this stage, there are no standard size considerations to accordingly overlock the pieces together. The intention however, is to produce a piece of flat fabric with the length of not less than 1m and the width of either 40 cm or 80 cm. For trousers it is generally 40 cm in width while 80 cm for the rest of the snake-based products. Moreover, when the cut pieces are overlocked to each other, quality check is done by the supervisor. In case it was proved that there is no defect or error, the pieces are sewn together. The result is called the "snake".

Snake functions as the flat fabric. The trousers' pattern is placed on top of the snake to check the measurements. In case the pattern and the snake matched in terms of their length and width, the pattern is cut out of the snake. Next step is to sew the cut pieces of trousers together and make the final product. The finished product is then ironed and sent to the store.

| Trousers |
|---|
| Best case Remake Production Per Month: 12 Pairs |
| Material Input for 1 Remanufactured Pair: 5 Old Pairs |
| Material Input required: 60 Old Pairs |
| Out Of Each Old Pair: 12 Pieces = 7 Pieces (27 cmx16.5 cm) + 5 Pieces (27 cmx10cm) |
| Takt time: 3 pairs of trousers in 5 days (0.6/day) |

| Value Stream Mapping | | |
|---|---|--|
| Stages | Inventory for (Rem) denim trousers | Value added time for 1 trouser |
| Preparation (Ironing, Mix & Match): | 0 | 5 mins |
| Cut & Disassembly: | ~500-600 patches ⁴ | 131 mins (6 mins + (7*5)*2.5 mins + (5*5)*1.5 mins) |
| Piles Making: | ~4-8 piles (~60 piec-es/pile) | 10 mins |
| Preparation (Mix & Match): | 0 | 10 mins |
| Over locking: | ~6-10 over locked snakes ⁵ | 30 mins for 1 snake |
| Sewing and Making Snakes: | ~6-10 snakes | 30 mins for 1 snake |
| Preparation (Matching pattern & snake): | 0 | 15 mins |
| Cut: | 0 | 10 mins |
| Sew: | 0 | 1:30 hrs ⁶ |
| Finishing & Packaging: | 0 | 10 mins |

⁴ Calculated as an equivalent to 27 x 16.5 cm² patches, where two small patches of 27 x 10 cm² is considered equivalent to one big patch for inventory calculation.

⁵ Overlocked and stitched snakes can be of dimensions 40x605cm², 40x305cm² or 40x708cm² for making trousers

⁶ Maximum upto 3 hours depending upon skill level of the seamstress

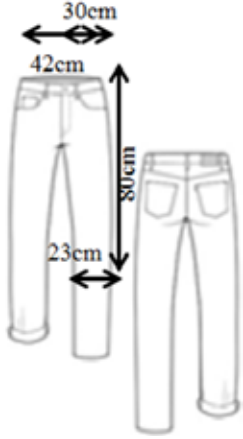
| | |
|---|--|
| Value added time: 5 hrs 41 mins |  |
| Manual Labor involved: About 4 people for raw material (snakes) preparation, 2-4 people for making the garments | |
| Machines: Around 4 sewing machines and 2 overlock machines are occupied for this line per day | |

Table 4.2. Value stream mapping for Full Disassembly - Full Reassembly process category (Product Category 2)

4.4.2. Semi-disassembly/Semi-Reassembly

A 50/50 shirt falls under the category of semi disassembly - semi reassembly and is produced out of two old shirts.

These shirts are first sorted and selected by the designer of the studio. Then the designer decides which two shirts should be matched together. This decision is usually based on the shirts' size, style, color and fabric material. Next, the two selected shirts are hung next to each other or what the designer calls "package making". The instructions also are hanging from the same hanger. The next step is operated by the assigned trainees (subsidized labor) who have been given the task. The process starts with cutting the two shirts as per instruction, which in this case is in the middle of the waistline such that both shirts are cut into two halves. This action is also recognized as "semi disassembling". Next, the cut shirts are ironed and are matched one more time, in terms of their sizes as well as the quality of cut. Finally the two pieces are sewn together and a remanufactured shirt is produced. The last steps include ironing and delivery of the 50/50 shirt to the store.

| 50/50 Shirt |
|---|
| Best case Remake Production Per Month: 10 Shirts |
| Material Input for 1 Remanufactured 50/50 Shirt: 2 Old Shirts |
| Monthly Material Input: 20 Old Shirts |
| Out Of Each Old Pair: 12 Pieces = 7 Pieces (27 cmx16.5 cm) + 5 Pieces (27 cmx10cm) |
| Takt: 2 in 5 days (0.4/day) |

| Value Stream Mapping | | |
|----------------------------------|---|------------------------------------|
| Stages | Inventory for 50/50 shirts | Value added time for 1 50/50 shirt |
| Preparation (Making packages): | 10 packages of shirts | 5 mins |
| Cut & Disassembly: | 3 packages containing disassembled pieces | 20 mins / piece |
| Preparation (Iron, Mix & Match): | 0 | 10 mins |
| Preparation (Mix & Match): | 0 | 10 mins |
| Over locking: | ~6-10 over locked snakes ⁵ | 30 mins for 1 snake |
| Sew: | 0 | 1 hrs 30 mins |
| Finishing & Packaging: | 0 | 10 mins |


| | |
|--|--|
| <div>Value added time: 2 hrs 15 mins</div> <hr/> <div>Manual Labor Involved: 2-3 people for making the garments</div> <hr/> <div>Machines: Around 1-2 sewing machines are occupied for this line per day</div> <hr/> |  |
|--|--|

Table 4.3. Value stream mapping for Semi Disassembly - Semi Reassembly process category (Product Category 4)

4.4.3. No disassembly/Minor value addition

Two products, a patched t-shirt and a patched denim jacket, falling under product categories 5 and 6 respectively are chosen to represent the category of no disassembly-minor value addition. The process of sorting and selection of the t-shirt and the denim jackets are done by the designer of the studio. In this manner the t-shirts and denim jackets with good quality are first, if required, washed and after that sent to the remanufacturing studio. These product groups do not undergo any disassembly process and value added activities are conducted on the old garments. The value adding activity on these selected candidates is through sewing of decorative patches on the garments.

The production processes and operations are the same for both the products; however, they vary in their time requirement. First step is to prepare the old product for remanufacturing process. Preparation includes ironing and matching the decorative patches in terms of size and style with the base garment. The next step is stitching and sewing the patches on the garment. This is the point the two products differ. The process of stitching and sewing does not take a long time for t-shirts as this is done by sewing machines, on the contrary, it can take up to two days for denim jackets as the entire process is done by hand stitching. Finally the products are ironed and send to the store.

| Patched Denim Jacket |
|--|
| Remake Production Per Month: 10 Patched denim jackets |
| Material Input for 1 Remanufactured Jacket: 1 Old denim jacket+ Patches |
| Monthly Material Input: 10 Old denim jackets+ Patches |
| Takt: 2 jackets each 5 days (0.4/day) |

| Value Stream Mapping | | |
|-------------------------------------|-----------------------------------|------------------|
| Stages | Inventory | Value added time |
| Preparation (Ironing, Mix & Match): | 5-8 jackets | 15 mins |
| Cutting patches | | Pre-done |
| Stitching and Sewing patches: | Mostly taken from Storage section | 2 days |
| Finishing& Packaging: | 0 | 10 mins |

| |
|---|
| <div> Total Production Time: 2 days + 25 mins </div> |
| <hr/> Labors: 1-2 people for making the garments <hr/> Machines: Maximum 1 sewing machines are occupied for this line per day, Denim jacket is done by hand <hr/> |

Table 4.4. Value stream mapping for No Disassembly – Minor Value Adding process category (Product Categories 5 & 6)

5. Case 2 - Distributed redesign

5.1. Case description

The case emerged as an experimental project with Lindex – one of Europe’s leading fashion chains, with the support of Retextile. The purpose of the project was to investigate how fashion items that have low stock turnover in the retailer’s stores can be updated or redesigned into more attractive models, using local production, and then made available for sales in selected Lindex stores in spring 2017. With this the main goal was to explore the possibilities of introducing, testing and evaluating a circular business model for redesigning fashion garments. This reduces environmental impact, as the garment could replace new production, and also very valuable knowledge about circular flows of fashion is created.

The case was developed exclusively with Lindex’s own garments with proper certification ensuring safety to wear. A major concern when it comes to collected, sorted and redesigned clothes is how the content of the garments has been affected in the user phase, i.e. if there is any risk that the garment contains allergens such as pet residues, or excessive levels of added chemicals such as detergents, which may harm the user. Since the project only used garments directly from Lindex’s warehouse and has not been in the user phase, the chemical contamination from the use phase was not a matter of concern any further. In addition to the retailer, a complete value chain for the experimental case was designed, as shown in Figure 5.1 below. All production took place in a network of distributed manufacturing set-up that was physically coordinated. This means that the fashion garments from Lindex’s warehouse went through the redesign production stages at different locations with local producers in Borås. For instance, Nordiska Etikettbolaget – a textile profiling company in Borås with infrastructure and machineries machinery for weaving, laser cutting, transfer printing, laser embossing etc. – handled the logistics and distribution, sewing, and printing of the denim trousers produced in the collection. Syverket – a local small-scale sewing company – cut the patches for the couple of products (Kimono and Bag), while Xvemiul – a local entrepreneurial craft studio – has sewn together the Kimono and the Bag.

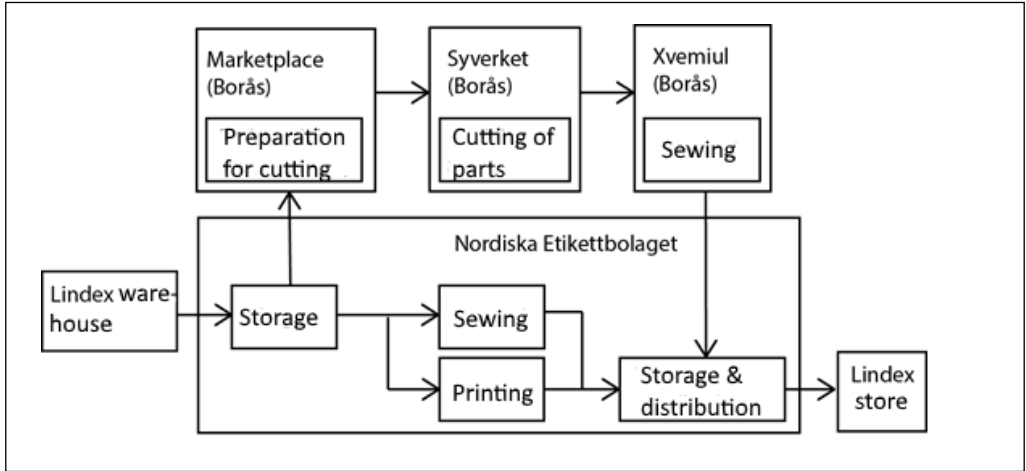


Figure 5.1. Total project value chain based on distributed manufacturing concept.

5.2. Description of redesigned fashion products

Three product types were selected for this experimental case: Denim jeans to be modified as shown in Figure 5.2, and two patchwork products, a kimono and a bag, redesigned from denim jeans as shown in Figure 5.3.

1. Denim jeans⁷



Prints were added and one of the back pockets removed for a completely new look. The jeans were also cut and given a raw edge. Available in sizes 34-42.



On one of the jeans models the legs were cut off, giving the jeans a raw edge, and a print with a splash look was added. Available in sizes 38-42.

On one of the jeans models the legs were cut off and the excess pieces turned out and in. Available in sizes 38-42.

Figure 5.2. Four modifications of denim jeans.

⁷ <http://about.lindex.com/se/redesign2/>

2. Patchwork products - Kimono and Bag

The patchwork products, described by Lindex are as follows, a kimono and a bag. These products (Figure 5.3) are made of material from five different pairs of denim trousers and a skirt, which have been separated and reassembled. The kimono's hanging strip in the neck consists of belt straps from the original jeans. For the inner compartment of the bag the back pocket was removed from one of the other garments and used. Available as One size.

The kimono consists of two front pieces and a back piece, two sleeves and two outer pockets. The front and hem ends have a double-folded edge of the same fabric, and in the neck a label and a hanging strip are placed.

The bag is lined with a white panama of 100% cotton to enhance the quality and provide stability to the product. On the inside of the bag, a pocket is formed from non-stretchable trousers, and the label is placed on the pocket.



Figure 5.3. Bag and kimono.

5.3. Basic redesign and construction principles

5.3.1. Denim jeans development

1. Initial tests were made at the Nordiska Etikettbolaget to find the right setting of the laser cutter for embossing the jeans. Strength and durability were assessed against the aesthetic effect of embossing.

2. The next step was to make samples based on Lindex's design (i.e. rectangular pieces overlapping with each other), 2-4 pieces for each side (rear or front) and each leg of the jeans. Sketches, specifications and Adobe Illustrator files were supplied by Lindex to Nordiska Etikettbolaget. However, the laser cutter used had too limited pattern repeat capability (approximately 300 mm x 300 mm) to carry out the desired design in one process. The option of making the design step by step was considered too costly to be feasible, so the design was modified (scaled down) to match the repeat limitation and a first run of samples were produced.

3. Delivery of first samples. These were not approved by Lindex for aesthetic reasons. The feel of the design was lost, due to the modification in design and the contrast between the embossed surface and the rest of the trousers was considered too low.

4. Because the first samples were not approved, new varieties were made with laser embossing. New tests were made internally by the staff of Re:Textile with the School of Textiles's laser cutter (GCC Laser Pro), which is also able to emboss large areas (60x90 cm) (Figure 5.2). This allows the front or back of a trouser leg to be embossed in one process, according to the design sketch.

5.3.2. Kimono development

The kimono in Figure 5.3 is made from five different jeans trousers and a skirt, and all products, except one pair of trousers, are in of stretch material. Four pairs of jeans are in a five-pocket model, while the fifth one pair is without pockets and has a zipper at the side. The skirt is fully buttoned at the front. The trousers come in varying sizes and are relatively similar in shade. The Kimono consists of two front pieces and a single back piece, two sleeves and two outer pockets.

5.3.3. Bag development

Figures 5.4 and 5.5 below represent the layout of the pattern development for bags with respect to the denim jeans used for the redesign.

Although the cutting efficiency was low, compared relative to conventional production, it was considered better to use the material from the trousers to make new garments than to throw it away. If the remaining shorts could be used, the useful part of the trousers would have been larger; and about 60 percent can be recycled. In order to further remedy the problem of the low cutting efficiency, cutting was done according to Figure 5.5. The inseams of the trousers were cut and the leg was unfolded, both legs were then joined by sewing along the line AB. In this way, a larger surface was made, which made it easier to lay out patterns.



Figure 5.4. Lay, pattern parts, cut-out.

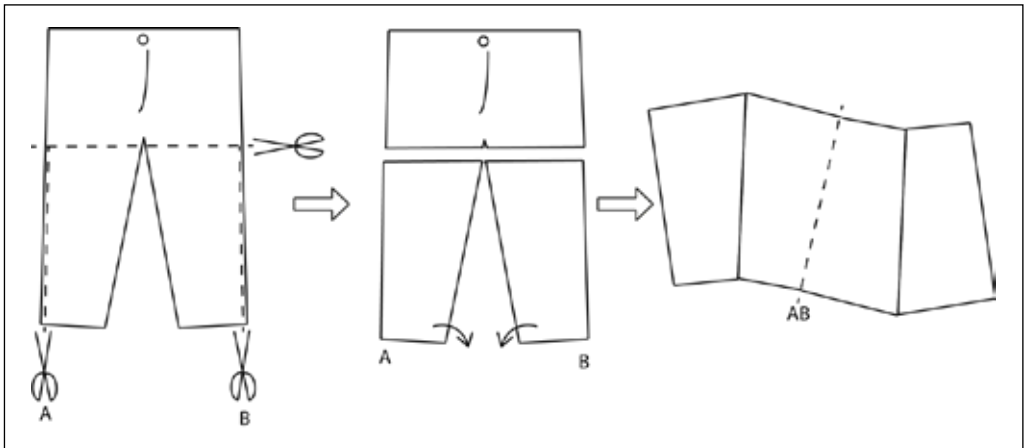


Figure 5.5. Cutting and unfolding of denim jeans parts.

5.4. Redesign process description

The denim jeans are examples of no disassembly or minor value addition remanufacturing process, while the kimono and the bag are examples of a full disassembly/full reassembly remanufacturing process.

5.4.1. Denim jeans

Used techniques

For denim jeans three different models were made, two pieces with transfer print and one by resewing only. In the development of the jeans, a variety of techniques were tested: laser embossing, transfer printing and cutting, then heating (appliquéing) and sewing. The only challenge encountered was for the jeans with the side stripes, where the stripes were longer than the transfer presses (the heaters), which required splitting the stripe print in two parts per leg, and then attach it thermally part-wise.

Laser embossing

Embossing took about 45 minutes of machine time, at an approximate cost of about 300 SEK. New tests were performed with reduced resolution (fewer stripes per inch) for faster processing. It was lowered from 500 to 250 stripes/inch. At 250 SPI, satisfactory results were obtained from embossing, and the machine time was halved to about 20-23 minutes. Laser processing technology was at the end not used but is considered to be a very good technique for redesign of clothing and fashion.

Transfer print

Different techniques were tested to apply stripes to the jeans. The original goal was to get a handpainted, somewhat uneven feel. Tests with textile dyes and a brush or spray were carried out. Possibilities for application with airbrush were discussed. A decision to use transfer print was taken. The goal of the design expression was therefore changed from handpainted and artistic to a more punk-like, taped feel, in order to take advantage of the "plastic" feel of transfer printing. The first samples were presented in two different color settings (white and pink according to specific pantone numbers). Six cm wide stripes were applied along and over the side-seams.

A laundry test showed that the transfer print discharges after about 4-5 washes when applied over the seam. The pink color did not achieve the desired effect. New samples were made in white and the new color scheme black, and the stripe was placed at the front of the trousers, along (but not over) the side seams to attach better to the fabric. The width of the stripe was changed to 4 cm.

The new samples passed the laundry tests and both colors were approved. It was noted that the stripe must be as close as possible to the side-seam. It must therefore be applied with the utmost care.

Sewing

Sewing was essential for only one model (Madonna Reverse), where lower parts of legs were in fact reversed (turned inside out) and sewn in place.

Lead time and process

First, the originals were prepared, then the transfers were produced (first templates, then prints, cut-downs and quality control). The goods were checked, the legs cut off, the back pockets unstitched, and then all thermal appliquéing, resewing and, finally, packing were made.

Specific value-added time: Model Amina Stripe: Appliquéing of stripes, about 10 garments/hour. Folding of pocket and shortening of legs, about 15 garments/hour.

Model Madonna Splash: Appliquéing of transfer (prints), about 20 garments/hour, Shorten legs of trousers, about 100 garments/hour.

Model Madonna Reverse: Sewing of legs, about 10 garments/hour. Transfer print not applicable.

With the project being an experimental development one, a steady-state production routine is not available. The process involved much communication efforts, much trial-and-error attempts and, as described above, some uncertainty regarding material availability. Apart from such adverse conditions, the production scheme became fairly straight-forward, as summarized in the previous section, Lead time and process.

Material Usage and Calculation

Material usage was determined from patterns and initial tests, and working hours were calculated from previous productions. There was a great difference from regular customers, as there was much two-way communication, several changes during the process, many test series needed, etc. It was difficult to propose an exact offer to customers, due to those circumstances, but more experience will make such proposals more precise.

5.4.2. Kimono

The fabric pieces from the trousers are about 80 cm long, where the front leg piece is approximately 14 cm wide and the back piece is about 17 cm wide. To get a variation in patchwork patterns, the pieces were cut in lengths of 20, 25 and 30 cm, respectively. In an analysis meeting with Lindex these dimensions were decided for the final design. Thus some cut pieces get the inside stitch of the jeans legs.

The bottom edges of the skirt and one pair of trousers are rough cut and used for the lower edge of the kimono. Fabric templates have been developed for a fast cutting solution (scissors). The pattern for the front and back pieces is adjusted -1 cm in width and -2 cm in length, and the sleeve -4 cm in length to fit the patchwork size. After the first test, adjustment of the model has been made by adding two pockets and one hanging strip and modifying the shape of the front edge. The label also has a new design. The first specimen had the same sewing technique for the front edge as for the sleeves.

All kimonos are cut in the same pattern. The size of the pieces is based on the size of the pattern part (width and length). Several pieces of fabric are laid on top of each other and the cutting is made with a cutting machine. The pieces are labelled with the fabric designation (A-D) and in which row it should be sewn in the kimono, FV, FH, HV, HH (front left, etc). Each piece's placement in the row is predetermined as per the design description. All pieces for a certain row are bundled with the bottom piece at the top of the stack. Each garment is cut as one piece according to the pattern template.

The front piece consists of a 14 cm row and a 17 cm row, where the 14 cm row is placed at the center front. The rear piece consists of two 17 cm rows and two 14 cm rows, where the 17cm rows are placed at the center back. The sleeve part consists of two 17 cm and two 14 cm rows, where the 17 cm sections are located towards the center. The sleeve head is placed towards the center of the part. Front edge and sleeve plackets are cut from the pants without pockets. The pants are split along the inseam and the crotch seam. The front pieces are used for the front edge, which is joined of four parts over the length.

Cutting width 10 cm. The back pant is used for sleeve plackets 20 cm and patch pieces. Pockets are cut from the pant according to templates (Figures 5.6-5.8 below).

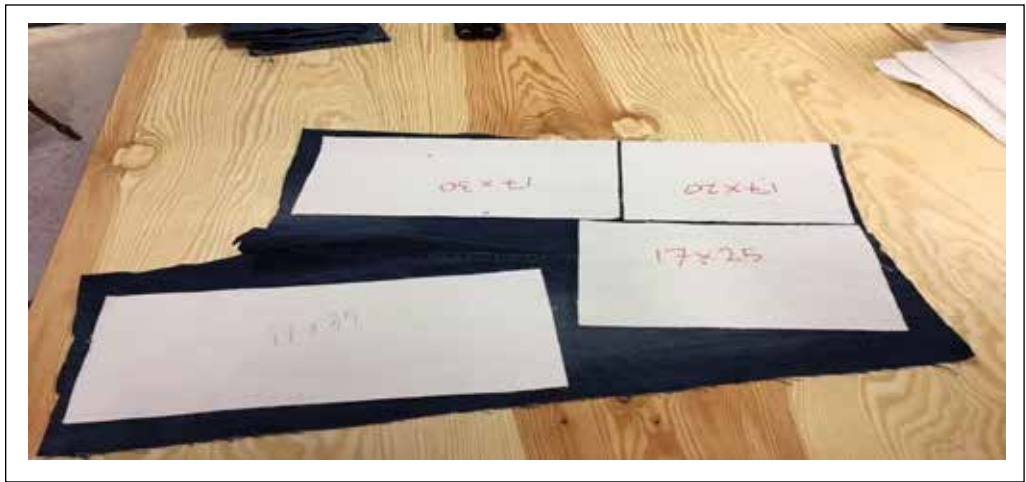


Figure 5.6. Templates laid out on cut trousers.



Figure 5.7. Cut pieces.



Figure 5.8. Cut pieces.

Used technique: Sewing

The patch pieces in a bundle are sewn together along the short sides to a row with double lock-stitch. The rows are sewn together, according to instructions, for front, back and sleeves, with double lockstitch. Pocket is hemmed and hanging strips are sewn with running stitch. Pocket is mounted to the front pieces with running stitch. Label is mounted to the rear piece with running stitch. After cutting the garment parts, the garment is assembled with double lockstitch for shoulder seams, sleeve seams and side seams. The front joint is sewn with running stitch and is pressed for the front end. The front edge is mounted on the garment with double lockstitch and the seam allowance is knit against the garment with 2 mm stitches.

Sleeve plackets are sewn together with running stitches and pressed. The mounting is with open piece (one layer), right side to right side, with running stitch and the bottom side is folded and knit 2 mm from the right side. Hanging strips and pockets are reinforced with a braid. The stitching process flow is as follows:

Double lockstitch: sew rows of patch pieces, join rows according to instructions.
Cutting: Cut out garment parts
Running stitch: Hem pockets and sew hanging strip and joint, sew front edge
Running stitch: Sew on pockets and label
Double lockstitch: sew garments together (shoulder, sleeve, side seam, front edge)
Running stitch: Knit front edge, sew on sleeve placket (two steps)
Braid: Pocket finish, hanging strip, where applicable front edge and bottom edge.

Lead time and process

Total time for development and process preparation of specimens was 40 hours. During the work, the process and the flow have developed. The first specimen took about three hours to cut, and the size of the pieces was determined during the process. The patch design also needed time to place the right fabrics next to each other. The shortening of the garment and the sleeve was adapted from the residual pieces by the material limitation.

Estimated production manufacturing time after the first specimen is 90 min. Cutting legs and outer seam allowance was made with scissors or hand cutters, or cutting out with a band-saw. Sewing was done with two double lockstitches and two running stitches and a braid. The production was divided into two parts, cutting out garment parts and sewing patchwork, with sufficient machine and personnel capacity.

The second specimen has an addition of two pockets and a hanging strip. The production time is adjusted.

Material Usage and Calculation

A front piece or backing piece (trouser parts) generally yields three pieces. For one row on the kimono five pieces are needed. There are eight rows on the front and the back piece, three rows of which are 106 cm and two rows are 60 cm, i.e. 15 pieces. Dividing 40 by 3 = 13.3 trouser parts, divided by 4 (a whole pair of trousers) = 3.33 trousers. One of the garments is a skirt, which yields fewer parts. Pockets were added, so the need was rounded up to 4 pairs of trousers.

Front and sleeve plackets = one pair of trousers. Sleeves consist of 12 pieces = one pair of trousers. Total amount 6 pairs of trousers.

Cost/minute, based on salary cost 37 000 SEK /month = 217 SEK/hr + 100 SEK/hr production equipment + 43 SEK/hr administration = 360 SEK/60 = 6 SEK/minute.

Total production cost (for production time = 90 minutes @ 6 SEK/minute) = 540 SEK.

5.4.3. Bag

The fabric pieces from the trousers are about 80 cm long, where the front leg piece is approximately 14 cm wide and the back piece is about 17 cm wide. To get a variation in patchwork patterns, the pieces were cut in lengths of 25 and 35 cm, respectively. In an analysis meeting with Lindex these dimensions were decided for the final design. Thus some cut pieces get the inside stitch of the jeans legs as a design feature.

All bags are cut in the same pattern. The size of the pieces is based on the size of the pattern part (width and length). Several pieces of fabric are laid on top of each other and the cutting

is made with a cutting machine. The pieces are labelled with the fabric designation (A-D) and in which row it should be sewn, V, H, M, G (left, right, centre, end). Each piece's placement in the row is predetermined as per the design description. All pieces for a certain row are bundled with the bottom piece at the top of the stack. The bag's front, rear and bottom are made in one piece, consisting of a 14 cm row and two 17 cm rows, where the 14 cm row is placed at the centre. The two ends are made from two pieces. Two handles, 10 × 50 cm, are cut from the trousers without pockets. The trousers are split along the inseam and the crotch seam. The front pieces are used for the front edge, which is joined. The lining is cut from a roll of fabric. It was decided that a firm, panama-woven cotton fabric for the lining would stabilize the bag advantageously.

Used technique: Sewing

The patch pieces in a bundle are sewn together along the short sides to a row with double lock-stitch. The rows are sewn together, according to instructions for the bag, from a large part forming front, back and bottom and two end panels. The handles are made with hidden stitches and knitted with running stitch.

A label is attached to the pocket, which is then mounted to the lining part with running stitch. A label is also mounted to the back piece with running stitch. The lining bag and the complete bag are assembled with double lockstitch. The edge around the ends is stitched 10 mm to a kind of piping. The handles are mounted to the front piece according to instruction. Bag and lining are sewn together with running stitch. The upper edge is stitched 10 mm.

The stitching process flow is as follows:

Double lockstitch: sew rows of patch pieces, join rows according to instructions.

Running stitch: Hem handles, stitch 2 mm

Running stitch: Sew on pocket to lining

Running stitch: Sew bag, front, back, bottom and ends

Running stitch: Sew lining bag

Running stitch: Stitch around ends of bag

Running stitch: Mount handles to the outer bag

Running stitch: Sew lining and outer fabric together

Running stitch: Attach handles to upper edge

Running stitch: Stitch from the outside across the joint between lining and outer fabric

Lead time and process

The process and the flow developed successively during the work. The first specimen took about three hours to cut and the size of the pieces was determined in the meantime. The patchwork design also took time to organize, so the right fabrics were placed together. The bag size was changed from 50×40×15 cm and 48×40×15 cm to 42×40×12 cm, in order to keep the need of fabric low and give the bag more stability. Total time for development and process for preparation of specimen: 40 hours.

Estimated manufacturing time in production after the first specimen is 60 min. Cutting of legs and outer seams was done with scissors or hand cutters, cut-outs and band saw, and sewing with a double lockstitch and two running stitches. The moment was divided, however with sufficient machine and personnel capacity.

The production will be divided into two parts, cutting parts and sewing of patchwork. The second part is assembly of the bag.

Material usage and calculation

A front piece or backing piece (trouser parts) generally yields three pieces. For one row on the bag three pieces are needed. There are five rows, three rows of which are 106 cm and two rows are 60 cm, i.e. 15 pieces. Dividing 15 by 3 = 5 pairs of trousers, divided by 4 (a whole pair) = 1.25 pairs. Handles measuring 10x60 cm means one pair is enough for four bags, viz. 0.25 pair/bag. Total amount 1.5 pairs of trousers. Delivered information to Lindex: 4 pairs of trousers are sufficient for 3 bags (excluding handles)

Cost/minute, based on salary cost 37 000 SEK /month = 217 SEK/hr + 100 SEK/hr production equipment + 43 SEK/hr administration = 360 SEK/60 = 6 SEK/minute.

Total production cost (for production time = 60 minutes @ 6 SEK/minute) = 360 SEK.

6. Case 3 – PSS redesign-as-a-service

6.1. Case description

The following case is built around an experimental project collaboration between Monki, a Swedish fashion retailer and University of Borås (Re:Textile). Monki is one of eight independent fashion brands under the umbrella of the H&M group with a mission to create on-trend collections for young women at an affordable price point. The Monki brand DNA constitutes of a mix of “Scandi cool and Asian street style” with their focus on-trend currently geared towards denim. Monki teamed up with Re:Textile in late 2017 in order to utilize the Re:Textile platform for developing a new in-store concept that aimed at extending the garments life cycle as well as creating a value adding experience for the consumers. A digital tool, in this case the GTX printer by Brother, was to be integrated in the concept and serve as the base for the surrounding additional digital advancements needed to create a complete experience for the consumer. The goal was to let the consumer create their personalized prints on their garments within minutes using the digital printer. A redefined role for the store assistant would need to emerge as well as the creation of a retail setting concept in order for the consumer to part take in the co-creation.

Thus this experimental action aimed at exploring the role of digital tools for servitization in fashion retailers in the form of direct-to-garment printing in store based on personalized demand from customers. The outcome of the project extended the understanding of feasibility within this context.

The direct-to-garment printing acts as a digital tool for enabling fast in-store personalization solutions to customers who walk in with his/her own garments with the attempt to prolong the garments' use life. The underlying assumption as to why the personalization could serve as a tool to extend the use lifecycle of a new garment is the added attachment that the consumer feels after having been a part of the co-creation process that could lead to the consumer holding on to the garment longer.

In order to test this in a retail setting the parameters and specifications needed for the implementation of the value-adding personalization process first needed to be explored and developed through trial runs. To ensure this, the experiment created a solution space, including a blueprint for the product service system (PSS) using personalized printing on garments, as well as designing an in-store customer experience. The customers were allowed to partici-

pate in the design stage while guided by the designer. In addition, the functionality of the direct-to-garment printer in the proposed retail setting was also tested in terms of how the consumers experienced the setting in order to evaluate the viability of the service adaptation to the business model.

6.2. Description of PSS redesign-as-a-service products

For the PSS redesign-as-a-service, interaction between the customer and product is an essential element of the co-design process. For this reason, a product configurator was developed in the project. Figure 6.1 shows the redesigned products that can be visualized on the configurator – offering the personalized products with a number of choices to select from. The interface of the prototype configurator with its clustered artwork options offers easy to visualize choices of garment color.



Figure 6.1. Product Configurator layout showing the product, its customizable attributes and the personalization options.

Development and testing of the prototype configurator was conducted in a mock-up retail setting with real customers. Such prototype testing aids the understanding of what needs to be considered when developing a product configurator for in-store PSS for personalized offerings. The design of the configurator interface also affected the core visual identity of the Monki brand. The configurator was presented to the customers by the Monki store assistant whose role was to act as a co-design facilitator. The customers were given one product (the Monki Taiki jeans) with two products attributes: (i) the color of the garment, and (ii) the choice of artwork to be printed on the right-side pocket. There were three garment colors and twenty unique artworks clustered in four categories amounting to a total of 60 product design combinations available to the customer.

6.3. Basic PSS redesign-as-a-service and construction principles

6.3.1. Blueprint

A service blueprint was designed in order to establish and thoroughly map out all key user interactions, the role of the service provider and the touchpoints that were needed. Thus the blueprint created a visual map of the processes required for PSS design, and includes the physical setting of the retail space, as shown in Figure 6.2. The initial PSS redesign-as-a-service blueprint conceptualized that the customer would be presented with a product configuration system that will not only serve as a choice navigation tool for the mass customization options but also could help each customer to choose the perfect style, fit and color of jeans. However, it was realized that there are many potential loopbacks in the PSS that this would lead to problems unless the number of co-creation design variables are not reduced. Especially, since the product chosen for this project are jeans, a garment where size and fit, as well as the comfort of the apparel are the most critical evaluation criteria, it has to be assumed that many customers after being presented with a pair of jeans on the configurator will not merely pick said garment off the shelf to get it redesigned, but instead, will take it to the fitting room to try it on first. This would lead to a loopback, in the sense that the co-creation process would be interrupted and the mass customization of the jeans will be delayed until the customer returns from the fitting room. Thus in the project, the product configuration by the configurator was narrowed down to offering only potential artworks to use on their already chosen garment. These recommendations were based on the color the garment picked as well as information elicited at the beginning of the process such as art style preferences, e.g., abstract or art color, e.g., black/white as well as art placement, e.g. left pocket and whether or not only one artwork is used or two different ones. In order to make the customer aware of the customization service, it was proposed that Monki clearly marks which garments are customizable with the help of a catchy hang tag. This removed the necessity to make differentiation of the service and the customer journey based on whether the customer brings in their own garments or purchases a new pair of jeans in-store. As previously mentioned the product configurator will mainly focus on assisting the customers in finding the art customization option that fits their needs the best and the only information it requires for an accurate visual digital representation of how the artworks would look on the garments is the color of the jeans that will be customized. Consequently, the product configurator process activities remain the same for used as well as new jeans as well.

KEY

- Processors implying physical movement
- Processors performed by the service operator
- Processors performed by user
- Automated operations
- Human authorized operations
- Processes performed by the service operator and user together

FRONT OFFICE

BACK OFFICE

PRODUCT CONFIGURATOR SOFTWARE

GARMENT CUSTOMISATION SOLUTION SPACE/PRINTER WORKSPACE

Anna enters the solution space → Product configurator (PC) login → Anna finish art work preferences → Designer assist with choice navigations → Digital configuration experiments → Anna shares her designs with the brand community → Anna saves her final product → Anna logs out of the PC → Anna goes to pay for her garment → Anna receives the finished product → Designer prints garment with Brother GTX → Designer starts the printing process → Designer cures the ink → Designer prepares the digital art → Designer prepares and cures the garment → Space and facilities maintenance → System backup → Designer runs software to clean system → Technical maintenance and updates

PRODUCT CONFIGURATOR SOFTWARE

Software gets ready for the new user → Software logs Anna on → Calculates matches between art work data base and Anna's preferences → SA updates Anna's preferences → Configure digital simulations based on Anna's design ideas → Software poses the design to the brand community → Software saves Anna's design → Design transmission to GTX graphic labs software → System backup → Designer runs software to clean system → Technical maintenance and updates

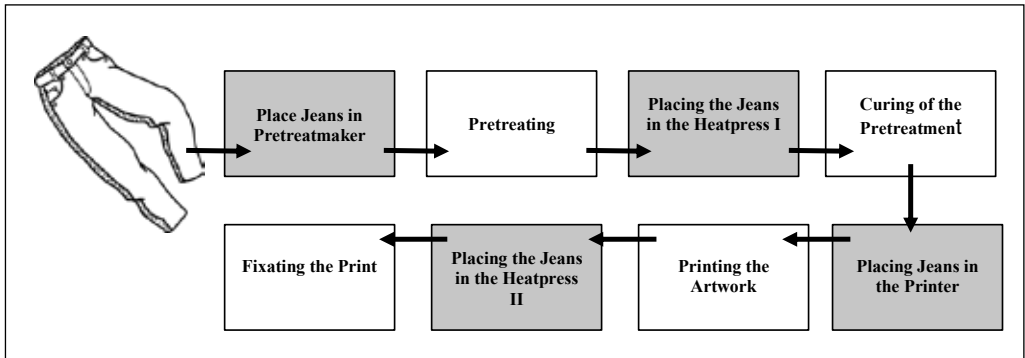


Figure 6.3. Processes necessary to customize jeans mapped out in execution order.

Used technique: Digital printing

The experiment was conducted using a Brother GTX-4 digital printer (with a projector), a Schulze PRETREATmaker IV, and a heat press.

Brother GTX-4 printer

It offers an accelerated print speed, well integrated and seamless design options and also low maintenance⁸, making it an interesting option for in-store mass customization. Compared to its predecessors, the GTX-4 printer is better in the following ways:

- has an accelerated print head, and this together with the integrated self-maintenance system results in a fast printing process with the largest print surface (40 x 53 cm) among all printers offered by Brothers commercially in the market.
- the adjustable print distance allows it to print on non-flat items.
- print quality and color is very accurate with the capability of photo printing quality even in its largest format.
- its printing software (GTX Graphics Lab), as shown in Figure 6.4 allows the user to configure the final artwork before creating a printable file such as adding text, altering fonts, colors, size or applying filters etc. In the Graphics lab, it is also possible to alter the specifications so that a print can look the same irrespective of what it is printed. This eliminates the discrepancy that can occur when printing on different materials with different base colors. It is possible to manipulate a wide variety of parameters such as sizing, placement, color intensity, background opacity. The program further enables the user to create a printable file that can be sent straight to the printer or stored in an AR3/ARX4 file format. The print file data holds information such as exact ink usage for that specific printing scenario which provides the user with options for calculating the costs involved.

Further the GTX-4 printer is compatible with Innobella Textile ink which is marketed as one of the more sustainable and environmentally friendly options available in the market. The water based pigment ink produces bold and bright colors that are ECO PASSPORT by OEKO-TEX® certified and are also CPSIA compliant. Innobella ink also has good abrasion and wash fastness properties during laundering. As per AATCC wash test, Innobella Textile ink scores > 4.0; this indicates great longevity⁹.

⁸ PRETREATmaker IV, Instruction Manual version 18.01, Schulze.

⁹ PRETREATmaker IV, Instruction Manual version 18.01, Schulze.

Towards the end of the testing period, the printer was equipped with a projector that projected the print file onto the garment before actual printing. With this it was possible to adjust the print placement as well as making sure that the print size truly fits the intended print area.

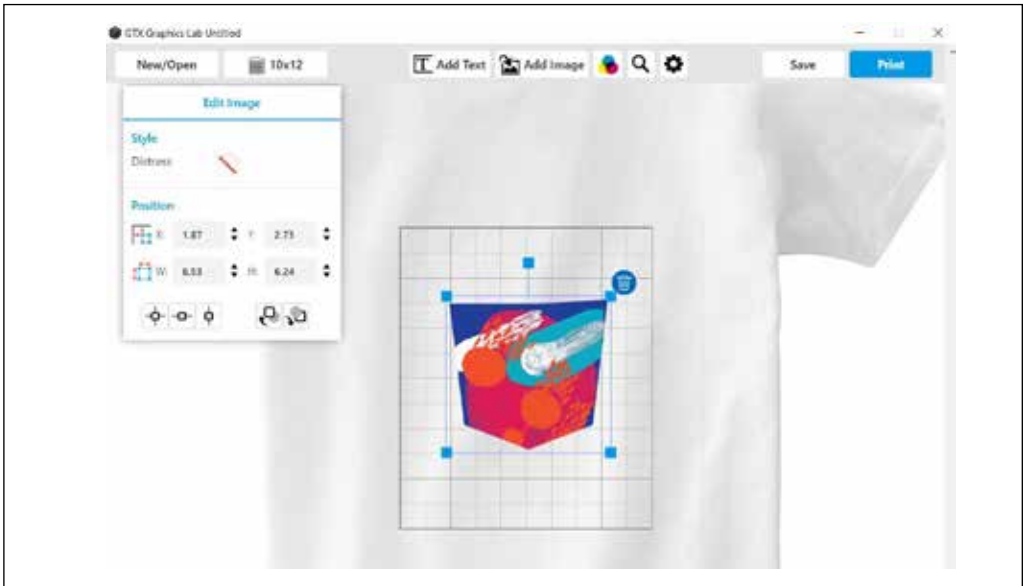


Figure 6.4. Graphics Lab Artwork Configuration Interface from a prototype print.

Schulze PRETREATmaker IV

It is an automatic pretreat machine that sprays a pretreatment solution onto the area in preparation for printing. The solution forms a thin layer on the garment in order to print light color on dark fabric and also to ensure sharp quality. The Schulze machine has four nozzles that spray a fine mist of solution onto the garment, it moves over a plate inside the machine with the nozzles slightly overlapping for an even result. It is also possible to apply the solution manually by spraying from a bottle or by rolling it on but the machine results in a more even spread and possibilities to calculate the amount of material being sprayed. The evenness of the pretreatment solution is crucial to ensure an even print.

Figure 6.5 shows a trial of amount of pretreatment fluid needed. The figure on the left has 15 gram pretreatment fluid and that on the right has the recommended 30 gram fluid. Visual inspection shows that figure left is less bright, misses details in the print, and also is not as sharp as the print with the correct amount of pretreatment fluid.



Figure 6.5. Example of print pilot testing with different amounts of pretreatment applied to jean pocket.

Finally in order to create a printable surface, curing of the pretreatment fluid was done using a heat press, for ensuring consistent temperature and specific pressure.

Heat press

This is equipped with a teflon sheet so not to smudge the print or stick to the garment. Further the temperature, pressure and time could be set to a constant. High temperature of 185°C is needed for the pretreatment solution to melt and form a smooth cohesive layer on the surface of the garment. A high pressure of 5,5 bar forces the water molecules from the pretreatment solution out of the garment and pushes the solution to the surface to ensure the development of a smooth surface, required in order to obtain a sharp print. The heat press is utilized one additional time to fixate the ink after the printing is complete, at a lower pressure of 2.0 bars.

Controlled, dependent and independent variables of the process

Initially, there were three variables that were identified for the digital printing process that impacted the overall lead time as well as cost, as per the Brother GTX 4 printer manual. These are: (i) fabric composition of the garment – this determines the amount of pretreatment required, (ii) color of the garment (light, medium, dark) – the base color influences the amount of white ink that is required in the mask layer upon which the artwork is printed on, and (iii) variation of amount of color used in the artwork for the customization.

Lead time and process

When measuring the times of the different activities, it is necessary to note that three activities that were part of the mass customization process and were performed by mechanical instruments were constant in their lead times, as shown in Figure 6.6 by the light grey rectangles with a red outline. "Pretreating of the jeans" in PRETREATmake IV requires 7 seconds, while "Curing the Pretreatment" and "Fixating the Print" activities in the Heatpress requires 30 seconds each. "Printing the Artwork" is the only activity carried out by a mechanical instrument where the time is not a constant thus, where the manipulation of the independent variables presumably will have an effect. All other activities represented in dark grey boxes are carried out manually.

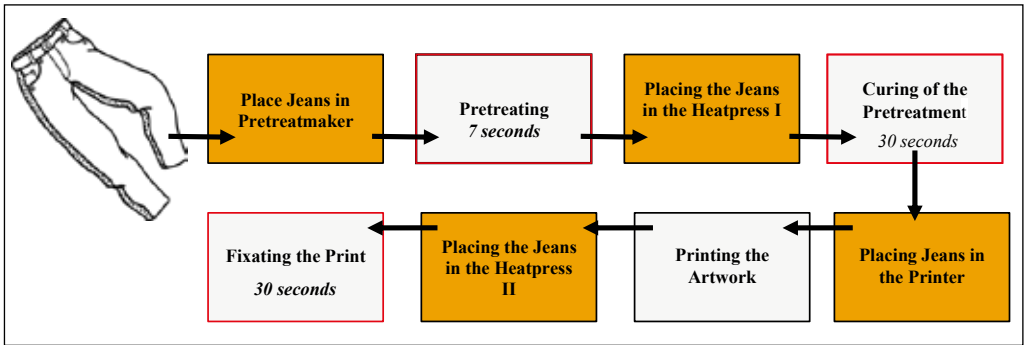


Figure 6.6. Mass customization process updated with time constants.

Because of the above reasons, when it comes to the time involved in the different mass customization process activities, the key variable is the lead time for the activity “Printing the artwork”, and its effect of the total lead time for all activities in the mass customization process.

The boxplot in Figure 6.7a shows the lead time for “Printing the Artwork”. To summarize the observations:

- Majority of the boxplots range between 91 and 92 seconds.
- All the test times measured are found within a small time interval of 16 seconds, which could indicate that the speed of the printer is high and the prints fairly small thus the time difference is narrow. Generally the printing time increases with the increase in CMYK color volume.
- “Dark Used Jeans HC” shows the longest printing time. The range is between 92 and 94 seconds.
- “Medium Used Jeans LC” holds the least printing time of 79 seconds, ranging maximum upto 81 seconds.

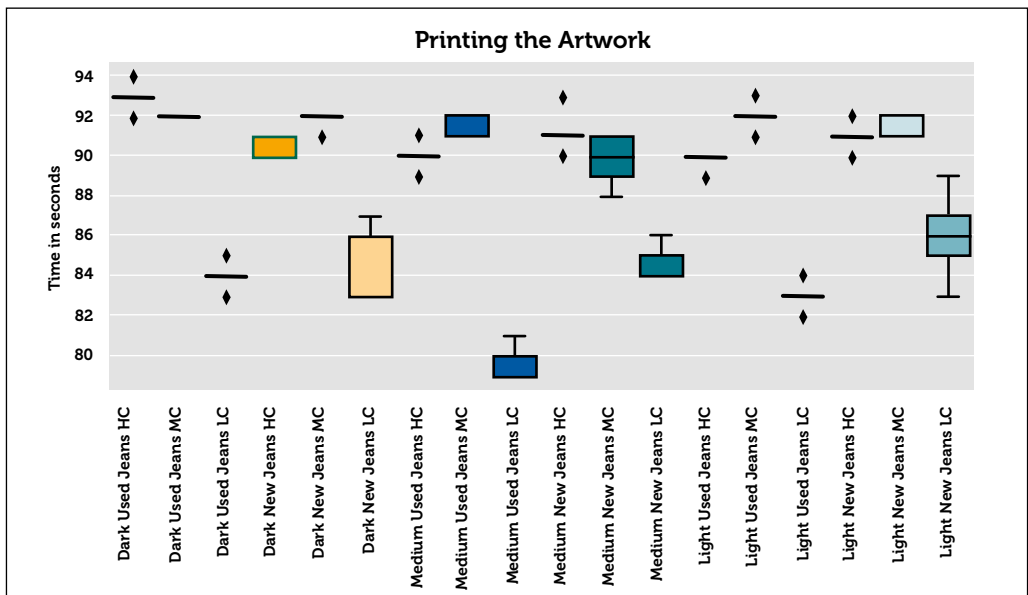


Figure 6.7a. Boxplot of the “printing the artwork” time for the mass customization process.

The boxplot in Figure 6.7b shows the combined effect of the independent variables (I. different CMYK ink volumes in the artwork – high, medium, low, II. dark, medium and light colored jeans, and III. new jeans versus used jeans) on total time for the mass customization process. To summarize the observations:

- All but four boxplots are found to have total lead time range of 180 to 190 seconds which indicates that the recorded lead times are similar and that the time range is narrow. Over-all range of the total lead time is between 171 and 199 seconds.
- “Dark Used Jeans MC” is the highest situated box on the time axis, with a mean lead time of 192.4 seconds, and the maximum of 199.0 seconds.
- Boxplot for “Medium Used Jeans LC” requires the shortest total lead time (mean = 175.8 seconds, and maximum time of 184 seconds).

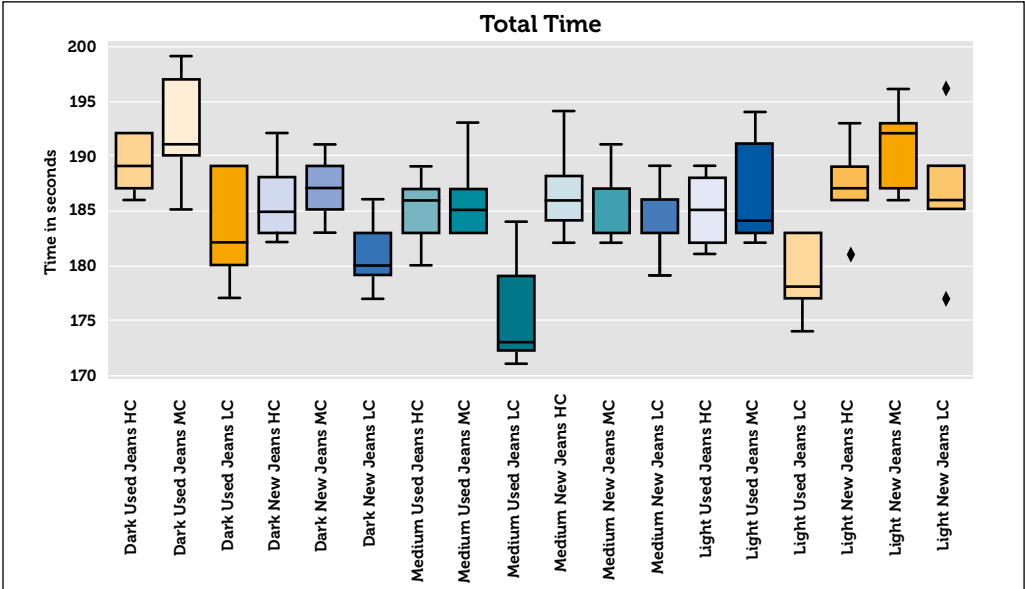


Figure 6.7b.Boxplot of the total time the mass customization process took for different artworks.

Material Usage and Calculation

The pocket size of all Monki jeans remains the same no matter what size the jeans are. So for this pilot the measurements of Monki’s Kimomo jeans model was chosen (as shown in Figure 6.8) for calculation of costs.

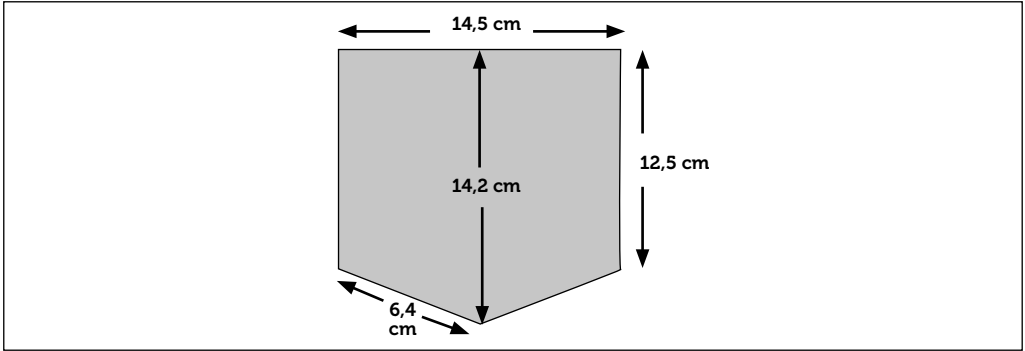


Figure 6.8. Pocket size on the Monki Kimomo model used throughout all experiments

In order to calculate the cost of printing the pockets for each conducted experiment, the volume of colored and white inks consumed (based on Brother GTX 4 graphics lab file readings) were exported, together with the amount of pretreatment used. The consumption of white and colored inks differed for each experiment, while the pretreatment amount remained constant (~30ml/ 3.14 SEK per print). The cost per cc of white ink was 3.38 SEK. Note that there is no equation in the printer manual showing by how much white ink the different mask settings increase/decrease. The amount of color used in artwork, is defined by volume of CMYK ink needed for printing, which is 3.2 SEK per cc. It is also attributed three levels which can be described as artwork with vibrant colors distinguished by the highest use of CMYK (0.38 cc), a second with fewer colors thus needing less CMYK (0.27cc) and the last artwork with the lowest amount of color usage (0.12 cc). This is one of the most critical variables affecting the total cost, hence deciding the economic feasibility of the project. The ink consumption was therefore thoroughly tested in different printing scenarios, with three colored jeans (dark, medium and light) and three types of CMYK levels (high, medium, and low).

Figure 6.9 illustrates the cost in SEK for the three colors of jeans tested, each in combination with the three types of artwork coloration or CMYK levels. The total cost of the prints depend upon three variables; CMYK, white ink, and pretreatment liquid consumption. The highest quantity of white ink consumed (3.16 cc) is associated with printing a medium colored artwork on a dark pair of jeans, resulting in the highest total printing cost (14.68 SEK). Printing a bright colored artwork on light jeans, with only 0.91 cc of white ink consumed, results in the lowest total printing cost (6.60 SEK). To summarize the observations:

- All artworks low in CMYK result in low white ink consumption, therefore, leading to the lowest printing cost. Medium CMYK artworks incurred the highest amounts of white ink, and the highest printing cost subsequently.
- The total white ink expenditure cannot be controlled by adjusting the mask levels only, but is assigned to artworks by the Graphics Lab software.
- The total printing cost is directly proportional to the overall quantity of ink consumed during the printing process.
- White ink consumption can be considered an essential component of the total printing cost, and is also slightly more expensive than CMYK. It is, however, impossible to qualitatively predict the total contents of the white ink in an artwork. The output thereof, using the Graphics Lab software, has to be considered if exact quantities of white ink used are essential for the artwork decision making process.

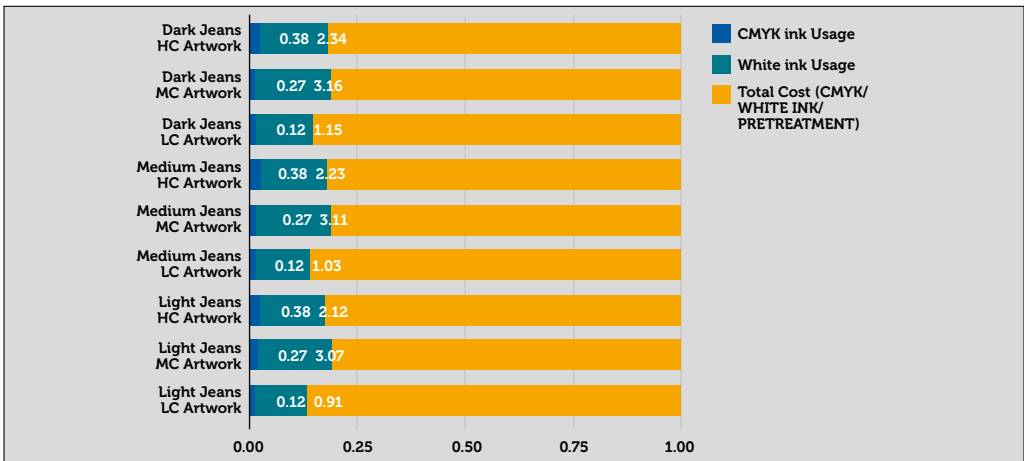


Figure 6.9. Total printing material (ink + pretreatment material) cost for each of the different variables.

7. Economic feasibility, a projection

7.1. Model description

The economic feasibility of apparel remanufacturing value chain depends on the market price of remade items and remanufacturing process costs. Feasibility is determined here by the viability of remanufacturing processes depending upon what economic margin of operability it has considering various fractions and yields from input material that can be obtained from collected used clothes. Fashion brands, retailers, and new actors such as remanufacturers will be interested in making attempts towards circularity and value addition by exploring novel remanufacturing business models, only if it is feasible economically at an industrial level. Besides price, quality is another issue as the input material may not have high quality to sustain multiple lifecycles. This chapter attempts to outline the cost drivers and likely costs and prices of apparel remanufacturing, by analyzing the 3 cases.

As feasibility has to be tested in numerous applications with a wide range of parameters we have developed a financial model that refers to the "LEEWAY FOR PROCESS COST", here remanufacturing process costs when the cost of input materials and remnants, fractions, yield and output price have been taken into considerations.

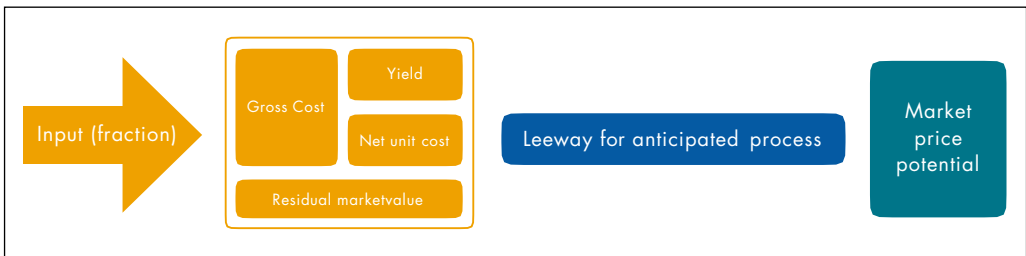


Figure 7.1. Leeway model.

NOTE: Considering the experimental nature of the Cases 2 and 3, the use of the leeway model was adapted accordingly.

7.2. Financial model for Case 1

Case 1's fashion remanufacturing value chain starts with collection of the used clothes as input material. In general, secondhand retailers and charities are by far the largest collector of used clothes; in Sweden nearly 16, 000 tons of clothes are being collected yearly by the ten largest secondhand retailers and charities. The parent charity organization, of which our case 1 is a part of, collects about 2000 tons yearly which is then sorted in its own facility. On an average, 55% are prime quality items which are cherry picked for being resold in the charity's own secondhand stores, while the rest is exported. Case 1 starts its remake journey here, by picking up boxes of used clothes to conduct a quality check. Through participatory observation we identified that this amounts to be roughly about 8 boxes, each containing ~8 kgs of used clothes. This is received either on a weekly or fortnightly basis, thus it roughly calculated that the total yearly amount that enters the remake journey equals to about 0.4% of 2000 tons. However, about 80% is returned for exports as they do not meet the criteria set in

quality inspection. Further our field observation indicated that during the remake operations, nearly 50% of the material amounts to be leftovers and wastes, like cutting wastes, zippers and buttons, broken parts of the garments etc. and cannot be reused. This is shown in the flowchart below (Figure 7.2).

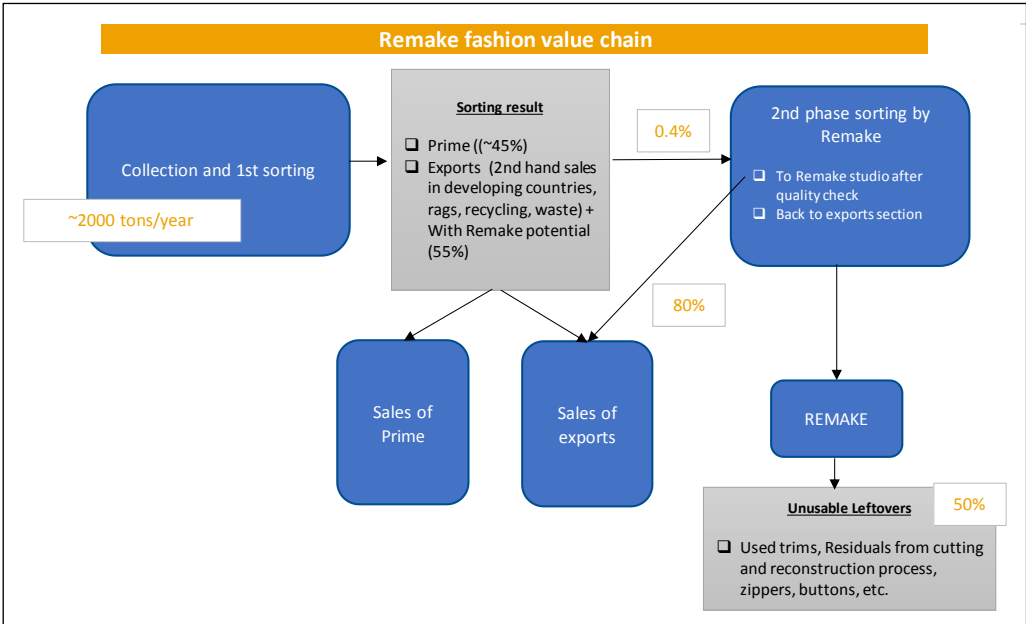


Figure 7.2. Generic scaled fashion remanufacturing value chain.

The critical success factors for Case 1's scaled fashion remanufacturing are as follows:

- Volume, fraction and costs of the 1st collection and sorting.
- Fractions in the 2nd sorting.
- Yield in remanufacturing processes through minimization of cutting wastes and unusable leftovers.
- Input material cost.
- Remanufacturing process costs, depending mainly on subsidies.
- Market price of the remanufactured items.
- Remanufacturability of the products, based on ease of redesign, quality, process repeatability and standardization.

The financial model used for testing Case 1's remanufacturing process feasibility is presented below. The aim is to define the leeway for remanufacturing process costs after collecting and sorting, by considering fractions and yields in various processes, in comparison to current market prices of remade fashion apparel.

CONSIDERATIONS IN THE MODEL

Realistic considerations for current process:

- 1) The input price of material is 8 SEK/kg. This is considered to be wholesale perice/kg of unsorted items (including prime)¹.
- 2) The prime fraction is sold directly in own second-hand stores and here this amounts to 45%. We assume that remaking prime items has low relative economic gain considering its high residual value.
- 3) The fraction of items that is picked up for remanufacturing is a variable depending upon the Case 1's operational capacity, presently estimated to be 0.4%, based on field observation.
- 4) The export materials, i.e. unsorted items (excluding primes) is calculated to be 54.6%.
- 5) Yield refers to the percentage of output obtained from input. Higher the unusable leftovers and cutting wastes in remanufacturing lower is the yield. This is estimated to be ~50%, based on field observation.

Other estimations and assumptions are as follows:

- 1st sorting process cost – 4 SEK7kg¹
- Market price for the 2nd hand store items – 49 SEK/kg
- Market price for the export items – 4 SEK/kg¹
- Market price for Remake items – Minimum 350 SEK/garment, Average/Mean 500 SEK/garment, Mode 1000 SEK7garment, Maximum 2500 SEK7garment
- Items/kg - 3²

1) Carlsson, J., H. Torstensson, R. Pal and m:k: Paras, Re:textile – Planning a Swedish Collection and Sorting Plant for Used Textiles – Feasibility Study, University of Borås, 2015
2) From Case 1's 2016 sales figures

Figure 7.3. Model considerations for Case 1.



Figure 7.4. Remanufacturing process output calculations.

The outcome of the model is made in Table 7.1 below.

| | Min. case | Av. Case | Max. case | Mode case |
|--|-----------|-----------|-----------|-----------|
| Market price | 1050 | 1500 | 7500 | 3000 |
| Material costs | 20000 | 20000 | 20000 | 20000 |
| Income from remnant sales | 24.25 | 24.25 | 24.25 | 24.25 |
| 1st sorting cost | 4 | 4 | 4 | 4 |
| Leeway for Remake processing cost | -18929.75 | -18479.75 | -12479.75 | -16979.75 |
| Leeway for Remake processing cost (with material cost = 0) | 1070.25 | 1520.25 | 7520.25 | 3020.25 |

Table 7.1. Leeway for Remake costs (SEK/kg).

The actual remake process cost (SEK/kg) is calculated as follows:

| Case 1's Remake process cost components | SEK/kg input* | | Calculation |
|--|---------------|----------|--|
| Salary costs | 229.6875 | 792.1875 | Total 11 labor (Fixed = 8 @25000 SEK/person/month; Hourly = 3 @ 15000 SEK/person/month) (+50% social costs). Subsidized labor receiving @15000SEK/person/month when subsidy stops (+50% social costs). |
| Subsidy received | -87.5 | 0.00 | Total 40 subsidized labor. Parent charity organization of Case 1 receiving 3500 SEK/person/month |
| Extra material costs | 33.75 | 33.75 | 4500 SEK/month |
| Electricity | 45 | 45 | 6000 SEK/month |
| Studio rent | 750 | 750 | 100000 SEK/month |
| Logistics | 15 | 15 | 2000 SEK/month |
| Machine maintenance | 6.25 | 6.25 | 10000 SEK/year |
| Cleaning | 112.5 | 112.5 | 15000 SEK/month |
| Total | 1104.69 | 1754.69 | |
| * @1600 kgs of input material for remanufacturing estimated as of 2016 data Out of total 51 employees, 46 are directly into production of which 4 are fixed, 40 are subsidized and 2 are hourly employed. Rest is designers and administrators (Fixed = 4, Hourly = 1). | | | |

Table 7.2. Actual remake process cost calculations (SEK/kg input).

Comparing results from the two tables above, the outcome of the model demonstrates that at the current fraction, process yields, various costs and market prices, all but the minimum case is feasible. The minimum case is a marginal one where the remanufacturing process

leeway is 1070.25 SEK/kg compared to the actual process costs of 1104.69 SEK/kg. However, this scenario depicted by Scenario 0 in Figure 7.5 is subjected to change due to the following: (i) subsidies may stop, (ii) Case 1 may need to buy material from collectors, mainly brands and retailers who on a mandatory Extended Producer Responsibility (EPR) system executed in Sweden may concentrate more on collection schemes thus making free access to large quantities difficult for charities, (iii) future fractions and yields may increase.

SCENARIO DEVELOPMENT

1. The model is flexible meaning that it can accommodate different variables and remanufacturing value chain structures. Here we consider only one structure as shown in figure 7.1. The variables considered are: a. Remake fraction from 1st sorting, b. Fraction for Remake after QC, c. Yield from remake process.
2. Scenarios considered are:
 - Scenario 0:** Base scenario as of now, i.e. with no material cost to be paid and subsidy received
 - Scenario 1:** With no subsidy
 - Scenario 2:** Remake buys 50% of the input material due to EPR in Sweden @ 8 SEK/kg from collecting brands + Scenario 1
 - Scenario 3:** Improved fractions and yield up to 5%, 75% and 75% respectively
 - Scenario 4:** Scenarios 3 + 1 + 2
 - Scenario 3":** Adjusting Scenario 3 at increased labor demand, productivity but reduced overheads/kg
 - Scenario 4":** Adjusting Scenario 4 at increased labor demand, productivity but reduced overheads/kg

Figure 7.5. Scenarios for leeway calculation for Case 1.

For Scenarios 3" and 4" where the remanufactured volume is increased due to higher fractions and yield from 800 kgs to 56250 kgs yearly, the calculation for remake process cost was adjusted at a higher labor productivity and other cost increments that is not directly proportionate.

The assumptions and calculations are as follows:

1. We assume that if the times required to produce a fully-fully, semi-semi and a no-minor product are ~5 hours, ~2 hours and ~1 hour respectively, average time to produce one is 2,67 hours, i.e. in 8 hour/shift/day, one person can produce average 3 products.
2. At fractions and yield of 5%, 75%, and 75% respectively, production is 234,375/day, i.e. we would need ~104 persons (@75% productivity).
3. Percentage of people who are employed as fixed, subsidized or hourly and are directly engaged with production remains the same.
4. The rent increases as step cost. With no addition to remanufacturing facility, this reduces to from 750 SEK/kg input to 16 SEK/kg. Other costs are assumed to be direct costs.

Table 7.3 shows the calculation of the actual process cost based upon these assumptions formulated.

| Remake process cost components | SEK/kg input* | | Calculation |
|---|---------------|-------|---|
| Salary costs | 8.3 | 29.1 | Total 19 labor (Fixed = 13 @25000 SEK/person/month; Hourly = 6 @ 15000 SEK/person/month) (+50% social costs). Subsidized labor receiving @15000SEK/person/month when subsidy stops (+50% social costs). |
| Subsidy received | -4.2 | 0 | Total 90 subsidized labor. Parent charity organization of Case 1 receiving 3500 SEK/person/month |
| Extra material costs | 33.75 | 33.75 | 4500 SEK/month |
| Electricity | 45 | 45 | 6000 SEK/month |
| Studio rent | 16 | 16 | 100000 SEK/month |
| Logistics | 15 | 15 | 2000 SEK/month |
| Machine maintenance | 6.25 | 6.25 | 10000 SEK/year |
| Cleaning | 112.5 | 112.5 | 15000 SEK/month |
| Total | 232.6 | 257.6 | |
| * @75000 kgs of input material for remanufacturing as per constructed scenario. | | | |

Table 7.3. Actual remake process cost calculations (SEK/kg input) for scenarios 3” and 4”

| | SCENARIO 0 | | | SCENARIO 1 | | | SCENARIO 2 | | | SCENARIO 3 | | |
|-------------------------------------|---------------|-----------|-----------|--------------|--------------|-----------|--------------|--------------|--------------|---------------|-----------|-----------|
| | Min. case | Avg. Case | Max. case | Min. case | Avg. Case | Max. case | Min. case | Avg. Case | Max. case | Min. case | Avg. Case | Max. case |
| Price before 1st sorting | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 |
| Remake fraction after 1st sorting | 0,40% | 0,40% | 0,40% | 0,40% | 0,40% | 0,40% | 0,40% | 0,40% | 0,40% | 5% | 5% | 5% |
| Fraction for Remake after QC | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 75% | 75% | 75% |
| Yield for Remake | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 50% | 75% | 75% | 75% |
| Remake output volume | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,028125 | 0,028125 | 0,028125 |
| Actual material costs to Remake | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 10000,00 | 10000,00 | 10000,00 | 0 | 0 | 0 |
| 1st sorting cost | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Remake process costs | 1104,69 | 1104,69 | 1104,69 | 1754,69 | 1754,69 | 1754,69 | 1754,69 | 1754,69 | 1754,69 | 1104,69 | 1104,69 | 1104,69 |
| Income from remnant sales | 24,25 | 24,25 | 24,25 | 24,25 | 24,25 | 24,25 | 24,25 | 24,25 | 24,25 | 24,10 | 24,10 | 24,10 |
| Market price | 1050,00 | 1500,00 | 7500,00 | 1050,00 | 1500,00 | 7500,00 | 1050,00 | 1500,00 | 7500,00 | 1050,00 | 1500,00 | 7500,00 |
| Leeway for. Remake processing costs | 1070,25 | 1520,25 | 7520,25 | 1070,25 | 1520,25 | 7520,25 | -8929,75 | -8479,75 | -2479,75 | 1070,10 | 1520,10 | 7520,10 |
| Leeway vs. Remake processing costs | Marginal case | Feasible | Feasible | Not feasible | Not feasible | Feasible | Not feasible | Not feasible | Not feasible | Marginal case | Feasible | Feasible |

| | SCENARIO 4 | | | SCENARIO 3" | | | SCENARIO 4" | | |
|-------------------------------------|--------------|--------------|-----------|-------------|-----------|-----------|-------------|-----------|-----------|
| | Min. case | Avg. Case | Max. case | Min. case | Avg. Case | Max. case | Min. case | Avg. Case | Max. case |
| Price before 1st sorting | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 | 8,00 |
| Remake fraction after 1st sorting | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| Fraction for Remake after QC | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% |
| Yield for Remake | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% | 75% |
| Remake output volume | 0,028125 | 0,028125 | 0,028125 | 0,028125 | 0,028125 | 0,028125 | 0,028125 | 0,028125 | 0,028125 |
| Actual material costs to Remake | 142,22 | 142,22 | 142,22 | 0 | 0 | 0 | 142,22 | 142,22 | 142,22 |
| 1st sorting cost | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Remake process costs | 1754,69 | 1754,69 | 1754,69 | 232,60 | 232,60 | 232,60 | 257,60 | 257,60 | 257,60 |
| Income from remnant sales | 24,10 | 24,10 | 24,10 | 24,10 | 24,10 | 24,10 | 24,10 | 24,10 | 24,10 |
| Market price | 1050,00 | 1500,00 | 7500,00 | 1050,00 | 1500,00 | 7500,00 | 1050,00 | 1500,00 | 7500,00 |
| Leeway for. Remake processing costs | 927,88 | 1377,88 | 7377,88 | 1070,10 | 1520,10 | 7520,10 | 927,88 | 1377,88 | 7377,88 |
| Leeway vs. Remake processing costs | Not feasible | Not feasible | Feasible | Feasible | Feasible | Feasible | Feasible | Feasible | Feasible |

* All calculations are made in SEK/kg

* All calculations are made in SEK/kg
 Figure 7.6. Scenario development and economic feasibility assessment.

The following conclusions can be drawn from the scenario analysis:

1. In the current scenario 0 (i.e. with subsidy, low fractions and yields, and no material costs) remanufacturing is feasible, except when the market price/item is 350 SEK.
2. When subsidy stops (as in Scenario 1), the average case (i.e. market price = 500 SEK/item) becomes marginally feasible while the minimum case (i.e. market price = 350 SEK/item) is not feasible. That means, compared to the current scenario 0 feasibility deteriorates.
3. Remanufacturing is least feasible when material has to be bought, i.e. in Scenario 2. None of the cases are feasible if 50% of the input material needs to be purchased from brands and retailers, at the same fractions and yield.
4. Interesting that, compared to Scenario 0 if the fractions and yields are improved to 5%, 75% and 75% respectively, the situation is marginally worsened as in scenario 3. This is because at no material cost to be paid, the income from the remnants is the only variable based on increased fractions and yield which reduces as a result. Along with this when material cost has to be paid, as in scenario 4, result is feasible only when all items are sold at maximum price of 2500 SEK/item.
5. In comparison, in scenarios 3" and 4" 'where the remake process costs are adjusted at higher labor productivity and stepwise cost increment for renting facility, feasibility is achievable even for minimum case scenario when all items are sold at 350 SEK/item.

7.3. Financial model for Case 2

The distributed redesign value chain of Case 2 starts with the identification of garments which need a remake to become more attractive in the consumers' minds. In the described case, such garments come from the same company, but it is entirely feasible to withdraw the material from also other sources. The garments have not been used or treated in a chemically adverse way, so there is no sanitation needed.

One problem is that the material must be diverted from the regular, linear supply chain, and that the procedures for doing that in a seamless manner are not fully developed. Improvements are needed for the management of logistics, in particular methods for early classification of 'unsellable' items, inventory management, network of collaborating, preferably local actors, IT support for the secondary flow, clever marketing, and reasonable pricing principles.

7.3.1. Costs and price of the product

Cf. also the material use and calculation sections for each item under Case 2.

The correct price must be ensured in the system, when the garment is taken from the distribution center. The correct way to determine the cost of the garment is uncertain, because the value (e.g. the value of the garment in the store or the recycle value of the material) is not determined. The price of the garment could also be the ELC of the garment (Estimated Landing Cost = FOB + shipping + customs + warehouse cost).

It became clear early in the project that it is difficult to establish the value of the input material, in order to ultimately determine a price. There are a few ways to calculate the value:

- a. Alternative value: The price Lindex would receive if they sold the garment in the store.
This value changes constantly, depending on how bad the garment sells (i.e. markdown %).
- b. Unsorted value: The price Lindex would receive if they sold the garment unsorted to a collector (approx. 3 SEK/kg)

c. Sorted value: The price Lindex would receive if they sold the garment sorted to a collector (20 SEK/kg). The method chosen may affect the shop's retail price.

CONSIDERATIONS IN THE MODEL

Realistic considerations for current processes:

Price of original items (assumed wholesale sorted/unsorted) – 20.00/3,00 SEK/kg

Original garments/products – 3/2

Yield from cutting – 34%

Fixed cost, development of pattern and process – 40 h

Process cost (average, depending on model) – 60 min, 7 SEK/min, 420 SEK/bag^{1,2}

Market price for remake items – 500 SEK/item (+VAT)

Items/kg – 2

Lead time (production start – delivery to store) – 11 weeks

1) Sorting Feasibility Report, Carlsson et al. (2015)

2) High cost for cutting out patches.

Figure 7.7. Exemplar Model considerations for Case 2 – For bag.

NOTE: We have considered the labor cost a bit higher than what was calculated in the Case 2 (i.e. 7 SEK/min instead of 6 SEK/min)

Assumed an input material price of 20 SEK/kg, the material need of 1.5 items/bag (due to yield factor), and the typical weight of 0.5 kg/item, the material cost is 15 SEK/item. The leeway for distribution, marketing, selling and profit is thus very small. Increasing consumers' perceived value by, say, developing the brand and their environmental awareness, may give room for raising the market price.

7.3.2. Scenario-based feasibility assessment

From a sustainability perspective there is a merit in the aim of this case to recreate value of obsolescent or otherwise unsaleable clothing. By streamlining the process, remade products can likely cover their cost and even generate some profit. It can be noted that small enterprises, often non-profit ones, exist, which work as described in Case 2, but with used or discarded clothing as material for remaking.

Various assumptions are needed for feasibility assessment considering the experimental nature of the project. These are summarized in the two scenarios depicted in Figure 7.8. For both scenarios, it is assumed that the regular, linear supply chain can be modified to allow a circular (or semi-circular) flow of such obsolescent objects into a distributed redesign value chain, that those objects are easily identified in the company's inventory, and that the logistics support systems are amended to allow withdrawal of material for the remake production.

Scenario 1. The original garments are priced as 'sorted' goods for recycling, viz. the initial value is estimated to 20 SEK/kg. The process is as described in the case study, however more efficient, due to the improved logistics flow. The outcome can be kimonos, bags or trousers (designed jeans). They will be sold under a well-known, reputed brand, facilitating a high-end retail price.

Scenario 2. The original garments are priced as 'unsorted' goods for recycling, viz. the initial value is estimated to 8 SEK/kg. The process is as described in scenario 1, but is carried out in sheltered, publicly supported workplaces. Hence we assume 50% subsidy in the processing cost. The outcome also in this scenario can be kimonos, bags or trousers, to be sold at various outlets.

Figure 7.8. Scenarios for Case 2.

Processing cost includes workforce salaries, extra material, place rent, machinery depreciation and maintenance (or rent) and logistics costs (cf. Case 2). Indirect costs include primarily marketing and sales, administration, initial design and set-up costs and write-off of obsolescent products.

NOTE: The figures for retail prices and indirect cost (as 50% of processing costs) are conditioned estimates.

| Scenario 1 | Kimono | Bag | Jeans |
|---|--------------|--------------|----------|
| Retail price (excl. VAT), SEK/item | 900 | 620 | 620 |
| Processing cost, SEK/item | 630 | 420 | 300 |
| Share of indirect costs, SEK/item | 315 | 210 | 150 |
| Weight (kg) | 3 | 0.75 | 0.5 |
| Material cost (excl. VAT), 20 SEK/kg | 60 | 15 | 10 |
| Resulting gain/cost, SEK/item | -105 | -25 | 160 |
| | Not Feasible | Not Feasible | Feasible |
| Scenario 2 | Kimono | Bag | Jeans |
| Retail price (excl VAT), SEK/item | 540 | 440 | 380 |
| Processing cost, subsidized, SEK/item | 315 | 210 | 150 |
| Share of indirect costs, subsidized, SEK/item | 157.5 | 105 | 75 |
| Weight (kg) | 3 | 0.75 | 0.5 |
| Material cost (excl VAT), 8 SEK/kg | 24 | 6 | 4 |
| Resulting gain/cost, SEK/item | 43.5 | 119 | 151 |
| | Feasible | Feasible | Feasible |

Table 7.4. Scenario development and economic feasibility assessment.

Under the assumed conditions, remanufacturing is clearly feasible for jeans, but not for Kimono and bag due to high processing cost (and associated indirect costs). The feasibility is improved through subsidy. There is of course a substantial uncertainty associated with the calculations, due to the experimental nature of the case and to whether the initial assumptions of adapting the logistics properties appropriately are feasible.

7.4. Financial model for Case 3

The PSS redesign-as-a-service case (3) starts with the individual customer walking into the store, either with his/her old pair of jeans or to buy a new one and redesign to add own creativity to it. In the described case, the customers were only allowed to redesign their Monki jeans as the artworks were earlier experimented for ink type, processes, resolution, etc. only on unisized Monki jeans pockets, pre-determined colors and material composition. But it is entirely feasible to adapt it to any jeans or even other garments from other brands. However, these factors will have different impacts on amount and type of inks required, treatment time, etc. and accordingly will influence the process costs.

7.4.1. Costs and price of the redesign-as-a-service

Direct process costs:

Cf. also the Figure 6.9 to get the total printing material costs, based on use of CMYK ink+white ink+pretreatment material. As stated earlier in the Case 3, this cost varies on three things: jeans color, volume of ink used/artwork and used/new jeans. The total printing cost range was 6.60 - 14.68 SEK.

When it comes to labor cost, we can estimate the salary cost of involving a co-design assistant in the store. As per Figure 6.7b, the overall range of the total lead time is between 171 and 199 seconds. We can take the approximate 7 SEK/minute multiplying factor (as was calculated in Case 2).

Overhead cost components:

Labor cost overhead, as per Case 2's estimation, is assumed to be 50%.

Estimated Maintenance Overhead Per Garment. As per BrotherDTG ROI Calculator¹⁰ this is 25% of direct ink cost/print.

Monthly Lease Payment for GTX4 = USD 799/month¹¹ for 24 months = ~7 200 SEK/month.

Monthly Lease Payment for Pretreatmaker¹² = USD 799/month = ~1000 SEK/month (evaluated at the same ratio as GTX4)-

Rent in Stockholm based on city average = 2200 SEK/m²/year and City maximum = 23000 SEK/m²/year. For roughly 10 m² store area required for the PSS set-up, and assuming a medium-high rent of 18000 SEK/m²/year, i.e. 1500 SEK/m²/month, total rent = 15000 SEK/month.

¹⁰ <http://brotherdtg.com/about-the-gtx/roi-calculator/>

¹¹ <http://brotherdtg.com/about-the-gtx/roi-calculator/> (GTX4 \$22,500 paid in full)

¹² <https://www.stormtextil.dk/en/machine-sales/schulze-pretreatmaker-iv> (Price = 2700 Eur)

Customer willingness to pay evaluation:

To estimate the value of customized service offered, 40 consumers were asked to state a price range they were willing to pay for the redesign service. No respondent valued the service under 25 SEK, 8 (20.00%) were willing to pay between 25-50 SEK, 17 (42.50%) would pay between 50-100 SEK, and 15 (37.50%) would consider paying more than 100 SEK. This is shown in Figure 7.9.

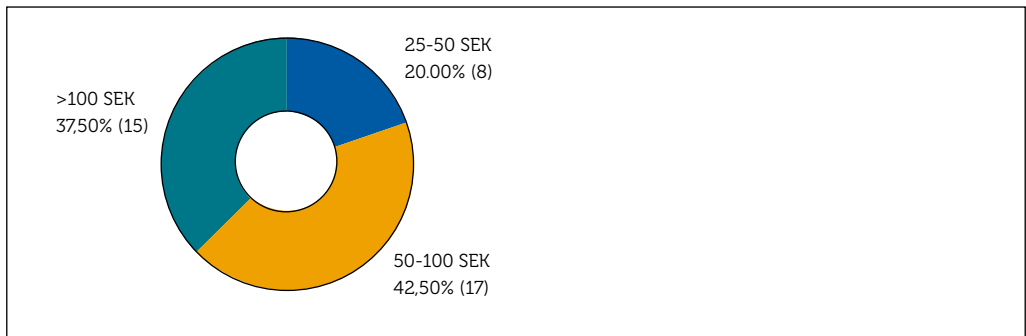


Figure 7.9. Customers' willingness to pay for redesign-as-a-service.

From the volume perspective, we made the following assumptions and considerations.

- Minimum capacity (M) = (20 days/month x8 hours/day x 3600) /199 seconds/print = 2894 prints/month.
- Maximum capacity (M) = (20 days/month x8 hours/day x 3600) /171 seconds/print = 3368 prints/month.

Based upon the above considerations, we have created two simple scenarios with maximum and minimum cost estimates, as shown in Figure 7.10.

Scenario 1. The redesign-as-a-service is offered at three customer willingness to pay (mini-
mum, middle, maximum) @ maximum cost estimates.

Scenario 2. The redesign-as-a-service is offered at three customer willingness to pay (mini-
mum, middle, maximum) @ minimum cost estimates.

Figure 7.10. Scenarios for Case 3.

| Scenario 1 (Piec-es/month = M) | Jeans Rede-sign-as-a-service | Jeans Rede-sign-as-a-service | Jeans Rede-sign-as-a-service |
|---|-------------------------------------|-------------------------------------|-------------------------------------|
| Customer willingness to pay, SEK/item | 25 | 50 | 100 |
| Maximum direct print costs, SEK/item | 14,68 | 14,68 | 14,68 |
| Maximum direct labor cost, SEK/item | 23,21 | 23,21 | 23,21 |
| Maximum labor cost overhead, SEK/item | 11,61 | 11,61 | 11,61 |
| Maximum maintenance cost overhead, SEK/item | 3,67 | 3,67 | 3,67 |
| Monthly Lease Payments, SEK/item | 2,83 | 2,83 | 2,83 |
| Monthly Rent Payment, SEK/item | 5,18 | 5,18 | 5,18 |
| Cost-Benefit | -36 kr | -11 kr | 39 kr |
| | Not Feasible | Not Feasible | Feasible |
| Scenario 2 (Pieces/month = M) | Jeans Rede-sign-as-a-service | Jeans Rede-sign-as-a-service | Jeans Rede-sign-as-a-service |
| Customer willingness to pay, SEK/item | 25,00 | 25,00 | 100,00 |
| Minimum direct print costs, SEK/item | 6,60 | 6,60 | 6,60 |
| Minimum direct labor cost, SEK/item | 19,95 | 19,95 | 19,95 |
| Minimum labor cost overhead, SEK/item | 9,98 | 9,98 | 9,98 |
| Minimum maintenance cost overhead, SEK/item | 1,65 | 1,65 | 1,65 |
| Monthly Lease Payments, SEK/item | 2,43 | 2,43 | 2,43 |
| Monthly Rent Payment, SEK/item | 4,45 | 4,45 | 4,45 |
| Cost Benefit | -20 kr | 5 kr | 55 kr |
| | Not Feasible | Feasible | Feasible |

Table 7.5. Scenario development and economic feasibility assessment.

Under the assumed conditions, redesign-as-a-service is clearly feasible in most cases, except when the customer willingness to pay is the least and the costs are the highest. There is of course a substantial uncertainty associated with the calculations, due to the experimental nature of the case.

8. Remanufacturing fashion business models

Business models are composed of three basic elements: value creation, value architecture and revenue structure (Osterwalder and Pigneur, 2010). For remanufactured fashion business models (RemfBMs) value creation includes value proposition and customer segment. The value architecture mainly covers elements addressing how the value is created and in what configuration, i.e. customer relationships, distribution channels, key resources and activities, and partners. The revenue structure highlights how the company can monetize. The following section highlights both current business model and future business opportunities for all the three cases. For Cases 2 and 3 (i.e. the test cases) the business models are adjusted due to their experimental nature, hence current business model refers to the experimental business set-up, while the future business opportunities refers to the proposal on how to scale them up.

8.1. Business Model Canvas – Case 1

Value creation includes:

Value proposition: Due to the inherent nature of the design and product development process, remanufactured fashion items are 'one-of-the-kind' in its type in terms of its material, fabric and color palette; only style, design and the pattern of the garments may remain the same with slight changes. Further the products provide a feeling of 'feel-good' and 'doing the right thing' to the 'sensitive' wearer by showcasing a sense of awareness on sustainability and environmental issues. Combined with uniqueness and authenticity using remanufactured fashion products provides a feeling of using vintage luxury. Also, unisex, unisize and free style garments apart from making a statement is convenient to use in daily life freeing wearer of everyday confusion in selecting what to wear!

Customer segments: The current customers are very passionate for 'vintage' fashion, i.e. who are receptive of vintage fashion trends. They are also ethically and environmentally aware of the implications of fashion industry thus desire to buy/use goods that are designed to lessen the impact on environment, and value garment longevity through design, style and fashion aesthetics rather than throwaway chics.

Value architecture includes:

Customer relationships: Through its retail shops Case 1 has the opportunity to interact directly with its customers and receive feedback on its products and also the sales reports are directly used as an input for production planning. For making this interaction more experiential the shop also offers repairing kits and sewing accessories, and along with tips on solutions for fixing and repairing your own garments and accessories.

Distribution channels: Remanufacturing stores located at popular shopping places has the potential to attract large customer traffic. Innovative visual displays, in-store concepts, smart choice of merchandize play a vital role in enticing the customer to pay. In addition, shop-in-shops play a vital role in establishing alliances with multi-brand fashion retailers for scaling-up sales.

Key activities:

- For **sorting**, Case 1's input material has a separate section in its parent organization's sorting plant and sorters start separating materials from sorting conveyor itself. Frequency of collection are 8 boxes/week and 8 boxes bi-monthly from sorting plant, respectively for two of the facilities. Case 1 presently does not have to bother much about the reverse logistics (acquisition of input material from varied sources, its transportation etc.) as the facilities are located close to the parent organization's sorting plant or the volumes are handled in small quantities.
- In terms of **preparation and quality checks**, cleaning and inspecting the input material before approving it is critical. Quality checks are done at various process intervals, i.e. before, in-between and after dis- and re- assembly stages.
- For **pattern design and product development**, sketches and patterns are constructed. Continuing products have formalized paper patterns already available which are used for marking for fully-fully products made from snakes. Construction principles are also noted in the product pattern documents that are used for remaking the semi-semi products.
- **Disassembling garments** are based on condition, possibilities and requirements; used clothes are completely, partially or not at all disassembled. Activities typically includes cutting, 'mix & match', piling, overlocking and sewing, depending upon the degree of disassembly.
- **Reassembling garments** are based on classification according to the product matrix, full or semi reassembling is done. This mainly includes 'mix & match' and grading (on snakes made from stitched fully disassembled patches), cutting, sewing, and finishing (ironing and packing). For garments that did not undergo any disassembly, minor value addition includes activities such as stitching, patching, and printing.
- **Demand planning** is done every month to serve as the basis for how much to source as input material. Weekly sales reports are also analyzed to determine remanufacturing volumes.
- Finally **distribution and retail** is made through exclusive shop. Retailing includes branding and advertising by displaying the products saleable manner.

Key resources: Case 1 employs designers, production operators, administrative personal and also shop manager and sales person. In the main facility there are over 50, majority of which are subsidized workforce (few are hourly employed). Among the fixed staffs, mostly are designers and production operators.. The task of the designers and production operators are multi-functional compared to conventional manufacturing processes. The designers are not only responsible for designing within the constraints of the fabric but are also responsible for sourcing the input material from the sorting plant. They are the ones who control the creative processes of pattern development and construction. However, the person responsible for cutting the patterns is also very skilled person and may or may not be the designers. The subsidized workforce is mostly responsible for the sewing activities. When it comes to essential equipment to develop the remanufactured product from a design idea; these include industrial and domestic sewing machines, overlock machines, bobbin filling machines, cutting and laying tables, and washing machines. The floor layout of the facility typically depicts a conventional, semi-industrialized remanufacturing plant design. Input material is a crucial resource, too. Boxes of input consist of different materials depending upon which facility it is heading towards, but mostly denim, men shirt and sheets. The quality of the material is good but there are most of the time stains or holes on them which makes it difficult to sell on secondhand stores. Further key to the brand's intellectual property is copyright of the brand.

Key partners: Majority of its input material from its parent organization, which is a charity. Further it also receives clothes donated by fashion brands and retailers. Very recently it has collaborated with a mainstream multi-brand fashion retailer to sell its products side-by-side to first-hand fashion items of other brands.

Revenue structure includes:

Cost structure: Focus of Case 1 is on creating more value (economic, environmental and social) for its product/services although cost minimization is also important. As of now due to the limited potential to achieve economies of scale (due to low volume of production), subsidy plays a crucial role in driving economic feasibility of such fashion remanufacturing. Such subsidies (generally between 2000-5000 SEK per month) from a variety of state-owned organizations (e.g. Försörjningsstöd, Försäkringskassan, etc.) finance subsidized workforce. The receiving amount depends on the degree of training program as well as workforce personal capabilities. Sometimes the overhead of fixed staffs are also received from state.

Revenue streams and pricing: Economic value can be gained through remanufacturing which includes a creative redesign process to mark-up the market price of remanufactured fashion products. In comparison to the average price range in 2nd hand store (between 40 and 150 SEK), the average price range for Case 1 is 350-2500 SEK. Social and environmental image value drives high the retail point of the remanufactured garments. Existing stores serve as a great opportunity to develop customer relationship and receive feedback.

| | | | | |
|---|---|--|--|---|
| <p>Key partners</p> <ul style="list-style-type: none">❑ Sorting plants for receiving input materials<ul style="list-style-type: none">– For some donation;❑ For sales❑ Academic and research institutes - e.g. Remake-Re:Textile | <p>Key activities</p> <ul style="list-style-type: none">❑ Sourcing input material from own sorting plant (inweekly boxes)❑ Reverse logistics (minimum checks)❑ Cleaning, inspection and quality❑ Pattern design & construction for new products❑ Disassembly (full, semi) - cutting, 'mix & match', piling, overlocking and sewing, depending upon the degree of disassembly❑ Reassembly (full, semi, minor recoupling)❑ Distribution and retail | <p>Customer value Proposition</p> <ul style="list-style-type: none">❑ Unique Customization thru one-of-the kind product❑ 'Feel-good and 'doing the right thing' feeling❑ Authenticity + vintage luxury❑ Univ-sex, uni-size, free style❑ DIY | <p>Customer relationship</p> <ul style="list-style-type: none">❑ Assistance in Remake shop❑ Repair solutions and kits <p>Distribution channels</p> <ul style="list-style-type: none">❑ Own retail shop with innovative visual displays, in-store concepts, ...❑ Shop in shop | <p>Customer segments</p> <p>Customers with:</p> <ul style="list-style-type: none">❑ vintage taste❑ Eco-fashion concern❑ Love for slow fashion/longevity❑ Social entrepreneurs |
| <p>Cost structure</p> <ul style="list-style-type: none">❑ Value driven - Its creative redesign process leads to a high mark-up factor, and a selling price about 10-15 times more than second-hand clothes❑ Subsidy driven - Between 2000-5000 sek/month per subsidized workman | | <p>Revenue streams and pricing</p> <ul style="list-style-type: none">❑ Retailing - Through Remake's store; recently as a shop in shop thru 'collaboration with a branded retailer❑ Mark-up factor, and a selling price about 10-15 times more than second-hand clothes | | |

Figure 8.1. Current RemjBM of Case 1.

A detailed evaluation of the current business model yielded a proposal for future RemfBM for Case 1. The proposed addition to the business model elements are presented below:

Added value creation opportunities:

Value proposition: Trans-seasonal garments could be developed. Also new design principles based on modularity and/or incremental design, e.g. “many-in-one garment” or “much functionality in one garment” as a package could be tried. Possibility to co-design the remanufactured garment will add unique customer experience. Some sort of redesign services offered can also enhance co-creation experience and at the same time extend garment longevity and its active use life. Such services can be offered to B2B customers (e.g. fashion retailers), as well, in the form of ‘remanufacturing as a ser-vice’ (RemaaS) option. Further possibility of using the product without having its ownership or re-sponsibility, e.g. sharing, renting, etc. can provide access to a large range of remanufactured garments.

Customer segment: New B2B customers, e.g. fashion brands and retailers through remanufacturing and/or sales of their items, e.g. deadstock, take-back items. Also by sharing knowledge on fashion remanufacturing and local design and production through workshops and trainings can be value add-ing.

Added value architecture opportunities:

Customer relationships: By operating a use-oriented service business model (e.g. renting, leasing of Remake’s garments) more attractive services related to delivery and pick-up, laundry, etc. could be offered. In addition, Case 1 can offer its consumers information on the benefits of using remanufactured fashion items, and at the same time delight them with creative options such as micro-blogging on sharing stories of user experience with the remanufactured garment, posting logs about daily life of the garments, etc. Sharing such personal experience can be rewarding in many ways, e.g. curated services to its online consumers, such as from simple information about the products’ made-in/by stories to more digitally advanced options like virtual configurations. For B2B customers, remanufacturing services could be explored.

Distribution channels: Offering users and wearers redesign service options in own retail shops, in the form of repairing and minor redesign service assistance in some workstation adjacent to the store’s retail area can be lucrative to attract more customer with diverse interests. Also a fully transactional website for e-commerce can be beneficial to sale remanufactured products due to the relatively low space productivity in remanufacturing retail outlets due to low turnover volume. Initially to reduce investments for running own e-commerce business, certain products could be sold via multi-brand e-tailers too. In connection, an App can be developed to allow customers avail simple information to more advanced features, such as browsing through digitally rendered product images with options to co-design, curated opinions, etc.

Key activities: Case 1’s could decide to source from other charities and secondhand clothes collectors, or contract third-party services such as cleaning. In product development, new garment redesign strategies, e.g. modularity can be tried. Further, remanufacturing services can be offered to both, fashion brands/retailers and individual consumers. This may include recoupling activities, such as dyeing and printing, cutting, stitching and embroidering, etc. In the B2C format this can be offered to consumers visiting stores or even online with degrees of co-creativity involved.

Key resources: Increasingly it can be seen that key roles in the fashion remanufacturing process demands more cross functional roles, such as 'designer-operators' and 'pattern makers-cum-seamstresses'. Additionally, with more technological opportunities there needs to be more skilled workforce versed with the latest techniques. In the near future visual merchandizers and brand man-agers can play a significant role in creating the *face* of a branded remanufacturer.

Future plans to scale up into a remanufacturing mini-factory needs purchase of more sewing machines and cutting tables, automatic cutting scissors and unpicking machines. In addition latest equipment that can be tried are leather cutting machines for cutting multiply irregular garments and patches, bonding machines for trying bonding technique for joining instead of stitching, digital printing machines for redesign purposes, etc. However with developments towards a remanufacturing mini-factory, there could be future requirements for more safeguards related to the knowledge and practices created in terms of its remanufacturing processes and product development methodologies.

Key partners: In the future possibilities remain in cooperating with other charity organizations and used clothes collectors to acquire large volume of prime quality items suitable for remanufacturing. Also, by offering RemaaS to fashion retailers, Case 1 can increase its business scope to bring down overhead costs and also get associated with new servitized business models. It can start selling online via a number of e-commerce platforms, both selling first-hand clothes and also those dedicated particularly for secondhand clothes.

Added revenue structure opportunities:

Cost structure: Viable economies of scale can be achieved by formalizing the remanufacturing product-process matrix such that more products can be remanufactured in a semi-industrial way more easily and faster. Presently this is hindered by creative heuristics in the remanufacturing stages, but the (Rem) product-process matrix and key product group requirements can be seen as a stepping stone for creating a formal fashion remanufacturing methodology to reduce ambiguities in the decision-making process and for setting a standard procedure. Such formalization can also routinize relatively low skilled subsidized workforce to perform certain creative remanufacturing stages in a more repetitive way, e.g. while producing more basic staple products, thus helping to achieve economies of scaled remanufacturing. Case 1 may also consider other production models, e.g. open remanufacturing where service can be rendered to fashion retailers willing to develop remanufactured fashion collection out of deadstock or collected used items. This way economy of scope can be achieved by distributing the costs related to fixed staff, equipment and facility rents for diverse remanufacturing product lines.

Revenue streams and pricing: More stores can be opened in near future depending upon requirement. Dynamic pricing can be tried for products which are developed based on principles such as modularity or incremental design, as a customized package, e.g. "many-in-one garment" or "many functionality in one garment", where the customer can choose and pay for the number of possibilities he/she opts for. Simpler use-oriented models such as renting and leasing options for high-end remanufactured products, e.g. bomber jackets can be tried out. Other options, such as re-design/repair services can be rendered to the consumers, either in store or mediated online. Customers can pay for the service and toolkit required for such operations. Based on incremental design features of the remanufactured garment, e.g. wearer can pay a service fee every time he/she redesigns (adds an embroidery, print, etc.).

After the rental/leasing period is over he/she can get the chance to own the garment he/she co-designed over a long period. Rental fees can be made more relation-based, i.e. a wearer pays less if him/her micro-blogs about the product to build the story of the dress in its “second-life”, or he/she chooses to take the co-design option. RemaaS option offered to fashion brands and retailers willing to redesign their leftovers and deadstock can be profitable in the near future. The service fees can be made dynamic, for instance, concession depending upon the volume of donation of used clothes received from the retailer. DIY remanufacturing lessons can be organized against small fees for niche consumers.

| | | | | |
|--|--|---|---|---|
| <p>Key partners</p> <ul style="list-style-type: none">❑ Other charities and second-hand clothes collectors to obtain large prime qties❑ Fashion brands and retailers – to offer remanufacturing as a service❑ E-commerce platforms, both selling first-hand clothes and also those dedicated partticularly for second-hand clothes.❑ Academic and research institutes – To create knowledge of new remanufacturing technologies, and new business models to support feasibility and scalability plans | <p>Key activities</p> <ul style="list-style-type: none">❑ Sourcing input material from other charities and second-hand clothes collectors.❑ New garment redesign and construction techniques, e.g. modularity based❑ Recoupling services – As B2B option to fashion brands and retailers, such as dyeing and printing, cutting, stitching and embroidering, etc. As B2C option to consumers visiting stores or even online with degrees of co-creativity involved | <p>Customer value Proposition</p> <ul style="list-style-type: none">❑ Trans-seasonal garments; Trying new design principles based on modularity and/or incremental design, e.g. “many-in-one garment” or “much functionality in one garment”❑ Co-creation to add unique customer experience; Redesign services to end customer; “Remanufacturing as a service” to fashion retailers❑ Accessibility - Sharing, renting, etc. can provide access to a large range of remanufactured garments | <p>Customer relationship</p> <ul style="list-style-type: none">❑ Assistance in Remake shop thru’ use-oriented services, e.g. renting, leasing, etc.❑ Online and social media interactions – e.g. information on simple DIY remake; micro-blogging on sharing remake garment experiences with peers❑ Advanced curated experiences, e.g. virtual configurations etc.❑ Remanufacturing service contacts with fashion retailers | <p>Customer segments</p> <ul style="list-style-type: none">❑ Business-to-business – To fashion brands and retailers through remanufacturing and/or sales of their items, e.g. deadstock, take-back items❑ Other stakeholders – By sharing of knowledge on fashion remanufacturing and local design and production through workshops and trainings |
| <p>Key resources</p> <ul style="list-style-type: none">❑ Mini-factory❑ Human resources - More cross functional roles, such as designer-operators and pattern makers-cum-seamstresses❑ Latest techniques – e.g. bonding, gluing, etc.❑ Visual merchandizers and brand managers for developing Remake brand❑ Equip –Automatic cutters, unpicking machines, leather cutting machines for cutting multi-ply irregular garments and patches, bonding machines for joining instead of stitching, digital printing machines for redesign purposes, etc.❑ IPR/patents on remake processes, product development methods | | <p>Distribution channels</p> <ul style="list-style-type: none">❑ Redesign service stations in own retail shops offering minor recoupling❑ Online sales thru’ either own or multi-brand e-tailers❑ Remake App | | |
| <p>Cost structure</p> <ul style="list-style-type: none">❑ Formalization driven – Routinizing remanufacturing product-process to support semi-industrialization, standardization and skill repeatability❑ Scope-driven – Remake may consider other production models, e.g. open remanufacturing | | <p>Revenue streams and pricing</p> <ul style="list-style-type: none">❑ Retailing – More stores both brick and mortar and online❑ Dynamic pricing for customized packages like ‘many functionality in one garment’❑ Use-oriented models such as renting and leasing options for high-end products, e.g. bomber jackets❑ Pay per incremental design. Relation-based discounts on rental fees; Per per redesign; etc.❑ Remanufacturing service fees; DIY lessons, etc. | | |

Figure 8.2. Proposed RemfBM of Case 1.

8.2. Business Model Canvas – Case 2

Case 2 differs from Case 1, regarding the scale of the production. Case 2 is a test case, to investigate how unsold items can be remade into perhaps more attractive variants, and much pioneering work was devoted to the development of the concept. Flexibility, ingenuity, availability of competence and rapidity from decision to implementation are essential for the concept. Thus a business model for a more steady-state production is still to be developed. Factors crucial to consider in order to develop a future for the business model in Case 2 are the following:

Partners: The principal partner was Lindex, supplying the material and also being ultimately responsible for the logistics, marketing and sale of the products. Efforts were needed to find sewing capacity and appropriate machinery; so in addition, locally available techniques and the requirements of different products were identified. Nordiska Etikettbolaget AB, a company specializing in profile clothing eventually became the main partner for printing and some sewing, as well as for storage and distribution. It also provided techniques typical of that industry. Usually, small machines with high flexibility were available, like laser cutters, which means longer lead times and thus higher costs than in the regular flow. Xvemiul made most of the sewing.

Key activities and resources: the source of the redesigned and remade garments is unsold clothing from the same company. Cf. also the design process below.

- In the **design process** it is important to first identify the garments suitable for redesign. They should have low stock turnover rate, without expected increase, and be suitable for remaking. There must be sufficient numbers in stock to form sales volumes in the store, etc. The inventory balances of the distribution centre and the e-business share were compared for this purpose. The process of identifying suitable models for re-production, finding and booking balances, and communicating it to the project team was very time-consuming. One challenge was that once the correct models had been identified and booked, there was a risk that they yet were not available when the production started. Suggested improvements comprise creating a process to identify models for re-manufacturing, to let those involved in the original product also be involved in the garment's re-design and production process, and to compile better lists of available stock with images.
- In **product development** there was in the initial stage a lack of experience in rational and large-scale production of new products out of garments, and product sketches did not match the possibilities. There was also a lack of knowledge about production time and material usage, which in one case implied a highly expensive product. In another case the stability of the material was underestimated. Customizing the size of the product to the material to minimize consumption and residues was a time-consuming task. Details like front edge and handles were designed from trousers without pockets to get as few seams as possible. Problems that were solved are for instance the following:
 - Rational cutting. How to divide the trousers to facilitate cutting several layers rather than one by one. The trousers were divided at back pocket level, to use two legs for the material. They were turned in and out, the unstitched seam cut away and an open piece is then available as material.

- The size of the patches. For the trousers, the patterns were not adapted to the size of the material. Here the available size of the front and back was assessed to 14 and 17 cm. A knitted seam in the middle of some pieces was desired as a design feature, and the bottom edge of the skirt and the unhemmed trousers should be used.
 - Layout marker-making. Pattern templates are made of fabric in appropriate sizes, then placed on the trouser material and cut out along the edge.
 - Design. The location of the patches on the different materials was set to achieve an attractive design. It was made once; thus each piece has its location ready and equal for all the garments.
 - Marking. The pieces were marked with article name, based on fabric, row location and garment part.
 - Sewing. The pieces are arranged in order for one row from bottom to top. The rows are assembled according to specifications for each part.
 - Cutting. From patch material to finished garment part, one by one according to pattern.
- In **patterns and layout** there are major differences between designing of patterns and making layout pictures in a linear flow, where the input material is in a roll, and in redesign process, where the input material consists of finished products. It is then time-consuming to identify dimensions or where the original patterns are not available as a starting point. For example, for conventional production software already exists for both patterns and layout marker-making (for example, Lectra Diamino3 and Gerber Accumark4), which makes the process more efficient and, for example, increases cutting efficiency. Cutting efficiency is usually 80-90% in conventional production. In this case, redesign is based on denim jeans as input, where the cutting efficiency will be considerably lower and more difficult due to undefined and difficult-to-measure dimensions.
- **Remake process planning** in Lindex is based on both pull and push inventory system. Initially products are pushed out to stores. Depending on how well the garments sell and what planned marketing efforts are made, it is determined what to fill. Some garments sell out quickly, while others sell slowly. The slow garments are interesting for this concept. That the inventory is changing slowly, but is not entirely static, creates problems as it reduces the predictability of input material for the manufacture.

Table 9.1 shows the material usage from the denim jeans that have been used in the project. The cutting efficiency for the proposed models is at best almost half of what it is in conventional production.

| Model | Flared | Amina | Omega Dark | Sandy | Skirt |
|--------------------|--------|-------|------------|-------|-------|
| Total | 2150 | 2610 | 2495 | 3000 | 2320 |
| Shorts | 1000 | 1250 | 1190 | 1417 | 1120 |
| Waste | 1028 | 682 | 450 | 583 | 420 |
| Final weight | 500 | 900 | 855 | 1000 | 780 |
| Cutting efficiency | 23% | 34% | 34% | 33% | 34% |

Table 9.1 Cutting weights in grams and cut-off efficiency

Production has been characterized by small volumes, which means that the production process cannot be fully rationalized. The sewing works satisfactorily, but there was a discrepancy with the cutting, which caused a less streamlined production. Better if cutting were closer to sewing. The most expensive manufacturing moment was the cutting of the pieces for the kimono and the bag. If the price of the product needs to be compatible with the Lindex brand, other cutting methods need to be applied, for example, punches can be used. During conventional production, once the garments are designed no consideration is taken for the garment to be re-made. This makes the garments difficult to disassemble and remake. One solution is to use the Wear2 technology (C-tech Innovation). It is a sewing thread that dissolves when exposed to microwaves of the correct frequency. Techniques of this kind could make disassembly of garments easier and cheaper.

- Several **logistics and delivery** related problems arose during the project. To get garments as input material for production, garments need to be booked in the Lindex inventory system and then withdrawn at the right time for production. One difficulty with this is that the stock levels are unlikely to remain static over time, if there is demand. The best scenario is where the quantities booked are also really reserved, so that the remake unit knows what will be produced. Different forecast methods are also conceivable for calculating available quantities at the various decision points. Below is a brief summary of important lead times for the project.
 - Project initiation until delivery to store: 44 weeks
 - Production start until delivery to store: 11 weeks.
 - First product idea until delivery to store: 23 weeks (115 working days).
 - First sample until delivery to store: 17 weeks (85 working days)

At the start of the project, only parts of the required process steps were in place at an industrial scale, and clear structures for circular flows in the intended supplier network were absent. This meant that all processes needed to be built from scratch and might not have been entirely completed during the project. In comparison with Lindex's conventional production, lead times and number of samples are acceptable, but there is room for major improvements.

- Existing **IT systems** have an architecture that allows a flow to customers but does not fully allow withdrawal from the inventory, other than from the store. This makes it difficult to take out garments for remaking.

Customer relationships: Prior to launch, photo samples were prepared. More samples had likely contributed to greater awareness among customers, however as a new project it generated good response in the organization and had benefits from demonstrated flexibility and unconventional solutions. The project was communicated efficiently and with very good results. Figure 8.3 is an example of communication material used.



Figure 8.3. Marketing communication material.

The communication was well prepared, and the sustainability communicator had been engaged early in the process. Thus it facilitated the narrative about the project. The images were very important and the PR department experienced that the value of the products increased 200% when shown. The photography reinforced the sense of authenticity and the story became more educational. For the main label, leftover material was used from production and transfer printing. Other labels were reused laundry labels from denim jeans.

Pricing: The price of the locally remade garment will be high. There are different solutions to it, for example, conversion can already start at the factory when sales figures indicate that the garment does not sell well enough. It is also possible to create a brand that makes a higher price acceptable. Clearly, the more elaborated products were more popular and therefore could have motivated a higher price.

The correct price must be ensured in the system when the garment is taken from the distribution center. The correct way to decide the cost of the garment is not ascertained, because the alternative value (e.g. the value of the garment in the store or the recycle value of the material) would have been the initial value of the garment, and it is not determined. The price of the garment may also be the ELC: estimated landing cost = price FOB + shipping cost + customs duties + warehouse cost). The value of garments as input material is also difficult to determine. There are a few ways to calculate it, as the price if the garment were sold in the store, a value that changes constantly, depending on sellthrough, or as unsorted value, viz. the price received if the garment were sold unsorted to a collector (approximately 3 SEK/kg), or as sorted value, viz. the price received if sold to a collector (20 SEK/kg). The method chosen may affect the retail price of the remade garment in store.

The business model canvas will have several features in common with Case 1, while some will still be developed. Overall, it can be concluded that there is a lack of competence in several of the activities and areas needed for distributed redesign to become a reality, both upstream and downstream from the user; upstream primarily as the garment is not designed to facilitate for the user to identify the fibre material or how the garment should be sorted in existing recycling infrastructure. The network of suppliers available locally has the equipment to remake garments, but it needs to be strengthened and become more interoperable. Educational efforts are needed primarily in: Production, Design for a circular flow, and logistics.

| | | | | |
|---|---|--|---|---|
| <p>Key partners</p> <ul style="list-style-type: none">❑ Fashion and clothing enterprises for waste reduction and "value-added re-design"❑ Local SME for redesign, cutting, sewing, printing, etc.❑ E-commerce platforms, both selling first-hand clothes and also those dedicated particularly for second-hand clothes❑ Academic and research institutes – To create knowledge of new remanufacturing techniques, associated technologies, and new business models to support feasibility and scalability plans | <p>Key activities</p> <ul style="list-style-type: none">❑ Sourcing input material from non-selling garments❑ New garment redesign and construction techniques e.g. modularity based❑ Redesign, incremental design, patchwork compositions and remake❑ Printing, cutting, stitching and embroidery, etc. and creating local supply chains for the purpose❑ Marketing and communication❑ Transformation into circular supply chains | <p>Customer value Proposition</p> <ul style="list-style-type: none">❑ New attractive design features, in limited editions❑ Creating a flavor of sustainability, by reducing waste and promoting local production❑ Price vs. value favorable | <p>Customer relationship</p> <ul style="list-style-type: none">❑ Customers may influence design and appearance❑ Social media interactions and novel modes of marketing and communication | <p>Customer segments</p> <ul style="list-style-type: none">❑ Business-to-business – To fashion brands and retailers through remanufacturing and/or sales of their items, e.g. deadstock, take-back items❑ Other stakeholders – By sharing of knowledge on fashion remanufacturing and local design and production through workshops and trainings |
| <p>Distribution channels</p> <ul style="list-style-type: none">❑ Redesign service stations in own retail shops offering minor recoupling❑ Online sales thru' either own or multi-brand e-tailers❑ Remake App❑ Development and adaption of circular supply chains | | | | |
| <p>Key resources</p> <ul style="list-style-type: none">❑ Human resources – more cross functional roles, such as "designer-operators" and "pattern makers-cum-seamstresses"❑ Knowledge and experience building, education and training❑ Suitable techniques – e.g. gluing, laser embossing, marker-making, and techniques facilitating disassembly❑ Visual merchandizers and brand managers for developing remake brand❑ Inventory management, suitable IT system❑ Equipment – machines for cutting multi-irregular garments and patches, bonding machines for joining instead of stitching, digital printing machines for redesign purposes, etc. | | | <p>Revenue streams and pricing</p> <ul style="list-style-type: none">❑ Retailing – online business for long tail items and ease of in-process communication❑ Dynamic pricing applicable for one-of-a-kind garments❑ Elevated prices possible by successful branding and consumer awareness | |
| <p>Cost structure</p> <ul style="list-style-type: none">❑ Estimate cost vs. recovery of value❑ Manual tailoring, adaptation and processing a substantial cost driver❑ Not scale-driven nor scope-driven – mass production or mass customization not feasible | | | | |

Figure 8.4. Future RemfBM of Case 2 (a proposal)

8.3. Business Model Canvas – Case 3

Case 3 is similar to Case 2 from the point of view that it is a test case for customized up-cycling through PSS design. Due to its experimental nature, an initial or wished business model canvas was designed at the commencement of the project, via a meeting between Monki and Re:textile. Here the implications of the project on the existing business model and value chain were discussed. A RemfBM was envisaged as below:

- **Value Proposition** - The value for the customer is twofold, both the experience and the product of the co-creation.
- **Customer Segments** - Monki customer core is political/indie. An on trend customer, brand-unloyal or not yet convinced is the hoped extension.
- **Customer Relationship** - How to scale the co-creation, what makes a repeat customer?
- **Incremental print designs**, collaborations with artists.
- **Distribution Channels** - IGC, UGC, physical stores, festivals and Pop Up. Monki consumers engage in sharing.
- **Key Partners** - Re:textile, Brother, ACG Nyström are the key partners. Berge Consulting, PR- agencies, Event coordinators and Monki Ambassadors will also be seen as partners.
- **Key Activities** - Activate IGC (influencer generated content) and UGC (user generated content). Create an Activity and Communications plan. Artwork need to be sourced or designed as well as paid for.
- **Key Resources** - The Monki brand. Being established already means having a market, designer, collaborations, purchase and logistics departments and trained staff at hand. Extra resources will be printers and machines specific for the customization activity.
- **Revenue Stream** - 50 SEK per print and 250 SEK for a limited edition print. Prints could be used instead of gift vouchers.

Based upon the above business planning, and after developing and testing the product extension service business model by utilizing direct-to-garment printer to mass customize in-store, a revised Business Model Canvas was proposed.

Value Propositions: The study indicates several possible additions to the value proposition segment relating to the end product, service extension and customer experience. The customer discourse of the customization experience was positive with expressions such as 'unique', 'surprising' and 'fun' being used. The customers showed great interest in, and willingness to engage with, the customization process. They also shared their designs via social online networks which indicate that the customers accredit a certain value to the product derived from the product extension service. During the configuration process customers were interested in the origin of the artwork, which indicates that artification could be used as another value proposition. Majority of customers showed high levels of product satisfaction, willingness to engage in similar activities as well as pay a premium price for the service.

Customer Segment: The Monki core customer profile is extended with the individualistic, environmentally conscious and trend sensitive consumers. Even though some of these characteristics are included already in the existing customer base there is value in defining and targeting them separately. The individualistic consumer has a high tendency to engage in the product extension service whilst the notion of circularity and product life extension attracts the environmentally conscious customer. More and more brands are engaging in co-creation and collaborations, constantly bringing new trends to the surface, which could serve to attract the trend sensitive consumers as well.

Customer Relationships: The implementation of a product service extension has the potential to contribute in building a strong customer to brand relationship. There are several touch points that allow customer interaction in the developed PSS, the product, the service/experience and the social/brand community touch point. Value propositions could be added at each of these touch points as well as that there is an opportunity for brand enhancement.

Distribution Channels: Mobile equipment like the direct-to-garment printer enables several channels for the PSS such as retail stores, pop-up stores, events or any other situation where the machines could be set up according to the operating specifics.

Key Partners: Most of the key partners stayed the same with the addition of engaging illustrators as well as artists for the project. Based upon the customers' keen interest in the design process it is advisory to explore the possibility of increased perceived product value as well as brand equity through the collaboration with designers and illustrators. The collaborations can strengthen the bond between the customer and the product which hold the potential to enhance the emotional durability and extending the use phase of the product.

Key Activities: The new value proposition lead to an implementation of several new activities such as creating a printer workspace, training co-creation staff, develop a full capability configurator, activate a brand community sharing and creating a soft launch plan.

In order for the direct-to-garment printer to function optimally it needs a climate controlled room with at least 35% humidity, but for shorter periods, and with increased maintenance, it can function in a less optimal environment. The staff will need training to handle the technological aspects such as the configurator, the printer software, the printer itself, the pretreater as well as the heat press. Since the staff will need to be able to guide the customer through both the decision and design process utilizing the configurator the staff will need to be comfortable with the advisory role. Furthermore, a fully integrated configurator need to be created and tested, to make sure it is all compatible with the printer software whilst offering a simplistic interface to the customers. The Monki customer has been described as happy to share their content online which indicated the importance of offering a platform for sharing their co-creation experiences as well as their finished designs. The community sharing of the new technology and servitization could have the added benefit of reducing the burden of choice and speed up the decisionmaking process for the individual consumer. Since the plan is for the proposed product extension service to roll out live in Monki stores and so far only has been tested in a mock-up environment it is advisory to create a soft launch plan where it is implemented in one or two stores and then reevaluated before the hard launch.

Key Resources: The additional key resources that were identified during the pilot testing were the need of a service technician as well as an integrated product platform. The printer performs on an optimal level when maintained continuously and the mechanical requirements are larger than first anticipated. To be able to train staff in the customer-related aspects and quickly be able to implement the PSS activity it is advisory to have a technician tied to the project as well. By offering an integrated product platform that merges the product extension service into Monki's omnichannel and social media present the customers opportunities to engage and share their experiences are maximized.

Cost Structure: There are some costs directly related to the activity such as acquiring the printer (lease, rent or purchase), product configurator development, co-creation staff training, and artwork as well as printer workspace.

Revenue Streams: The streams are similar to the existing ones, online or physical store sales, though events and pop-up activities could pose as additions. The recommendation, based on the findings of the project, is to employ a value based pricing strategy as opposed to a cost based strategy since there is a strong willingness from the customer's perspective to pay for the service.

| | | | | |
|--|---|---|--|--|
| Key partners <ul style="list-style-type: none"> ❑ Monki ❑ Re:textile ❑ Brother/ACG ❑ IT consultancy ❑ Illustrators and Artist ❑ PR agencies | Key activities <ul style="list-style-type: none"> ❑ Create printer work-space ❑ Train Co-creation staff ❑ Create fully functioning product configurator ❑ Source final prints ❑ Activate brand community sharing ❑ Soft launch plan ❑ Marketing and Communication | Customer value Proposition <ul style="list-style-type: none"> ❑ Collaborative customization experience ❑ Artification and craft consumption ❑ Higher levels of product satisfaction ❑ Emotionally durable products ❑ Affordable price point | Customer relationship <ul style="list-style-type: none"> ❑ Collaborative ❑ Engaging experience ❑ Value co-creation ❑ Social/Brand community | Customer segments <ul style="list-style-type: none"> ❑ Existing Monki target customers ❑ Environmentally conscious consumer ❑ Individualistic consumer ❑ Trend conscious consumer |
| | Key resources <ul style="list-style-type: none"> ❑ Established Brand/ market position ❑ Direct to garment printer ❑ Co-creation staff ❑ Service technician ❑ Integrated project platform ❑ Design collaborations | | Distribution channels <ul style="list-style-type: none"> ❑ Flagship stores/ pop ups ❑ Monki social media channels | |
| Cost structure <ul style="list-style-type: none"> ❑ Printer leasing ❑ Product configurator development cost ❑ Staff training/labor cost ❑ Print acquisition cost ❑ Printer work space cost | | Revenue streams and pricing <ul style="list-style-type: none"> ❑ Store/pop up sales, print sales ❑ increased sales | | |

Figure 8.5. Future RemfBM of Case 3 (a proposal)

9. Legitimacy issues in fashion remanufacturing

There is currently no certification specific to the process of remanufacture within the fashion industry, and a lack of any kind of mandatory or voluntary certification system or standard hinders the legitimacy of remanufactured fashion products. WRAP (2015) highlights that lack of guarantee and lack of durability has prevented buyers from repeat purchase of remanufactured fashion items. For this three requirements are specified:

- 'Must-have' legal obligations to meet the standards related to product safety, non-use of hazardous chemicals, traceability of materials, composition, and ac-quisition source,
- Common standards and labelling, e.g. related to environmentally and socially re-sponsible remanufacturing processes and practices, and
- Niche voluntary standards, e.g. eco-labels and certificates, for remanufacturing brand building.

1. Legalities concerning international trade

Developing legal frameworks for international trading and consumers' confidence for remanufactured fashion is challengeable. This is due to issues regarding manufacturing rema-

nufactured fashion products across global trade policies and frameworks that are accepted between trading parties, e.g., the need for cleaning or fumigation certifications, the ban on intimate apparel, socks, etc., the size or weight of individual bales of secondhand clothes and the total amount imported, etc. (Hawley, 2011). Therefore, to develop remanufactured products globally across global trade policies, it is essential to reach trade agreements on import-export of used (core) garments as well as universally acceptable certifications for remanufactured fashion products.

2. Extended producer responsibility (EPR)

Textile waste management and collection of used products are still performed voluntarily by retailer and producers as compared to other industries where retailers have integrated waste collection activities into their operations. For example, for electronic and electrical equipment and cars, the producer takes the responsibility for product take-back and recycling, as detailed under EPR policy (Van Rossem et al. 2006). In textile and fashion industry some take-back systems already exist, such as EcoCircle and I:CO where the retailers take responsibility of taking back the products from the consumers and passing them to a waste collection companies. This system can benefit remanufacturing process by:

- a. Providing retailers access to a significant volume of a particular style and/or brand through waste collectors, e.g. done by Cheap Monday in collaboration with I:Co,
- b. Offering preparation services (laundry, quality management, and reverse logistics) to textile waste management companies,
- c. Developing new businesses for disassembling garments,
- d. Collaborating with fashion retailers to develop a closed-loop remanufacturing process and bring remanufactured fashion back to the store. (Sinha et al., 2016)

3. Eco-labels and certification schemes

Eco-labels are used by companies for providing environmental information about a product to the consumer and communicate that the environmental impacts are reduced over the entire life cycle of a product without specifying the production practices (Piotrowski and Kratz 2005). Thus, Remanufactured fashion might be also certified by eco-labels due to its environmental objectives. However, common eco-labels assigned to certify textile and fashion products, e.g. Oeko-Tex (health and safety), GOTS (organic textiles), FairTrade (social and labor conditions) follow a "cradle-to-grave" approach and only few certification programs based on "cradle-to-cradle" approach, e.g. Global Recycled Standard (GRS) and R Cert are available. Lack of universal agreement on definition for the term "remanufactured fashion" leads to several challenges regarding warranty and development of an eco-label, for instance:

- a. Eco-certification can be prohibitive to micro and small sized remanufacturing companies due to the cost of certification in relation to the value of the product (this can be as high as 20, 000 Euros for annual renewal),
- b. Current remanufacturing certificates does not determine the carbon footprint or environmental quality of remanufacturing or the remanufacturing practices, instead only certifies the remanufactured product,
- c. Legal issue that is more typically seen with regard to retailing and licensing of remanufactured fashion brands, sales and returns policies,
- d. Garment labels do not necessarily indicate that the garment is remanufactured and may have been previously worn, and if it is of at least equal or higher manufacturing specifications to the original,
- e. Lack of consumers' awareness and acceptance of such labels.

Key areas of consideration for certification of potential remanufacturing process have been highlighted by Sinha et al. (2016). These are:

- a. **Environmental and LCA standards** – e.g. (i) specifying the percentage of reused material that replaces virgin material that would otherwise be used in the garment (this will give an indication of the environmental benefits of a remanufactured fashion product to certain extent), (ii) use of chemicals, cleaning agents, water etc. while laundering, (iii) amount and method of transportation (and associated carbon footprints) for remanufacturing, i.e. involved with collection, distribution and redistribution/resell reverse logistics.
- b. **Social standards** – e.g. (i) health & welfare, safety, and working conditions involved with remanufacturing process, (ii) related to local business support based on the 'proximity principle' (within the zone of disposal and collection) to enhance regional self-sufficiency and job creation in the region (see Regio-tex¹³).
- c. **Remanufacturing process standards** – this will allow striving for certain industry level best practices e.g. standard allowed minutes for dis- and re- assembly stages, fabric usage efficiency, etc.

10. Analytical conclusion

10.1. Key decision variables

For case 1 (on scaled remanufacturing), the key considerations as design elements or variables that affect decision-making are:

Remanufactured product-process related:

- Level of disassembly and reassembly to be made. 3 dominant combinations were observed (fully-fully, semi-semi and no-minor) based upon the total number of remanufacturing steps/stages, being >8, between 8 and 5, and <5.
- Yearly production volume per product: mass if more than 100, standard if between 10 and 100, and limited if less than 10.

6 different product groups can be identified currently, based upon the above combinations in addition to its DIY product range.

Remanufacturing supply chain operations related:

Further analyzing these product groups in terms of their supply and operational capacity requirements, three important characteristic variables can be noticed. These are:

- Easy of sourcing the input material (in terms of kgs/month). For most product groups this is easy, i.e. volume over 100 kgs/month.
- Degree of remanufacturing skill required. This is evaluated in terms of demand for number of months of training of the workers required for remanufacturing, and could be more than two months, about four weeks, or lesser.
- Production lead time. High if more than 2 days, low if less than 1, while inbetween is classified as intermediate.

¹³ <http://www.textile-platform.eu/regiotex-regional-investment/> (17.07.2017)

Finally, 8 product groups can be identified.

For case 2 (on distributed redesign) the key considerations as design elements or variables that affect decisionmaking are related to creative pattern development and construction principles, particularly as the cutting efficiencies are low. As highlighted above the keys are:

- Rational cutting for deciding how to cut effectively, and where.
- Deciding the size of the patches, and covering up for any irregularities by highlighting it as a design feature.
- Layout markermaking as source fabrics are not rolls for fabric but individual garments of varying shapes.
- Design based upon understanding of where and how the patches should be placed to create an attractive design, and then ensure some degrees of repeatability.

For denim jeans development, redesign pattern repeatability was crucial. The option of making the design step by step is considered too costly to be feasible, so the design needs modification (scaling down) to match the repeat limitation. For Kimono, the pattern development is also crucial as it is made from five different jeans trousers and a skirt, with different stretch material. The input material variabilities and specifications need careful assessment before understanding the potential to transform them into a new product. For the bags, in a similar way the layout of the pattern development is crucial.

For Case 3, the decision variables are mainly related to designing the PSS redesign-as-a-service. This related to developing:

(i) *physical front office* garment customization solution space/printer workspace. Here the three key process variables are: fabric composition of the garment, color of the garment (light, medium, dark), and variation of amount of color used in the artwork for the customization.

(ii) *virtual front office* product configurator. Here: (i) the color of the garment, and (ii) the choice of artwork to be printed are the key decisions to be taken by the customer with aid from the co-design assistant.

Apart from these, the back-end processes are also crucial to support the decisionmaking stages frontend.

10.2. Critical success factors

For Case 1, the critical success factors for scaled fashion remanufacturing are identified as follows:

- Fraction of input materials obtained for remanufacturing. The amount is meagre in comparison to what is referred as “mass” in case of apparel manufacturing. This amount is reduced further due to loss after quality check prior to the remanufacturing process stages.
- Yield. Due to current disassembly techniques (particularly for fully-fully items) and low degrees of repeatability, yield of remanufacturing processes is low.
- Remanufacturing process costs. Majority of the workforce are currently subsidized which is a key consideration in evaluating remanufacturing process costs. In the absence of feasibility would be difficult to attain. Similarly, the input material cost is currently zero, which in the near future can change in consideration to a mandatory EPR in place.
- Remanufacturing lead times. Currently, value adding processes are slow. Using of new tools and technologies in remanufacturing process (e.g. textile glues instead of sewing, rotary knives and industrial cutters for disassembly, computeraided pattern cutting,

multilayer pattern cutting, etc.) can improve process efficiency and reduce lead times to increase both remanufacturing volume potential and yield.

- Market price of the remanufactured items. Higher sales at a higher market price ensure higher consumer approval towards wearing remanufactured apparel.

For Case 2, the critical success factors for distributed fashion redesign are identified as follows:

- Material cost. The correct price of the material, here garment when taken from the distribution center is crucial. There is high uncertainty because the value/cost can be determined in various ways, e.g. the Estimated Landing Cost of the garment, the alternative value/cost with consideration after markdown if otherwise would have been sold in store, unsorted value/cost to the collector, sorted value/cost if they were sold sorted to a collector.
- Material usage. Often the cutting efficiency is important to determine the amount of garments required to make one redesigned garment, thus influencing the input material cost.
- Redesign process cost and lead time. Low material usage results in higher amount of cutting required. Considering that the cutting of the individual garments has to be done manually the labor cost is high. In addition the process is highly time-consuming.
- Subsidy received. If marginalized workforce could be employed through support from Government or municipality then the process costs can be reduced. In its absence feasibility is hard to attain.

For Case 3, the critical success factors for distributed fashion redesign are identified as follows:

- Direct process costs. The total printing material costs, based on use of CMYK ink+white ink+pretreatment material is dependent upon three things: jeans color, volume of ink used/artwork and used/new jeans, and needs optimization.
- Overhead costs. A large part of the overhead is the leasing cost of the DTG printer. So perhaps a better investment is to buy the printer. But in that case such PSS must be a longterm strategic consideration by the company, as a drive to move towards circularity.
- Customer willingness to pay. To estimate the value/price of customized redesign service this is critical.
- PSS Lead time. The total time for the mass customization process is impacted by the combined effect of the independent variables (I. different CMYK ink volumes in the artwork – high, medium, low, II. dark, medium and light colored jeans, and III. new jeans versus used jeans), and needs optimization.

10.3. Feasibility assessment

For Case 1, at its current scale of yearly production (~800 kgs) (determined by the fractions and yields), remanufacturing is feasible with subsidized labor, no material costs, and that the products are not sold at lowest label price. When subsidy stops, the actual process cost increases, which makes the average case not feasible as well; thus feasibility deteriorates. Remanufacturing is least feasible when input material has to be bought. Changing the scale of remanufacturing by changing the fractions and yield, feasibility is marginally worsened compared to the base scenarios because at no material cost to be paid, the income from the remnants is the only variable based on increased fractions and yield which reduces as a result of this. However, when these scenarios with high fraction and yield are readjusted by changing the process costs calculated at higher labor productivity and step-wise cost increment for renting facility, feasibility is achievable even for minimum case scenario. In the best case, scaled remanufacturing could create additional job for 50+ people in one organization. Regionally the potential is larger and also in other roles apart from remanufacturing operators.

For Case 2, remanufacturing is clearly feasible for jeans, but not for Kimono and bag due to high processing cost (and associated indirect costs). The feasibility is improved through subsidy. There is of course a substantial uncertainty associated with the calculations, due to the experimental nature of the case and to whether the initial assumptions of adapting the logistics properties appropriately are feasible.

For Case 3, redesign-as-a-service is clearly feasible in most cases, except when the customer willingness to pay is the least and the costs are the highest. There is of course a substantial uncertainty associated with the calculations, due to the experimental nature of the case.

11. Future considerations and recommendations

11.1. Scaled fashion remanufacturing

We perceive future potential for scaling up fashion remanufacturing to be largely dependent on growing from a redesign studio concept towards a mini-factory, to create higher economic profitability, environmental impact and jobs.

To fuel such mini-factory key requirements are:

- Supply of good quality material in considerable volume,
- High productivity and flexible remanufacturing systems, e.g. Toyota Sewing System,
- High demand and price propositions for the remanufactured products

For streamlining the supply fashion remanufacturers planning to scale-up should consider the following:

- Collaborate with other collecting organizations, e.g. fashion retailers with a WIN-WIN negotiation,
- Acquire more prime material inputs.

On the other hand, to streamline the demand and price points they should consider:

- Creating a branding strategy and identify 'new' customer segments
- Creating innovative design ideas
- Target more and innovative sales channels

Finally in order to synchronize the supply and demand, extra resources, 'new' technologies (for disassembly, pattern development and cutting, manufacturing), and flexible remanufacturing systems need to be considered.

11.2. Distributed redesign

We perceive future potential for establishing distributed fashion redesign to be largely dependent on creating a strong interconnected network suppliers and value-adders regionally. At the larger survey conducted by the Fashion Incubator, presented in autumn 2016, it is important to note that all types of production could be solved in the neighborhood around Borås, but there is currently a gap of competence that needs to be filled. This applies to both the supplier and the customer side where the supplier side would need to be clearer about "what is possible to do" and the other side needs to know better "what can be done". Educational efforts are needed primarily in

- Circular product development and design
- Circular production processes
- Circular local flows and establishment of collaborative networks.

11.3. PSS redesign-as-a-service

For PSS redesign services, the future potential lies in developing both the technical solution and improving the customer satisfaction in a larger retail setting.

The direct-to-garment printing solution tagged with the product configurator should be exploited for any type of garment (jeans, t-shirts, shirts) made of any material, and for any brand. This will scale-up the number of individuals walking in to use the service.

Further the product configuration solution space should incorporate more fun features for customers to "play around", e.g. in terms of artworks, 3D visualizations, customization features, etc.

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