Resources, Conservation and Recycling 104 (2015) 94–102

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

An examination of the product development process for fashion remanufacturing

Geetha Dissanayake [a,*], Pammi Sinha [b]

[a] Department of Textile & Clothing Technology, University of Moratuwa, Sri Lanka
[b] School of Design, University of Leeds, Leeds, UK

ARTICLE INFO

Article history:
Received 20 June 2015
Received in revised form
12 September 2015
Accepted 14 September 2015
Available online 9 October 2015

Keywords:
Remanufactured fashion
Reverse supply chain
Sustainable fashion
Second hand clothing

ABSTRACT

Fast changing fashion trends have led to high consumption rates of clothing, shortening of life-spans for many fashion products and increasing amounts of textile waste. Addressing the problems caused by the unsustainable landscape of the fashion industry requires alternative solutions, new business models or whole systems rethink. Fashion remanufacturing is one such strategy that supports material recirculation and thus reduces land filling of fashion waste. This paper examines the concept of fashion remanufacturing, the requirements for a reverse supply chain and the barriers and opportunities that exist for future growth of this sustainable business. The investigation reveals that although collaboration among key players along the reverse supply chain is essential for business growth, the extent of this growth is dependent on the commitment and involvement of large fashion retailers and the fashion consumer. We conclude the paper by considering the implications for the fashion industry if fashion remanufacture were to become a more mainstream business model.

1. Introduction

The apparel industry is global in nature, rich and contribute significantly in the development of the economy of a country; e.g. in the development of the East Asia's export growth and participation in the global economy (WTO, 2014). Global apparel exports value rose by 48% between 2005 and 2011, to 412 billion US Dollars in 2011, and 58% of the export market consists of the top ten developing country suppliers (37% for China, 4.8% for Bangladesh and 3.5% for India). Global apparel consumption is highly concentrated in three regions; as of 2011, 72% of global imports of apparel were into the European Union, the United States and Japan (WTO, 2014).

The apparel industry today is characterised by rapidly changing fashion cycles and unsustainable consumption practices of consumers (Niinimäki and Hassi, 2011). The growth of cheap industrial mass production of apparel has led to unsustainable consumption and frequent disposal habits described by Jana Hawley as "a clothing accumulation that stems from planned obsolescence, the core of fashion" (Hawley, 2008, p. 210). Nature of fast fashion encourages retailer to sell large volumes at low prices which stimulates a high frequency of fashion purchase (DEFRA, 2007). Frequent buying habits encourage a throwaway attitude among consumers, where new clothes are frequently purchased and old, yet usable clothes are discarded (Birtwistle and Moor, 2007). This mechanism of the fashion industry raises many issues pertinent to the sustainability landscape. In general, fashion consumption and sustainability are contradictory in nature: fashion consumes many natural resources and generates waste, whereas sustainability strives for resource conservation and zero waste (Dissanayake and Sinha, 2012). To minimise the adverse environmental impact, fashion industry is forced to incorporate sustainable aspects into the business (Li et al., 2014).

Discarded textile and apparel is a rapidly growing category of waste in household waste stream in the UK and recent studies found that the consumers discard around 350,000 tonnes (approximately £140 million worth) of apparel every year (WRAP, 2014). From an environmental perspective, early replacement of a product is generally detrimental (Mugge et al., 2005). According to Kumar and Malegeant (2006), there are five mechanisms to recover the value of used products: repair/reuse, refurbish, remanufacture cannibalisation and recycle; which are appropriate in recovering the value of used textiles. The biggest impact on reducing environmental burden is in extending and keeping clothes out of landfill. According to Woolridge et al. (2006), around 65 kWh of energy is saved for a kilogram of virgin cotton substitutes by discarded apparel, and 90 kWh for a kilogram of polyester substitutes by discarded apparel. As the volume of throwaway fashion increases, there is a need for an innovative approach to managing this type of waste.

* Corresponding author.
E-mail address: geethadis@uom.lk (G. Dissanayake).

http://dx.doi.org/10.1016/j.resconrec.2015.09.008
0921-3449/

Many authors have highlighted the issue of used clothing waste and emphasised on the benefits of reusing or recycling them (Birtwistle and Moor, 2007; Fletcher, 2008; DEFRA, 2009; Gwilt and Rissanen, 2011). Indeed, research has also identified that two-thirds of UK consumers buy or receive used clothes, and express their interest to wear more, especially if a better range were available (WRAP, 2015). In addition to reuse or recycling, Allwood et al. (2006) suggest that second hand clothes (SHC) could be upgraded to a certain extent by 'remanufacturing' them: i.e. replacing few panels of a dress with new fabrics which may provide a new look and some form of a 'fashion upgrade'. The strategy of fashion remanufacturing has been recognised as a new business opportunity by many sustainable fashion designers; however, this business still operates in niche market level. Limited research has been conducted about fashion remanufacturing process and the operation of its reverse logistics process.

Remanufacturing, in general, is a process of reinstating a discarded product back to its useful life (Lund, 1996), by upgrading the quality of the product and its life span (Savaskan et al., 2004; Fleischmann et al., 1997). Remanufacturing minimises the use of virgin materials and therefore recognised as one of the best methods for sustainable production and managing wastes (Krystofik et al., 2015). The process of remanufacturing is described as the disassembly of used products, inspection, cleaning and reworking of component parts, and use them back in a manufacturing process to create a product as new quality (Nasr and Thurston, 2006; Majumder and Groenevelt, 2001). Remanufacturing differs from repairing or recycling; repairing means restoration of broken or damaged product to the working order (Khor and Udin, 2013), and recycling converts materials to a different product with different functions (Michaud and Llerena, 2006). Moreover, the terms 'upcycling' and 'remanufacture' have often been used interchangeably, and the distinctions between them have been poorly explained. The similarity between the two terms is that both are strategies to avoid wasting materials by using them to design products of at least equal to, if not higher value than the original product held. From the literature reviewed, the differences appear to be: the design goal or strategy, the process approach, product end use or function, the material input and the need for a warranty. For upcycling, the goal or design strategy is to achieve a higher value at retail than the original product would (Sung, 2015; McDonough and Braungart, 2002), whereas in remanufacture, it is to achieve an 'as good as new' product that is at least equal to if not better than the original product (Lund, 1984; Ijomah et al., 2007). In upcycling, the process approach is to develop a crafted, individual and possibly unique product requiring (often) manual intervention (Vermeer, 2014; Upcycle magazine, 2009), whereas in remanufacture, the process approach is an industrial process that can be carried out in factory environment, i.e. the process goal is to be reproducible (He, 2015; Goodall et al., 2014; Hazen et al., 2012; Steinhilper and Hieber, 2001; Lund, 1984). The product end use or function in upcycling can serve a completely different function or end use from original use (Sung, 2015; Cassidy and Han, 2013; Upcycle magazine, 2009) whereas in remanufacture, the product should serve the same function or end use as the original (Hatcher et al., 2013; Lund, 1984). For upcycling, the material input may or may not have been used (i.e. the materials may be spare for the production line) and, therefore, may or may not be faulty (Sung, 2015) whereas in remanufacturing the materials have been used, they may be worn out in parts, or destined for waste if not used (Lund, 1984; Hatcher et al., 2013). Regarding warranty, there is no need for a warranty indicating quality in upcycling as the resultant product is usually crafted and marketed at a higher price than the original; the manufacturing quality is surpassed by the design and creative output. In remanufacturing, a quality indicator is necessary (such as a warranty) both to attest to the "good as new or better" quality and to differentiate from a 'new' product (APRA, 2014; Ijomah et al., 2007; Lund, 1984).

For this study, remanufactured fashion is defined as fashion clothing that is constructed by using reclaimed fabrics, which can either be post-industrial or post-consumer waste, or a combination of both. Post-industrial waste consists of waste material generated in the textile or apparel manufacturing processes, and post-consumer waste refers to the discarded garments by end-consumers. The quality of the remanufactured fashion clothing is equal or even better than brand new fashion clothing. The concept of remanufacturing fashion clothing can be traced back to the period of the Second World War. Due to the short supply of fashion clothing during the 1940s, the UK government started the "make do and mend" campaign in order to encourage people to remake their old clothes into modern styles (Barrow, 2011). This idea has been reformed in recent past, in response to the sustainability issues within the fashion industry and to reduce growing amounts of fashion waste that ends up in landfills. Although this is currently a niche market approach, Mintel (2009) highlights that there is a great potential for growth and this could offer business opportunities as the sector expands. Young et al. (2004) conduct a study in sustainable design of apparel using second hand clothing, where discarded garments are deconstructed and reconstructed into new styles. The study suggests that there is a potential of creating unique, limited-edition personal items for the customers who are willing to spend more for an individual product. Fraser (2009) describes a 'ReFashion' process, which intercepts discarded trousers, re-cuts and refashions in order to return the item to the clothing stream. While the possibility of developing a standard fashion product was evident, quality of the discarded garment and the disassembly expertise were found to be the necessary elements for successful remanufacture.

Sinha et al. (2009) analyse the second hand clothing sector and present a proposition to reuse SHC and remanufacture fashion for the mass market. A remanufacturing process network has been suggested, which consists of textile recycling firms that collect waste textiles, technology providers for latest pattern cutting/management software, local craft entrepreneurs in destination markets for second hand clothing, and the manufacturing facilities that supply clothing to large retailers. The concept of the proposed network is to minimise the waste dumping in destination markets, utilise the skill of craft people in the value adding process for fashion remanufacturing and to make use of existing technologies, manufacturing and retailing facilities to develop the remanufacturing process. According to Sinha et al. (2009), main challenges for developing the remanufacturing process need to be investigated such as; implementation of a reverse logistics systems, development of sorting, disassembly and manufacturing facilities, and the strategies to access the market.

Cassidy and Han (2013) describe an upcycling process that reuses denims to produce one-off garments. Key stages of the process are indicated as collection of denims, sorting, unpicking, sorting the deconstructed pieces, designing, and retailing. While the process focuses only on upcycling denims and making one-off pieces, the design stage highlights key steps for two alternative design strategies; design on the stand (draping on the stand, marking, sewing, completed garment for sale) and design by using a paper pattern (arranging a paper pattern and marking, sewing, base garment embellished, completed garment for sale). Major implications for the mass production of upcycled fashion are highlighted as inconstancy of fabric types, labour intensive production and cost implications (Cassidy and Han, 2013).

In order to remanufacture a garment, discarded garments should be retrieved from the end consumer and processed, which sets up a reverse supply chain. Reverse supply chain is described as the backward movement the traditional supply chain where

used products are moved back from the consumer to the retailer or the manufacturer (Agrawal et al., 2015; Kahhat and Navia, 2013; Prahinski and Kocabasoglu, 2006). The process consists of a sequence of activities required to recover a used product from a consumer, with the intention of disposing the product or recovering value (Prahinski and Kocabasoglu, 2006). Forward flow of a supply chain is scheduled and processed by manufacturers and retailers within a certain time frame, whereas the reverse flow is initiated by the consumer. Reverse logistics process is explained as "a process of planning, implementing and controlling the efficient and effective inbound flow and storage of secondary goods and related information for the purpose of recovering value or proper disposal" (Kumar and Chatterjee, 2011). According to Agrawal et al. (2015), a firm may implement reverse logistic process by choice or by force, i.e. due to economic reasons or legislative requirements. By implementing a reverse logistics process, a firm could contribute to environment sustainability (Khor and Udin, 2013), however, managing a reverse supply chain is a challenge in terms of capacity planning, controlling, and gaining profit from recovery activities that requires additional consideration in planning, designing and controlling of its activities (Guide and Van Wassenhove, 2001). The process could become complex as the consumer may return the product during the life cycle of the product or at the end of life, and each situation requires an appropriate reverse supply chain to optimise the value recovery.

At the beginning of the 21st century, several fashion designers made use of the concept of remanufacturing to create sustainable fashion collections by using post-consumer textile waste (Niinimäki and Hassi, 2011; Gwilt and Rissanen, 2011). In this process, fabric, which has already been made, is pulled out from the waste and used as a resource. This has been recognised as a new business opportunity for sustainable fashion designers. Even though literature presents an overview about fashion remanufacturing process, further research is required to get a broader understanding about the reverse logistics process and the designers' approach to the product development process. In this paper, we examine the reverse logistics system and the product development process for fashion remanufacturing, and discuss the implications for fashion remanufacturing process to become a more main stream model.

2. Methodology

We conducted on-site studies and semi-structured interviews with five fashion remanufacturing companies within the UK in order to examine the reverse logistics and product development processes that account fashion remanufacturing. Information about such companies within the UK were searched using literature based on journal papers, text books, and other published information in magazines, newspapers and company websites. Requests were made to collect information from eight companies identified as potentially suitable companies for this study. Request letters were sent out by explaining the nature of the study and asking permission to conduct interviews with them. Since fashion remanufacturing is relatively a new business, and most companies operate in niche market, some of them were reluctant to share information. Selection of the companies was based on the nature of the business and their willingness to share information. The nature of the business appeared to be similar in all the companies where SHC were collected and transformed into new fashion clothing, however, the category of product and the target consumer market were different to each other. All the companies operated in micro scale as defined by European Commission (2015); a company less than 10 employees and less than €2 manual turnover. On-site observation and semi-structured interviews were used to collect data. Each interview was recorded, photographed, transcribed and analysed. This paper presents the results of the interviews conducted with the companies described below;

Company A, based in London, is recognised as a fashion remanufacturing business and a sustainable fashion label. Comprising eight fulltime employees, company collects discarded men's suits and transforms them into timeless fashion pieces. Best quality men's suits are mixed with either recycled, fair trade or organic materials to create unique fashion pieces. The target customer group for the business is women/men who really have a strong identity, love to be unique, and prefer the individual look. The interview was conducted with the Business Manager of the company.

Company B is a fashion remanufacturing business and a social enterprise, owned and operated by a designer based in Leeds. The designer collects discarded apparel and combines them with household textiles and waste fabrics of textile mills to produce sustainable fashion collections. Moreover, the designer conducts enterprise community recycling workshops to teach participants the skills of remaking and extending life of the garments. Designer believes that knowledge transfer through community workshops helps to reduce air miles associated with clothing and improve local design and manufacturing capabilities. The business targets women in the local community, who loved sustainable fashion. The interview was conducted with the designer and owner of the company.

Company C, located in Manchester, is owned and operated by a designer who is inspired by couture styling. Designer's concern about sustainability in the fashion industry, especially environmental issues inherent with the cotton fibre, has led her to start a business that reclaims cotton materials and remakes high quality fashion pieces. Denim fabric is selected as the main material because denim is mostly made with 100% cotton and also it is a fabric that never goes out of fashion. Designer collects discarded denims, disassemble tem and transform into high-end designer pieces. Part-time staff members are employed to support the remanufacturing process, especially because the disassembly of denim trousers is a time consuming and labour intensive task. The target consumer group is women, aged 25–50, who are socially, ethically and economically aware to choose sustainable, recycled alternatives to mass produced high street clothing, and who also have a disposable income to spend on their wardrobes. The interview was conducted with the designer and owner of the company.

Company D is a forward thinking womenswear vintage clothing and accessory label that offers a new life for tired vintage clothing. The business based in Liverpool was initially supported by John Moore's enterprise programme and the Prince's Trust funding. The company is owned and managed by the designer herself. She was trained in adult education and used to coach people of all ages to develop their skills and creativity. She teaches fashion and textiles in school, colleges and in the community. The target customer group for the remanufacturing business is girls aged 18–25, who loved vintage fashions. The interview was conducted with the designer and owner of the company.

Company E, located in London, is a fashion remanufacturing business and a sustainable fashion brand. It operates as a small enterprise, comprising four full time employees and few fashion students spending their internships. The company designs and produces innovative, quality women's apparel and accessories which are made from hand-picked, locally sourced, discarded apparel and textiles. Company's own brand continues to grow and wins a number of awards including Trefor Campell Award for Creative Enterprise and SME (Small Medium Enterprise) Innovation Award. The interview was conducted with one of the designer of the company.

3. Results

The data collected from each of the five companies were analysed in detail, in order to get a broader understanding about reverse logistics and product development processes. A cross-case analysis was conducted by comparing processes and detecting similarities and differences between each of the process. The study identified a common pattern of the processes operated by each company, providing generic reverse logistics and product development processes for fashion remanufacturing, as described in the following section.

3.1. Reverse logistics process

This study reveals that the starting point of the reverse logistics process for fashion remanufacturing is the collection of discarded clothing and surplus textiles from various sources, as listed in Table 1. SHC are mainly collected from consumers who donate unwanted clothing (directly to the company or through swapping programmes), or from charities or wholesalers who collect unwanted garments from consumers, sort them and redistribute. Surplus textiles are the fabrics discarded by textile mills or apparel manufacturers due to the excess requirements or damages. Those fabrics could be obtained directly from fabric mills or through merchants. Depending on the source of supply, following issues are raised.

SHC supplied by the consumer – Given by the consumer at a very low cast (mostly £1) or mostly free of charge, however returns could consist of various categories of garments in different quantities and quality levels. Therefore extra time is needed to check and accept.

SHC collected from charity shops – A garment would cost around £2–5 and it is time consuming task to hand-pick SHC, yet better control over quality and quantity. It may take approximately two weeks to visit charity shops and collect a sufficient amount of SHC, before starting a new collection.

Sourcing SHC from Wholesaler – Less time consuming because the designer does not need to go around collecting SHC, rather it takes around 5 days from order to the delivery, if the stocks are available. Moreover, there is a better control over quality and quantity, yet the purchasing price is high (£8–10 per garment) when comparing with the other options.

Surplus textiles – Time consuming task to hand-pick textiles in good quality, and therefore it may take 2–3 days to visit shops and purchase them. However, a sufficient amount of materials could be purchased in order to mix with SHC. Furthermore, availability of large quantities from the same material enhances the repeatability of the styles.

Most of the companies are depending on the returns from end-consumer or charity shops because those appear to be less costly options. Many consumers are willing to supply their used clothes free of charge to anyone needed, because their main purpose is to clean the wardrobe to accommodate clothes for the upcoming season. Sourcing from charity shops is not that costly and unsold items can be purchased at a reduced price. Wholesaler appears to be a better option for bulk purchase of a certain category of garments or fabric types, and also in required quality and quantity, but the cost would be high. Company D obtains SHC from a wholesaler where the wholesaler is informed in advance regarding the type of products and the quantities needed. Company D mostly uses plus size ladies dresses with colourful prints, which are pre-sorted by the wholesaler according to the information provided by D.

Collected SHC and surplus textile materials are sorted based on the fabric type, colour and the product category (e.g. trousers, dresses, T-shirts, etc.). Sorting is a manual, time-consuming and labour-intensive operation for all the companies. Time taken for the sorting process varies with the quantity of SHC that need to be sorted, number of people involved in the sorting process and their knowledge about fabric types. In most of the cases, sorting process starts simultaneously with the collection process, in order to minimise unproductive time. Company D receives SHC based on the pre-requested categories from the wholesaler and therefore spends less time in the sorting process than the other companies.

Once the fabrics and SHC are sorted, they are cleaned, if necessary. Garments or fabrics those need to be cleaned are identified while sorting is carried out. Those are either dry-cleaned or washed using domestic washing machines. Dry cleaning process is usually outsourced and therefore takes few days to get the stuff back. However, domestic washing takes only few hours, because SHC are cleaned only if required. Finally all the fabrics and SHC are stored according to the product categories, colours, types of fabrics, etc. Fig. 1 illustrates the reverse logistics process revealed through the study.

3.2. Product development process

The product development processes of all the companies were investigated by analyzing interview transcripts and field observations. The results show a fairly similar pattern of the product development process followed by each of the companies, which consists of five common steps. These five steps are fairly similar to the key steps identified in general product development process, however the approach taken in the remanufacturing process is totally different to the general manufacturing process. The five key steps and their similarities/differences to the general product development process are described below.

3.2.1. Research and analysis

Gathering trend information is the beginning of the conventional design process, whereas in the remanufacturing process, trend information are used only to propose design directions in general, because the intention is to produce sustainable, trans-seasonal fashion collection. Therefore, trend information such as seasonal colours, fabrics and silhouettes are not taken into consideration in this process, yet a collection has a definite colour theme, which is not influenced by seasonal information. Designers are mainly inspired from the fabric itself, and spending significant time in analysing the available SHC and fabric stock. Discarded clothes collected from various sources are analysed to identify their adequacy and suitability for creating new designs. Outcome of the material analysis brings many constraints in developing new design ideas such as limited space of the materials recovered from SHC, large variation of colours, and quality issues. The outcome of material analysis is largely dependent on the designer's creativity and the ability to judge the suitability of materials for future designs. The lack of designer skills and experience could act as a constraint in the material analysis process.

Based on the outcome of trend and material analysis, conclusions are drawn regarding the types of fabrics and colours that can be used to produce a fashion collection. Materials with similar colours or prints are used to produce repeats. Initial design ideas are generated by using the information gathered through material analysis.

3.2.2. Concept development

In conventional design processes, generating design ideas is performed through sketches, whereas in the remanufacturing process, design ideas are generated by experimenting with various possible shapes and colour combinations that can be achieved with the available material stock. Most of the SHC are disassembled before redesigning, in order to obtain a workable, flat piece to rework.

Table 1
Sources of input materials.

Source of SHC/fabrics	Company				
	A	B	C	D	E
Charity shops	√	√	√		√
Public donations	√	√	√		√
SHC collectors/sorters	√			√	√
SHC swaps		√	√		
Fabric mills					√
Fabric merchants	√	√	√	√	√

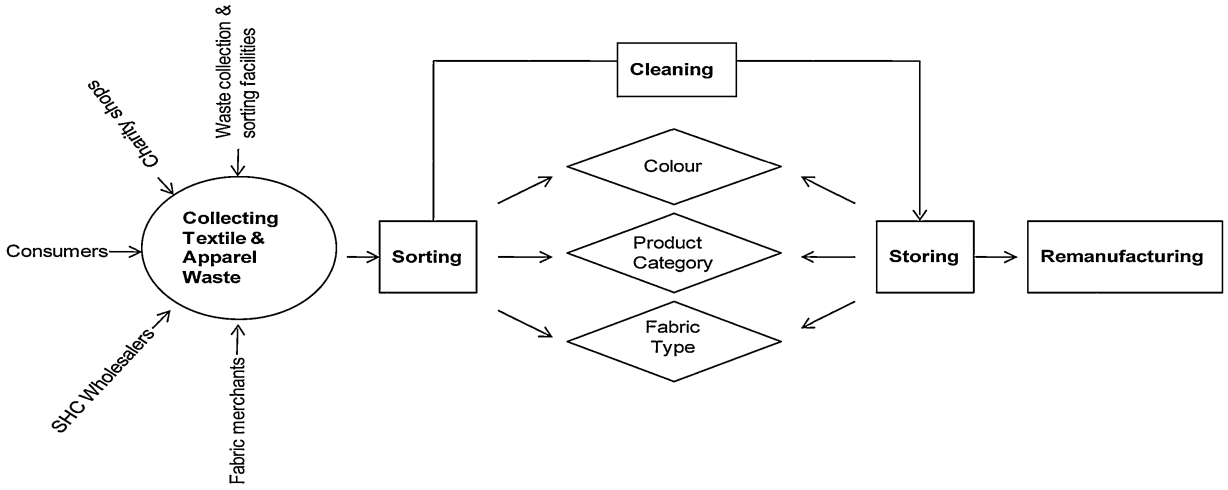

Fig. 1. A simplistic representation of the reverse logistics system for fashion remanufacturing.

3.2.2.1. Disassembly. Disassembly is a manual, time consuming operation and carried out by unpicking the seam threads or cutting along the seams of a garment. All the garments are either partially or fully disassembled base on the requirements of the new design. Some of the designers make an attempt to modify existing designs in order to minimise the time and effort put in the disassembly process. Company E outsources the disassembly function, which would otherwise create a high throughput time in the remaking process. Nevertheless, this is an unproductive activity where the use of designers' time is a waste, therefore use of low skilled labour appears to be a viable option.

3.2.2.2. Development of design ideas. Instead of sketching the design ideas, designers work directly with the SHC or disassembled fabric pieces to explore design ideas. Design possibilities are restricted by the dimensions of the material piece, its type, prints and colours. Therefore, a high level of design thinking and creativity is required in the design development stage. Draping technique is largely used to explore unusual, unique design ideas. Disassembled pieces are mixed with remnant fabrics to form different shapes on the mannequin; photographs are taken and analysed later to investigate possible combinations of fabrics and colours. Company A prefers minimal disassembly and therefore designers follow a very creative approach to generate design ideas; for example, the designer drapes a shirt or a trouser in various different directions to create a skirt or dress etc. Using SHC with remnant fabrics helps to overcome material restrictions and to produce commercially viable and repeatable styles.

After exploring several design ideas, the most suitable designs that could possibly be manufactured with the available material stock are selected as final designs. Finalising the design idea is heavily influenced by the characteristics of the materials and the production quantity requirements. The possibility of repeating the design is considered depending on the availability of fabrics. Most of the styles are created for multi-functional purpose, i.e. one design could be worn in few different ways.

3.2.3. Sample preparation

As in the conventional design process, all the companies make toils and samples by using the working patterns and the appropriate fabrics selected. A colour theme and a design theme are selected when producing a sample collection for catwalk events and a sample collection could include 20–50 pieces. The collection is mostly trans-seasonal in nature and represents a full range of design possibilities. Company A and E used to prepare two sample collections for the two seasons; Spring/Summer and Autumn/Winter, and presented their collections in London Fashion Week as a part of Estethica, the ethical arm of the British Fashion Council, and also in several international catwalk events. However, company E has recently decided not to operate as an ordinary fashion brand, which usually shows two collections per year. Instead, company has planned to create a trans-seasonal look book that includes a range of designs. None of the other companies (companies B–D) produce seasonal collections, because the whole idea is to break the seasonal time boundaries and to produce timeless fashion. However, they occasionally present their sample collections in regional fashion shows and sustainable fashion events.

3.2.4. Pattern development and cutting

Production patterns are created for the orders placed by the retailers after catwalk events. Original patterns are amended in this stage if modifications are requested by the retailers. Moreover, all companies produce some of the designs to sell on their own shops or through websites. Working patterns created during design development are used to develop production patterns.

Cutting is the most critical and time-consuming operation in the remanufacturing process. This is not as straightforward as in a conventional manufacturing process, and the adaptations of

conventional cutting technologies are limited due to fabric restrictions. Because the dimensions of material pieces, colours and prints differ, each piece has to be hand-cut individually. The cutting operator requires a set of skills to mix and match the fabrics and colours together and also to obtain the required size of the cut panel from a dimensionally restricted fabric piece. The idea is to standardise the product design throughout the order, even though the fabrics are non-standard in terms of colours and types. Slight adjustments to the production patterns in terms of shapes and dimensions are required in some cases to achieve the optimum utilisation of fabric, yet without affecting the final design. Therefore the cutting operator needs to have the design and construction knowledge to make decisions in cutting operation.

3.2.5. Manufacturing

This phase of the process involves garment construction and testing. All companies provide the details of production quantities and the sizes needed. Manufacturing can be a single garment from each design (one-off pieces), or repeats of a particular design, depending on the production orders received from the retailers. A typical production order could contain 100–300 pieces. All the companies are equipped in-house manufacturing facilities to produce small order quantities in-house. Company E outsources some of the production orders to other manufacturing facilities around London. If the target is not to fulfil an order quantity, production tends to be unique, individual pieces or a few repeats of a particular design.

Once the design is finalised, the production patterns are created and each garment is hand cut. Cut pieces are stitched together, checked for quality and fit, and further decisions are made about trims and other amendments required. Production output would be one-off designs or small quantities of a particular design, depending on the orders placed by the retailer. Creating repeats of a design is largely restricted due to the inconsistency of the fabric dimensions and features. Within one production order, the basic design could be same, though the fabrics used to create each individual garment could vary depending on the fabric availability. However, by standardising the basic design and fabric type, it is possible create a production order with a collection of garments that appear to be similar. Scale of production of company A and E are approximately 100–150 pieces per month. Company B and C produce mostly on-off pieces and therefore the monthly output is around 10–20 pieces. Company D produces around 50 pieces as the monthly average. Production systems used in the conventional manufacturing process are difficult to adopt due to frequent variations in design and colour. Therefore, one piece manufacturing system is being used with results low production efficiencies.

Retailing prices for most of the remanufactured fashion are just above the average market price for a similar type of original product. The study showed that the price of a remanufactured garment may be high mainly due to the time spent in redesigning the garment, and that mass production does not take place. Due to the high price and non-standard collections, several attempts to sell the products through major retail shops were unsuccessful. However, the products are sold using various channels such as online, sustainable fashion shops or in market stalls.

Fig. 2 summarises the generic product development process for fashion remanufacturing as evident through the study.

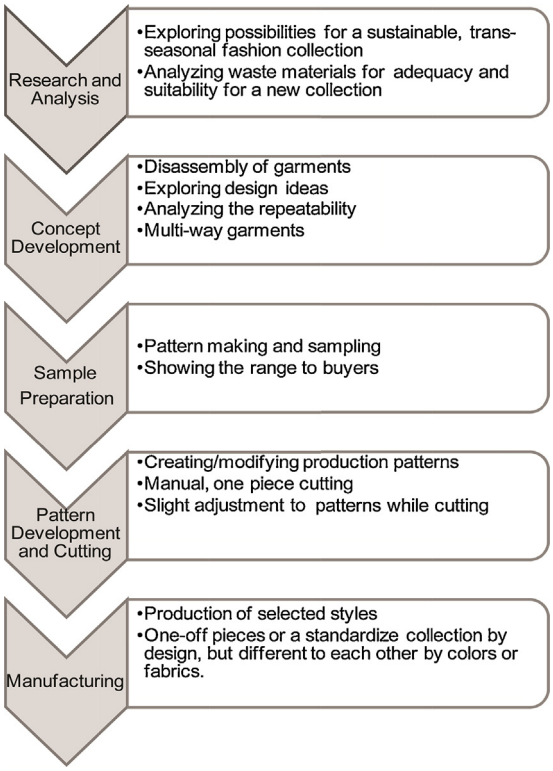

Fig. 2. Generic product development process for fashion remanufacturing.

4. Discussion

Remanufacturing in the fashion industry remains largely within a niche market at the moment, however, the global shortage of raw materials would presumably bring remanufactured fashion into the mainstream. The price of cotton has risen dramatically due to the global shortage, and farmers have reduced the crop to artificially inflate the price (Key Note, 2011). Furthermore, China is consuming more cotton than is being produced there, thus adding to the shortage of cotton. Key Note (2011) suggests that the 'cheap clothing phenomena' will come to an end if the price of cotton continues to increase, because it is unlikely that consumers could continue excessive consumption patterns and throw-away attitude when the raw materials are in short supply. Following section discusses implications for expanding fashion remanufacturing process from niche market to the mass market.

4.1. Remanufacturing for the mass market

The fashion industry has yet to develop the process of fashion remanufacturing, even though elements of the remanufacturing process are available in the industry as the case studies presented evidence. The process is currently carried out by SME fashion designers who produce small volumes for a niche market. Reducing the environmental burden caused by waste textiles would presumably be possible through remanufacturing greater volumes, potentially through mass markets. Some remanufactured fashions have been successful through high street stores serving the mass market, however, there are difficulties due to lack of sales volume to achieve sale targets set by the retailer, and the lack of price sensitivity to the market. These commercial pressures are compounded by the lack of effective marketing strategies for the interaction between mass market (high volume, high use of current fashion trends, low price) and the remanufactured fashion (low volume, high use of design, higher price). Ultimately the commercial success of remanufactured fashion is highly dependent on achieving process efficiencies and quality levels. Following section discusses the key issues highlighted from the study and recommends appropriate solutions.

4.1.1. Product returns

Remanufacturing firms currently have little or no control over the reverse supply chain and firms are largely depending upon unpredictable sources such as consumer donations to collect SHC. Management of the whole reverse logistic network is impeded by the cost implications, resulting in (i) high variability of quality and quantity of incoming materials and finished products; (ii) increased operational costs due to additional space and labour requirements to sort and grade of incoming materials and (iii) unpredictably variable processing times that complicate production planning. To minimise these issues, it is vital for remanufacturers to build collaborative networks with established textile waste collection authorities or to develop product return systems. The growth of reverse logistics channels in the remanufacturing business could be facilitated by retailer involvement in collecting waste. If fashion retailers take the responsibility of taking used garments back from the consumer and passing them to a waste collection or remanufacturing company, it is highly likely the waste collectors would receive a significant volume of a particular style and/or a brand. This type of a reverse flow enables remanufacturing firms to obtain volumes of similar categories of clothing, directly from the fashion retailers or from waste collection companies. Some take-back systems already exist; for instance, the fashion retailer Marks and Spencer has teamed up with Oxfam, a globally renowned aid and development charity, to promote consumers to recycle unwanted clothes. The SOEX group, a global of textile collectors have developed a system called I: CO; a network of retail organisations with collection boxes for discarded clothing which are returned to retailers and those boxes are sent to SOEX for sorting and processing.

It would be cost-effective and environmentally friendly for remanufacturing firms to utilise established reverse flow capacities rather than investing in building up new reverse logistics channels. The benefits for the textile waste collection and sorting companies would be: the development of a local market for SHC and less dependence on overseas markets; increasing their visibility by becoming part of the remanufacturing sector; and the local market development may lead to higher profit and may facilitate developing innovations/technologies to increase the efficiency and productivity in the sector.

4.1.2. Disassembly

Disassembly is currently an issue in fashion remanufacturing where the process is highly labour-intensive and time-consuming. This is complicated and difficult process to standardise since every garment is different. Moreover, the degree of disassembly is dependent on the design of the new garment. However, technological advances are taking place, a consortium led by the University of Leeds and C-Tech Innovation with Madeira Threads, have developed a disassembly technology using a new sewing thread that loses its tensile strength when exposed to microwave radiation. By using this technology, designers and manufacturers can choose to manufacture either whole or parts of a garment, depending on disassembly needs. The sewing thread behaves conventionally until exposed to the radiation (Philpot et al., 2013). Although not in use commercially as yet, the speed of disassembly again suggests commercial benefits to remanufacturing.

4.1.3. Pattern creation and cutting operation

One significant difference of the product development process for general fashion products and the remanufactured fashion is that the sequence and source of fabric selection. For the general product development process, the design ideas are generated before appropriate fabrics are sourced, whereas in remanufactured fashion, fabrics are sourced before generating any design ideas. Pre-cut and pre-shaped fabric pieces to develop new apparels with introduce constraints in design requires creativity, pragmatism and technical knowledge gained through several years of experience of pattern drafting and cutting. The remanufacturing designer therefore needs to be both a creative thinker as well as having good pattern drafting expertise to judge what is possible within a given shape/area and how the fabric may handle. Although adopting pattern creation technologies seems to be limited in the remanufacturing process due to the inconsistency of fabrics, it is suggested that pattern creation software could bring some advantages to the process. With a great degree of pattern changes, such software solution may allow pattern modification and grading in a faster rate than the manual modification.

Cutting cost of the remanufacturing process is higher than the conventional manufacturing process, as each garment has to be hand-cut individually. In the mass-manufacturing process, fabrics are purchased in bulk and several garments are cut at once by using modern cutting technologies. In the process of remanufacturing, obtaining several plies from irregular shapes is difficult due to high dimensional variability of the materials recovered from SHC. However, a technology similar to that used by leather cutting machines, combined with a pattern-making software, could be a possibility to increase efficiency in creating volumes. Leather cutting machines allow cutting required shapes over an irregular shaped single ply. By using an inbuilt projector camera, the user can place the digital patterns effectively in an irregular shaped material and also make timely modifications to the patterns. This kind of a technology would minimise the cost and unproductive time associated with manual pattern cutting, and also increases the material consumption.

4.1.4. Quality standards

Currently, the quality of remanufactured fashion is dependent on the designer's and machine operator's skills and experience, however, a standardised quality inspection system needs to be implemented if the firms expect to progress from niche markets to high volumes. Designers/manufacturers may be able to develop a quality standard for the inspection of discarded clothes (possibly through use of T4T machine) and for the final product. As quality is a key factor for the mass market, remanufacturers may explore incorporating existing final garment inspection quality standards into their process.

4.1.5. Retailing and marketing strategies

Remanufactured fashion is becoming more acceptable among consumers, but still fails to reach the mass market because, for the retailer, those products can only guarantee a design but not a standard fabric. Therefore, retailers are still not prepared to take the risk of having non-standard fashion collections in store at a high price. Nevertheless, remanufactured fashion could be a valuable marketing point for fashion retailers to inform the world about their sustainable initiatives. The marketing strategy should be to promote those products as trans-seasonal, sustainable fashion at a high price. Retailing such products at a cheap price would be a wrong strategy as it encourages more consumption. The target consumer group would be the people who appreciate both sustainable and fashionable lifestyle, and who are willing to pay a high price for a sustainable product which can be used beyond one season.

Retaining those products online would be the best short-term strategy to minimise the effect of a non-standard collection. As a long-term strategy, a remanufactured fashion collection could be offered in store with parallel to the standard collection, which would help to increase the awareness and interest among regular consumers. The remanufactured collection would probably make use of the fabrics from standard collections of previous seasons. Large mass market retailers produce collections that are predominantly basics, that are repeated every year but amended in small details year after year. They may either use similar fabrics from

previous seasons for designs that take in new trends in styling, or the same shapes using different fabrics; the resultant product is still a new design for the fashion consumer (Sinha, 2000). Remanufacture of fashion using fabrics from previous collections would therefore not be a departure from the mass market retail approach to product development. The marketing of the collection would have to be very clear about the remanufacturing aspects, and the costs of the collections would need to take into account the mass market customer's expectations of price as well as recoup the costs of production. Differences between price ranges and marketing approaches would help to minimise the potential competition between standard and remanufactured collections. Eco-minded consumers should be prepared to accept the fact that the collection is non-standard, and paying high price would contribute to save the environment. Meanwhile, designers should attempt to produce multiples of standard simple designs rather than creating complex and unique products at high prices. This would be the way forward in approaching the mass market.

The process of fashion remanufacturing is important as it extends the life of a product and maximising all the resources, energy and labour spent on producing it. Moreover, the results of this research could contribute to minimise the soil contamination and air pollution caused by dumping waste in landfills and incineration. Other environmental benefits may include the reduced demand for virgin materials and thus the reduced used of harmful chemicals for dyeing and finishing of textiles. Moreover, this type of a process generates new business and employment opportunities, while encouraging the industry to adopt circular economy thinking.

5. Conclusion

This study provides useful models for understanding the reverse logistics and product development processes for fashion remanufacturing. Currently, remanufacturing firms are independently producing small volumes, but by networking with textile waste collectors and fashion retailers, they may be capable of raising production volumes and bringing costs down. Collaborative relationships among sustainable designers, fashion retailers and commercial waste collectors may result in synergies and drive innovations. It is also necessary to develop new technologies to make sorting, grading and disassembly operations standardised. The possibilities of adopting existing technologies and quality control systems in the conventional fashion manufacturing process should be investigated. It would also be interesting to research whether the mass customisation of remanufactured fashion would be a feasible means of offering individually tailored products on a large scale. This would be a new business opportunity for remanufacturers and retailers while providing exciting choice for eco-minded consumers.

Acknowledgement

This work is based upon a PhD research supported by the Sustainable Consumption Institute, The University of Manchester, UK.

References

Agrawal, S., Singh, R.K., Murtaza, Q., 2015. A literature review and perspectives in reverse logistics. Resour. Conserv. Recycl. 97 (2015), 76–92.
Allwood, J., Laursen, S.E., de Rodríguez, C.M., Bocken, N.M.P., 2006. Well Dressed? The Present and Future Sustainability of Clothing and Textiles in the United Kingdom. University of Cambridge Institute for Manufacturing.
2014. Automotive Parts Remanufacture Association (APRA), Available at: www.apra.org.
Barrow, M., 2011. Britain Since the 1930s, Available at: http://www.chiddingstone.kent.sch.uk/homework/war/campaigns.htm.
Birtwistle, G., Moor, C.M., 2007. Fashion Clothing – where does it all end up? Int. J. Retail Distrib. Manage. 35 (3), 210–216.
Cassidy, T.D., Han, S.L., 2013. Upcycling fashion for mass production. In: Gardetti, M.A., Torres, A.L. (Eds.), Sustainability in Fashion and Textiles: Values, Design, Production and Consumption. Greenleaf Publishing.
DEFRA, 2009. Maximising Reuse and Recycling of UK Clothing and Textiles, Available at: http://www.oakdenehollins.co.uk/pdf/defra_173_summary_issue_4.pdf.
DEFRA, 2007. Sustainable Clothing Roadmap Briefing Note December 2007: Sustainability Impacts of Clothing and Current Interventions, Available at: http://www.defra.gov.uk/environment/business/products/roadmaps/clothing/documents/clothing-briefing-Dec07.pdf.
Dissanayake, G., Sinha, P., 2012. Sustainable waste management strategies in the fashion industry sector. Int. J. Environ. Sustain. 8 (1), 77–90.
European Commission, 2015. What is an SME?, http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/index_en.htm.
Fleischmann, M., Bloemhof-Ruwaard, J.M., Dekker, R., Van der Lann, E., Van Nunen, A.E.E., Wassenhove, L.N.V., 1997. Quantitative models for reverse logistics: A review. Eur. J. Oper. Res. 103, 1–17.
Fletcher, K., 2008. Sustainable Fashion and Textile Design Journeys. Earthscan, London.
Fraser, K., (masters dissertation) 2009. ReDress: ReFashion as a Solution for Clothing (Un)Sustainability. AUT University, New Zealand.
Goodall, P., Rosamund, E., Harding, J., 2014. A review of the state of the art in tools and techniques used to evaluate remanufacturing feasibility. J. Cleaner Prod. 81, 1–15.
Guide, D., Van Wassenhove, L., 2001. Managing product returns for remanufacturing. Prod. Oper. Manage. 10 (2), 142–155.
Gwilt, A., Rissanen, T., 2011. Shaping Sustainable Fashion: Changing the Way We Make and Use Clothes. Earthscan Publishing, London.
Hatcher, G.D., Ijomah, W.L., Windmill, J.F.C., 2013. A network model to assist 'design for remanufacture' integration into the design process. J. Cleaner Prod. 64, 244–253.
Hawley, J., 2008. Economic impact of textile clothing. In: Hethorn, J., Ulasewicz, C. (Eds.), Sustainable Fashion – Why Now? A Conversation About Issues, Practices and Possibilities. Fairchild Books, New York, pp. 207–232.
Hazen, B.T., Overstreet, R.E., Jones-Farmer, L.A., Field, H.S., 2012. The role of ambiguity tolerance in consumer perception of remanufactured products. Int. J. Prod. Econ. 135, 781–790.
He, Y., 2015. Acquisition pricing and remanufacturing decisions in a closed-loop supply chain. Int. J. Prod. Econ. 163, 48–60.
Ijomah, W.L., McMahon, C.A., Hammond, G.P., Newman, S.T., 2007. Development of design for remanufacturing guidelines to support sustainable manufacturing. Robot. Comput.-Integr. Manuf. 23, 712–719.
Kahhat, R., Navia, R., 2013. A reverse supply chain can enhance waste management programs. Waste Manage. Res. 31 (11), 1081–1082.
Key Note, 2011. Market Report 2011: Clothing Retailing, Available at: https://old.keynote.co.uk/market-intelligence/view/product/10402/chapter/10.
Khor, S.K., Udin, Z.M., 2013. Reverse logistics in Malaysia: investigating the effect of green product design and resource commitment. Resour. Conserv. Recycl. 81 (2013), 71–80.
Krystofik, M., Wagner, J., Gaustad, G., 2015. Leveraging intellectual property rights to encourage green product design and remanufacturing for sustainable waste management. Resour. Conserv. Recycl. 97 (2015), 44–54.
Kumar, N., Chatterjee, A., 2011, January. Reverse supply chain: completing the supply chain loop. In: Cognizant 20-20 Insights.
Kumar, S., Malegeant, P., 2006. Strategic alliance in a closed-loop supply chain: a case of manufacturer and eco-non-profit organization. Technovation 26, 1127–1135.
Li, W., Choi, T., Chow, P., 2014. Risk and benefits brought by formal sustainability programs on fashion enterprises under market disruption. Resour. Conserv. Recycl., http://www.sciencedirect.com/science/article/pii/S0921344914001748.
Lund, R., 1996. The Remanufacturing Industry: Hidden Giant. Boston University, Boston, MA.
Lund, R.T., 1984. Remanufacturing. Technol. Rev. 87 (February–March (2)), 19–23, pp. 19–23, 28–29, MIT.
Majumder, P., Groenevelt, H., 2001. Competition in remanufacturing. Prod. Oper. Manage. 10 (2), 125–141.
McDonough, W., Braungart, M., 2002. Cradle to Cradle. Remaking the Way We Make Things. Vintage.
Michaud, C., Llerena, D., 2006. An economic perspective on remanufactured products: industrial and consumption challenges for life cycle engineering. In: 13th CIRP International Conference on Life Cycle Engineering, Leuven, May 31st–June 2nd.
Mintel, 2009. Ethical Clothing, UK, Available at: http://academic.mintel.com/sinatra/oxygen/search_results/display/?no_redirect&id=393875#search_this_report.
Mugge, R., Schoormans, J.P.L., Schifferstein, H.N.J., 2005. Design strategies to postpone consumers' product replacement: the value of strong person-product relationship. Des. J. 8 (2), 38–48.
Nasr, N., Thurston, M., 2006. Remanufacturing: A Key Enabler to Sustainable Product Systems. Rochester Institute of Technology.
Niinimäki, K., Hassi, L., 2011. Emerging design strategies in sustainable production and consumption of textiles and clothing. J. Cleaner Prod. 19 (2011), 1876–1883.

Philpot, B., Pye, A., Stevens, G., 2013. De-labelling Branded Corporate-wear for Re-use, project MPD007-007, WRAP, Available at: http://www.wear-2.com/news/De-labelling-branded-corporate-wear-report-pdf.

Prahinski, C., Kocabasoglu, C., 2006. Empirical research opportunities in reverse supply chains. Int. J. Manage. Sci. 34 (2006), 519–532.

Savaskan, C., Bhattacharya, S., Van Wassenhove, L.N., 2004. Closed-loop supply chain models with product remanufacturing. Manage. Sci. 50 (2), 239–252.

Sinha, P., Dissanayake, D.G.K., Hussey, C.J., Bartlett, C., 2009. Recycled fashion. In: Proceedings of the 15th ISRDC Conference, Netherlands, 5–8 July.

Sinha, P., (unpublished PhD thesis) 2000. A Comparative Study of Fashion Design Processes in UK Womenswear Manufacturing Companies. University of Salford.

Steinhilper, R., Hieber, M., 2001. Remanufacturing-the key solution for transforming downcycling into upcycling of electronics. Proceedings of the 2001 IEEE International Symposium on (2001). Electron. Environ., 161–166.

Sung, K., 2015. A review on upcycling: current body of literature, knowledge gaps and a way forward. Part I. In: Proceedings of the ICEES 2015: 17th International Conference on Environmental and Earth Sciences, Venice, Italy, April 13–14.

Upcycle magazine, 2009. What is Upcycling? http://www.upcyclemagazine.com/what-is-upcycling.

Vermeer, D., 2014. 7 Upcycling Companies that are Transforming the Fashion Industry, Available at: http://daniellelvermeer.com/blog/upcycled-fashion-companies.

Woolridge, A.C., Ward, G.D., Phillips, P.S., Collins, M., Gandy, M., 2006. Life cycle assessment for reuse/recycling of donated waste textiles compared to use of virgin material: an UK energy saving perspective. Resour. Conserv. Recycl. 46, 94–103.

WRAP, 2015. Textiles – Overview, Available at: http://www.wrap.org.uk/content/textiles-overview.

WRAP, 2014. Fast Facts for Textiles, Available at: http://www.wrap.org.uk/content/fast-facts-textiles.

WTO, 2014. Aid for Trade and Value Chains in Textiles and Apparel, Available at: https://www.wto.org/english/tratop_e/devel_e/a4t_e/global_review13prog_e/textles_and_apparel_28june.pdf#page=10&zoom=auto,-43,354.

Young, C., Jirousek, C., Ashdown, S., 2004. Undesigned: a study in sustainable design of apparel using post-consumer recycled clothing. Cloth. Text. Res. J. 22 (1–2), 61–68.