UPLIFT CIRCULAR FASHION BUSINESS THROUGH APPLICATION OF VIRTUAL PROTOTYPING FOR REFASHIONING

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Dissertation submitted in partial fulfillment of the requirements for the degree Master of Science in Textile and Clothing Management

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DECLARATION

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ABSTRACT

As a dynamic industry in the globe, the fashion industry is still growing with constantly changing trends. Even though the apparel industry is transforming with new technology and innovation, the limitations in waste management systems and traditional take – make – waste linear business models accumulate higher level of waste every day. Therefore, the industry demands more circular initiatives such as upcycling (redesign and refashion); green and clean lifecycles of products; timeless designs; Product Service Systems (PSS) such as rent lease, swap, secondhand/ vintage clothing; on demand production under circular fashion business models. Circular fashion concept is one of the key aspects in the circular economy, which aims to minimize the waste and optimize the resources. Though the published literature profusely discussed the sustainable fashion, there is still a gap between how theory applies into practice. On the other hand, digital technologies (mostly CAD technologies) are emerging to enable strategic adoptions into the apparel industry such as on demand manufacturing, mass customization and virtualization; which controls unnecessary productions, thus waste. Therefore, the aim of this research was to explore digital technology applications (CAD and Blockchain technology) to establish a new venture in circular fashion business. Accordingly, the study tested the viability of utilizing 2D/3D CAD technologies in proposed circular fashion business approach. In particular, it focused on the capabilities of aforementioned digital technologies for a novel business model for circular fashion, focusing refashioning second-hand clothing. Importantly, 2D/3D CAD technologies were utilized in re-fashioning the second-hand clothes while the Blockchain technology was suggested to establish the traceability and as a networking tool for the supply chain in proposed circular fashion business. Subsequently, this business model was developed with the contribution of industry (CAD and fashion design) experts. As a result, this study extends the existing circular fashion business model with a novel approach of digital technologies and tested CAD applications. This proposed model suggests longevity of product lifespan by encouraging the refashioning second-hand clothing as an upcycling option through CAD and relevant digital technology.

Key words: CAD, Circular Business Models, Circular Fashion, Refashioning, SHC, Virtualization.

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LIST OF ABBREVIATIONS

AR – Augmented Reality

BMG – Business Model Generation

BMI – Business Model Innovation

CAD – Computer Aided Design

CAM – Computer Aided Manufacturing

CE – Circular Economy

CF – Circular Fashion

DIY – Do It Yourself

DLT – Distributed Ledger Technology

DOI – Digital Object Identifier

EF Renew – Eileen Fisher Renew Programme

IOT – Internet Of Things

PAAS – Product-As-A-Service

PDS – Pattern Design Systems

PSS – Product Service Systems

RAAS – Retail-As-A-Service

SHC – Second Handed Clothing

VR – Virtual Reality

WRAP - Waste & Resources Action Program

1. INTRODUCTION

This chapter includes the background to the research (1.1), research problem (1.2), aim of the research (1.3), three research objectives (1.4) and scope of the study (1.5).

1.1 Background of the research

The environmental footprint of the fashion industry is accelerating due to higher level of raw material consumption, pollution and waste (Claudio, 2007). At present, fashion industry is considered as one of the major polluting industries; also it will be same in the near future. Therefore, industry demands to enhance more sustainable strategies such as circular fashion, where garments and materials are reused (Morrison, 2019). In Circular Fashion concept, the waste is redesigned to keep materials/ products in use for as long as possible in a cyclical way. Further, it is a regenerative system, where garments are used in to maximum to retain their maximum value. Additionally, meaning full designs are incorporated in initial design stages considering their next life in use (Ki, Park, & Ha-Brookshire, 2020) Even though it is not sufficient enough; there is some progress, which has already been made by the industry and legislatives, such as emerging of new sustainable materials, incorporating circular design principles, and trialling take-back and material recycling schemes, waste management systems (Caniato et al., 2012; Pedersen et al., 2018). Majority of global fashion brands have committed to circularity in their business models and some regime-based legislations and policies such as European Commission's circular economy package, which aims to recover 70% of the waste from landfills to 10% by 2030 and roadmap to a resource efficient Europe, sustainable clothing action plan by Waste & Resources Action Program (WRAP) have been established to accelerate circular adoptions while reducing the waste (Pensupa, 2020; Putilin, 2019). However, the consumer behaviour of more frequent fashion shopping still demands the augmented productions of fast fashion and disposing them before the intended lifespan, which impacts negatively on human and physical resources on the earth. Such situations create a great need of making apparel supply chains more cyclical with sustainability. Therefore "Re-Services" such as reusing, recycle, re-

selling, re-commerce will be prioritized in future business models in global apparel industry (Morrison, 2019).

The booming up of Second Hand Clothing (SHC) industry brings numerous options to both eco loving consumers and producers through circular fashion concepts. Recycling by upcycling such as refashioning and by downcycling such as material recirculation, refurbishing are names to few examples. However upcycling of SHC like refashioning, still remains in niche level, because it requires higher levels of design skills and workmanship (Dissanayake and Sinha 2015). At the same time, the factors such as higher degree of time consumption, material limitations, difficulties in reproducing or producing in mass scale, and the production cost also affecting to keep this in a minor scale. Additionally, many new SHC related business models that are developed based on circular and upcycling concepts were not reached the expected success due to technological and technical limitations, consumer attitude related matters and strongly rooted fast fashion business models in the world (Todeschini et al., 2017). Therefore, it is essential to minimize the gap of efficiency and adeptness between traditional mass scale (fast fashion) business and circular business solutions in terms of productivity, availability, cost, consumer demand and other constituents.

Use of Computer Aided Design (CAD) along with other digital technologies such as Blockchain technology and internet of things (IOT), haste the productions and build strong rapport among customers, retailors, suppliers and the designers within the circular fashion concept. Here Blockchain technology can be defined as a digital ledger system of recording transaction information across entire network of a process (in the case of this research process is the fashion manufacturing). The IOT means a network of physical objects (in the case of this research different pieces of disassembled garments) that are embedded with sensors, software, and other technology.

At the same time, recycling based business models seems more appealing to the current requirements in fashion industry (being sustainable while satisfying consumer) as they incorporate minimum waste and circulate fashion with mechanisms such as fashion libraries, garment subscription schemes and product return rewarding systems. Therefore, this study will focus on exploring the provisions of upcycling second hand clothing by refashioning, with the support of CAD and other digital

technology, with the means of delivering circular adoptions to the circular fashion industry, towards a novel circular fashion business model.

1.2 Research Problem

With the above background, this study emphasises the global threat of waste and need of cyclical approach to the fashion industry. SHC becomes a critical concern there. Therefore, it is highly required to explore new strategies to re-employ used garments/ SHC by occupying new and advanced technologies. Although the circular fashion industry has lot of promises towards circularity, it has many challenges to overcome in the production process, supply chain and consumer perception. However, there are many untapped new potentials in digital technologies (CAD/ Blockchain) to support circular fashion industry. With this context, it is required to study,

What are the potential opportunities to enhance SHC business with the aid of CAD and other digital technologies...?

1.3 Aim of the research

This research aimed to explore the potentials to enhance SHC industry using digital (2D/3D CAD and Blockchain) technology in circular fashion business. Specially, it focused on refashioning SHC over traditional downcycling methods such as producing rags and cleaning wipes or reselling as cheaper seconded items. Therefore, it is planned to explore the opportunities and challenges in SHC industry and technological (2D/3D CAD and Blockchain technology) possibilities address those opportunities and challenges further in this research. Finally, it focused to develop a new business model for refashioning SHC with such digital technologies and additionally, the applicability of CAD technology for this model is tested with an experimental research approach.

1.4 Research Objectives

The main intentions of this research are exploring potentials and challenges in circular fashion industry for SHC and proposing a novel approach for circular fashion business models with CAD technology to harness the potentials of SHC. Further it intended to suggest other technological solutions such as Blockchain technology, to establish the traceability during circular operation. The expected result was a new

venture of the circular fashion business model and a framework for refashioning SHC, by enabling digital technologies. Additionally, it intended to test the applicability of 2D and 3D CAD technologies into the proposed business model with an experimental research approach.

RO 01. To explore the opportunities in circular fashion industry with reference to Second Hand Clothing (SHC).

RO 02. To propose a new business model to implement refashioning SHC, with adaption to circular fashion by enabling digital technologies (CAD and Blockchain).

RO 03. To test the applicability of 2D and 3D CAD technologies in the implementation of new business model for SHC, in the circular fashion business.

1.5 Scope of the study

This research mainly focussed on how the current circular fashion business model can be extended with the producer's/ production capabilities. Therefore, the customer attitude and behavioural perspectives towards refashioning SHC (towards proposed business model) are limited to the secondary information.

As an initiate of evaluating the business model, the phase three of this research (refashioning experiments) mainly focused on selecting A-grade used garments where mostly in good condition and belong to luxury or above market levels in their first life. Specially, foundation garments and lingerie were not selected for experiments since there are limitations in using those garments. Refashioning experiments were limited for size 12 women's casual/ smart casual wear. Based on the desk research and initial discussions with CAD experts, Browzwear VStitcher software was chosen for refashioning experiments of SHC. Additionally, Gerber AccuMark software was used for digitising garment panels. Further, the validation of the proposed business model and the framework is limited to the virtual prototyping experiments due to time limitations. However, since the published literature and industry expertise were evidenced for the success of replacing physical prototypes by virtual prototyping in first-hand clothing industry, it is assumed that it will be same for refashioned garments from SHC. Therefore, the phase three, validation is limited for virtual refashioning of SHC without production of physical garments.

2. LITERATURE REVIEW

This chapter includes a review of literature about circular economy and circular fashion, with regards to SHC. In addition, consumer perception to SHC was studied through he published literature. Explicitly, this research extended to explore digital technologies such as CAD and Blockchain technology applications for circular fashion regards to SHC. Literature survey was completed using peer reviewed indexed journal articles mainly on Google scholar database. Findings of the literature are presented as circular fashion in circular economy (2.1), Circularity in global fashion industry (2.2), Apparel waste and second hand clothing (SHC) (2.3), SHC markets (2.3.1), Recycling SHC for circular fashion (2.3.2), Refashioning SHC for circularity (2.4), Consumer attitudes towards SHC/ refashioning (2.5), Technology intervention for circular fashion (2.6), Digital technology applications for circular fashion (2.6.1), "IOT" The Internet Of Things (2.6.2), Blockchain Technology/ Distributed Ledger Technology (DLT) (2.6.3).

2.1. Circular fashion in circular economy

Circular Economy (CE) is an industrial system that priorities restoration and regeneration through the superior design of materials, products, systems, and business models. The concept mainly consider the designing based on waste, continuous use of materials and products and regenerating natural systems (Naser, 2019). There are three principles for the implementation of the circular economy, which bridge between sustainability and circularity i.e. Environmental impact through the minimization of solid waste, landfill expansion, and emissions; economic benefits through the redesign of products, supply chains, and choice of materials; and resource scarcity through reductions in the use of materials, as well as reuse and recycling (Lieder & Rashid, 2016). The Circular Economy concepts could be applied into any industry by trickling down through government policies and legislation or by trickling up and across through the industry competitiveness and profitability. The fashion industry contributes circular economy by making process more cyclical. Specially in recirculation of used clothing such as SHC. Therefore, the circular fashion concept is considered as a subsidiary of circular economy smart economic system, which minimizes the waste with utilizing resources in to most.

Importantly, circular fashion concept challenges the linear production system of the fashion industry, which consists 'make –sell and dispose clothing' that ends with clothes being discarded in landfill or burned. Therefore, it is required a drastic transformation to move in to circularity from linearity and at the same time, it is an enthusing opening to play strategically and innovatively to explore new potentials of fashion (Alexander, 2019; McCartney, 2019). Further elements of circular economy are illustrated in Figure 2.1 below.

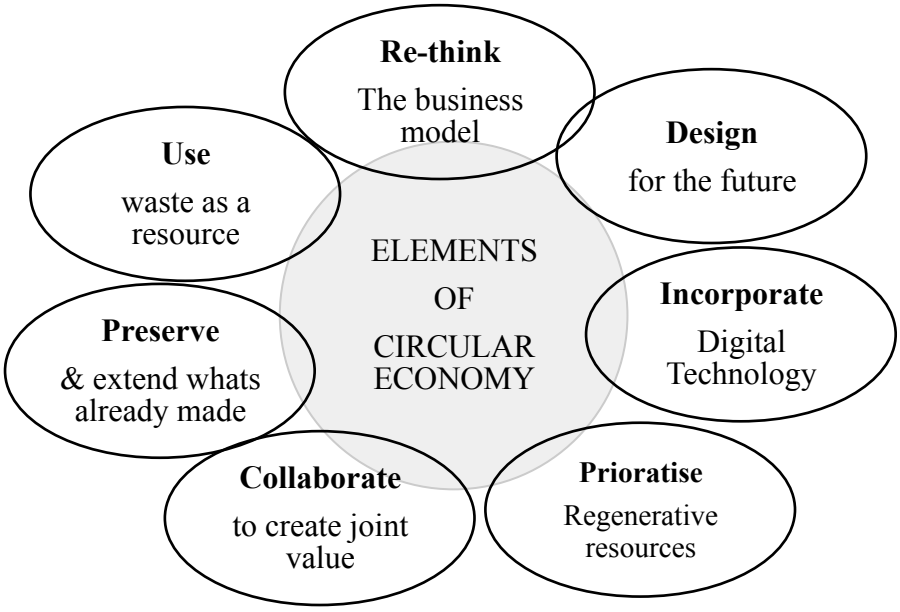

Figure 2-1: Elements of Circular Economy

Source:https://www.circle-economy.com/circular-economy/7-key-elements

2.2. Circularity in global fashion industry

Most companies in the fashion industry (total of 94 companies) together with HUGO BOSS have signed the industry-wide 2020 Circular Fashion System Commitment, in which they commit to promoting closed loops in the textile industry, together with HUGO BOSS. The life cycle of the products is extended by returning them to the material cycle at the end of their life, for example, through recycling (Hugoboss.com, 2019).

With the Circular Economy (CE) trends, fashion industry also committed for circularity by being more cyclical and ethical, not only by just recycling SHC and other textile waste; but also by inputs at the designing stage of the new products such as considering product longevity, focusing on recyclable materials and product designs, considering animal rights, fair-trading, ethical manufacturing. Stella

McCartney, Patagonia, NIKE, Eileen Fisher and H&M are pioneers who initiate circularity beyond the sustainability. H&M encourages shoppers to return unwanted clothing with an in-store consumer-recycling scheme by offering £5 vouchers (Alexander, 2019; Lehmann, 2018). The legendary brand Patagonia has a well-known history of eco sensitive practices introducing the "*Common Threads Initiative – Reduce, Repair, Reuse, Recycle, Reimagine"*. Apart from that, Patagonia launched a new "*Worn Wear*" programme with an online specialized shop, allowing customers to trade in their SHC for credits from the company. A competitor of Patagonia, the well-known brand "The North Face" launched an innovative re-commerce programme called "The North Face Renewed" to reduce waste by remaking refurbished clothing.

"Dyecoo" is another pioneering company, with partnerships with NIKE and IKEA, initiating the technology uses reclaimed CO_2 as the dyeing medium in a closed loop process. Further, world famous fashion brands such as GAP, Hugo Boss are using advanced technologies in order to enhance the circularity in the global fashion industry.

2.3. Apparel waste and second hand clothing (SHC)

Unlike other industries, the rapidly changing fashion trends with fad and fashion items, which have shorter lifecycles cause most of the landfilling of textiles as post and pre consumer waste. Other than that, the fast fashion trends speedup the productions in order to achieve quick selling outs and offer freshly baked clothes to the market more frequently while encouraging customers to increase the frequency of fashion shopping. Hence the shorter lived cycles, the longevity and the quality of these products are low due to cost effective means of productions. Thus, it increases the textile waste for land filling without many provisions of recycling. On the other hand, due to excessive production and wear reduction of purchased fashion, garments are discarded still with the label. Furthermore it is found that 95% of discarded clothes are in good wear conditions (Fernandes, 2019). The literature reveals that 300,000 tons of clothes are moved for binning every year and less than 1% of clothing are recycled in to new clothes while 73% goes to landfill (Alexander, 2019; Naser, 2019). Due to this underutilization of clothing and less recycling along with the traditional make –sell – dispose model, the industry drops over USD 500 billion of value annually. Additionally, this outmoded business model has numerous negative environmental and societal impacts. Moreover, large amounts of non-renewable

resources are extracted to produce clothes that are often used for a short time, after which they are mostly sent to landfill or incinerated. Such fast fashion practices discourage the ethical and sustainable behavior of the apparel industry and demand more cyclical initiatives (McArthur, 2020). The pioneer of the sustainable fashion; Stella McCartney argues the importance of being circular while emphasizing that one dump truck of clothing is burned or landfilled in every second, and if this continues the clothing waste accumulation could be equal with the world population in weight by next five years (Moorhouse & Danielle, 2018). In this context, 12.5% of the fashion industry has already committed to circularity (Morrison, 2019).

Garments, which stuck at personal wardrobes are also can consider as waste since they are not being used and expectant to be removed as SHC and landfilled in future. Predominantly it is essential to encourage consumers to use those garments in strategic means. The average life expectancies of different garment categories are showed in below Figure 2.2 and further it depends on the textile material, the design and the manufacture of the garment and maintenance. In circular fashion approach, it is essential to think about the designing and other backward linkages of the supply chain of first life of the product as well as recycling post-consumer waste. SHC becomes more critical for such strategies.

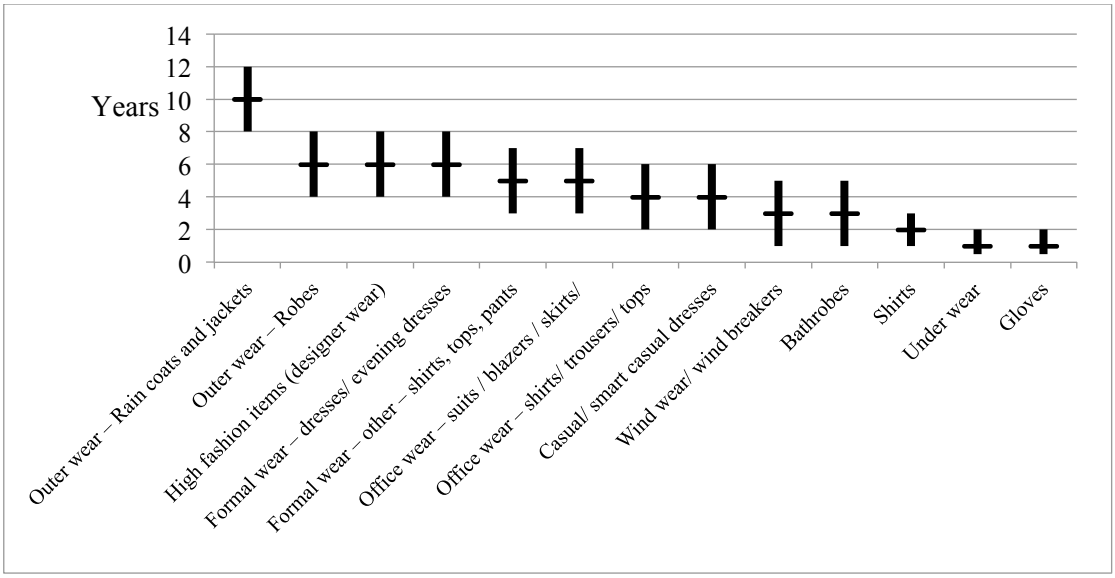

Figure 2-2: Average expected lifespan for clothing categories

Source:(Laitala & Klepp, 2015; Pensupa, 2020)

2.3.1. SHC markets

Second-hand trade is not a completely new concept to the world. In great history, in Victorian era and Edwardian era[1], most of luxury consumer goods were trickled down[2] vertically into the high-street market after using by elite class. The same practice could be seen today, as many developed countries export their seconded products, specially clothing, in to developing countries such as Africa (Brooks, 2012; Brooks & Simon, 2012). Today the scope of the second-hand practices has been expanded with online technologies for raw material as well as refurbished clothing markets. However, this second-hand economy interpreted as a way of consuming goods creatively and smartly due to current ethical practices of both consumers and suppliers along with the advancements of technology.

It is predicted that the SHC market to get doubled in 5 years in resale, leading towards a growth of nearly 150% the volume of fast fashion by 2028. In other words, the second-hand market will be worth US$64 billion, in comparison to US$44 billion for fast fashion in next five years (Reinhart, 2019; Thredup INC., 2019). The current SHC business consists different strategies in collecting, sorting, reselling and recycling. There are two main types of SHC, sorted SHC and unsorted SHC. The unsorted SHC are collected from textile banks and door-to-door collections, which may contain high quality untouched clothing still with tags. The process of the sorted SHC, is done according to season, gender and the quality of the garment. Seasonal categorizations are winter, summer or mixed. Mens', womens' and kids' categorization is the base for gender based sorting. The quality is categorized by grades such as A, B, C and D as the grade A has the best quality (for direct reuse/ resell), grade B is for wiper grade where products are down cycled in to rags and other cleaning products. The C graded SHC are mostly suitable for fiber-to-fiber recycling while grade D has the lowest quality considered as waste which cannot be (Dissanayake & Sinha, 2009; SecondHand4Business.com, 2018) reused or recycled These categorizations and grading systems could vary for different countries and

[1] The period of Queen Victoria's and king Edward VII's reign, from 1837 to 1910, which mainly consisted of three social classes upper class, middle class and lower class.

[2] The **trickle-down effect** is a model of product adoption in marketing that affects many consumer goods and services. It states that fashion flows vertically from the upper classes to the lower classes within society, each social class influenced by a higher social class.

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sellers, i.e. some sellers maintain “Branded SHC” or “Cream” sub grades with the category A to cater luxury second-hand markets in a niche level (Elias, 2020; Norris, 2012; Zaman et al., 2019). Mostly these SHC are collected from developed countries like UK and USA and exported to Guatemala, Somalia and other African countries as cloth bails. However, those countries have controlled importing SHC now, in order to protect their local clothing industries. Therefore, it is essential to find innovative solutions for SHC to keep used garments away from landfills by extending their active lifespan with strategic transitions within the period. Further, to enhance the circularity in fashion industry, it is important to limit the accumulation of lower graded SHC. Therefore, the initiatives should be implanted at the design stage of the virgin clothing.

2.3.2. Recycling SHC for circular fashion

Recycling of SHC mainly consists of two areas, upcycling and downcycling as shown in Figure 2.3. Upcycling is based on different methods such as refashioning, refurbishing, repurposing to upgrade or remanufacture for adding value to compositional elements. The downcycling is the mostly practiced as an end-of-pipe option and turned those SHC into by-products such as rugs, upholstery etc. (Fernandes et al., 2019; Singh et al., 2019).

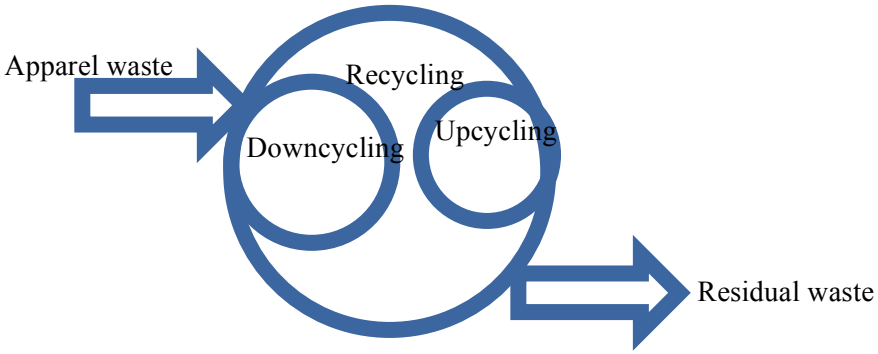


Figure 2-3: Current recycling process

Within above two major areas, there are many other mechanisms such as 9R framework for recover the value of used clothing, Figure 2.4 (Kirchherr et al., 2017). The biggest impact on reducing environmental burden is extending the active life and keeping clothes out of landfill (Schmidt et al., 2016; Woolridge et al., 2006)

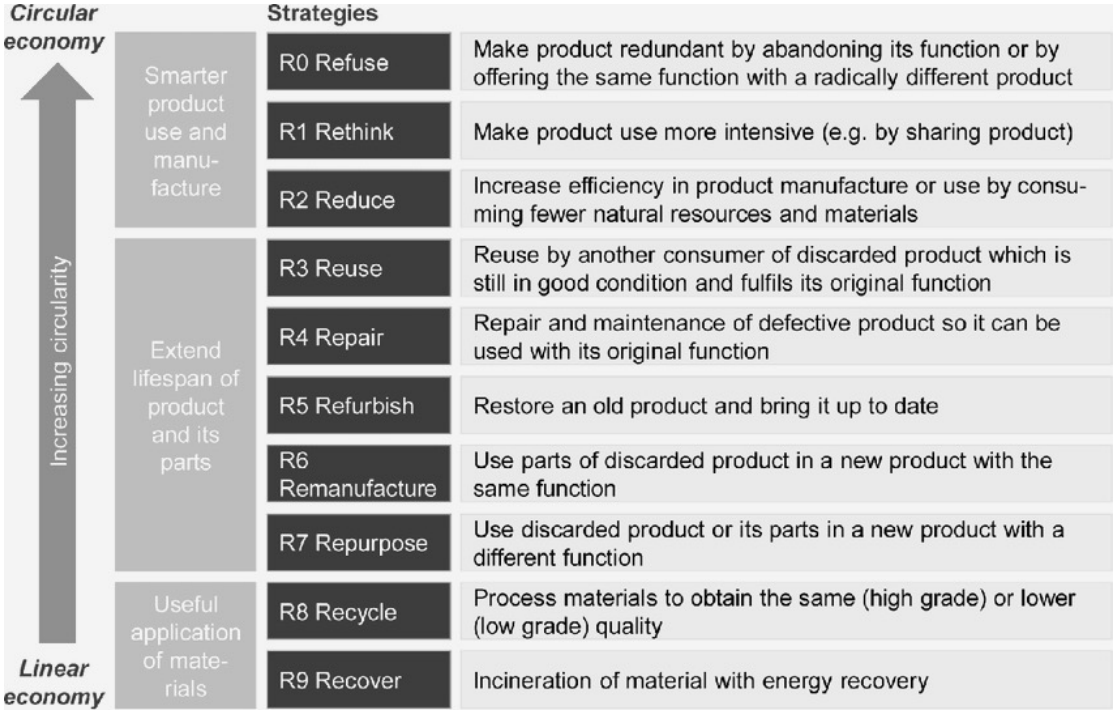


Figure 2-4:9R framework for circular economy

Source:(Kirchherr et al., 2017)

2.4. Refashioning SHC for circularity

It could be identified the process of refashioning by upcycling along with refashioning, reselling and renting also are efficacious options which exist in the circular fashion industry. Although such "garment – to – garment" value added refashioning practices provides enormous competing and thriving business opportunities, they are still sparse in apparel retail industry. Since the commercial value of SHC as a raw material is comparably low, it is much profitable to find possibilities of creating new value added products by refashioning SHC in effective and efficient manner. However, the fashion refashioning process is yet to be developed in the global context in the apparel industry. Even though the industry is capable and consists of necessary elements such as technology for fashion remanufacturing, the process is carried out for a niche market, but remains largely within it (Dissanayake & Sinha, 2015). Further, the scarcity of virgin raw materials, availability of technology and global trends towards circularity, creates more opportunities for using SHC as a raw material for fashion remanufacturing in the circular fashion industry. However, there are number of limitations could be identified in this process such as difficulties in collecting and sorting used or rejected garments,

time restraints, need of higher level of designer skills, and workmanship, difficulties in repetitive productions (Arzaga, 2017; Dissanayake & Sinha, 2015). Other difficulties are the lack of effective marketing strategies, lack of price sensitivity to the market and lack of properly formed reverse supply chains to collect second-handed clothing and lack of transparency in the production process in order to win customer loyalty (Ekstrom & Salomonson, 2014). In order to achieve success in refashioning SHC, the foundation must be laid in the design phase in the first life of clothing. Materials should be long last, recyclable. Otherwise, the garments can be disassembled (fully or partially) into individual components again at the end of its first life in order to redesign into new product. To execute such design strategies, Computer Aided Design (CAD) software could be used in a strategic manner.

2.5. Consumer attitudes towards SHC/ Refashioning

Today's responsible consumers are rapidly shifting in to "circular fashion" concepts such as slow fashion, second-hand clothing and over unsustainable fast fashion. According to the "ThredUp" online resale platform; the sustainability has become the priority for consumers with 74% of 18-29 year old in fashion shopping and one third of the "Generation Z"[3] are willing to buy SHC (Thredup INC., 2019). "Millennials"[4] and Gen Z are driving the growth of second-hand market (18-37 years). The new instagram generation's desire towards sustainability, environmental benefits through fashion and desire for frequent turnover of wardrobes make this resale/ SHC/ refashioning concepts raise among other fast fashion business models (James, 2018). Such business models provide a great platform for SHC. On the other hand, there is an ever-growing global demand for transparency. With 70% of consumers most interested in the sustainability impact of the products they buy. Therefore, it is new opportunities for differentiate, develop new business models, which deliver products with more transparency. With these changing customer preferences and environmental pressure, fashion companies will have to rethink the way they serve their customers.

2.6. Technology intervention in circular fashion

Today's fashion industry is vastly reinforced by advanced technologies. Many of the mass-producing companies exploring and adopting newest technologies in the

[3] Those born after 1997, who are next to enter the workforce.
[4] Anyone born between 1981 and 1996 (ages 24 to 39 in 2020) is considered a Millennial

competitive fashion world. Brands such as Gucci, Tommy Hilfiger, LVMH, Loomia, NIKE, Patagonia and Everlane are already playing with digital technologies in the circular fashion industry. Moreover, the technology is involved in all stages of the apparel production process. Artificial Intelligence (AI), IOT, Mobile commerce, Augmented Reality (AR)/Virtual Reality (VR), and Blockchain technology are name to few examples for such technology trends, which will change the future of fashion industry (Behr, 2018; Kose & Karaman, 2016). Apparel producers tend to hybrid with tech companies to explore infinite possibilities of technology to create inspiring customer experience while being trendy. LVMH linked with Microsoft, Farfetch linked with Libra Association to enable Blockchain and other digital applications for their retails. Contactless shopping, live video shopping, digital showrooms, "try on" with AR, digital tokens and rewarding systems, smart labels and barcode system, product and process tracing are few options to mention among the countless opportunities for the circular fashion industry (Mcdowell, 2020).

2.6.1. Digital technology applications in circular fashion

The advanced applications of CAD (Computer Aided Designing) technology reinforce most stages of the apparel supply chain by increasing accuracy and efficiency while eliminating unnecessary activities. In the traditional fast fashion practices, CAD software are mostly used for designing, and pattern making for new garments, further to be synchronized with manufacturing technologies such as automated cutting, manufacturing and packaging (production systems) (Yuan & Huh, 2018). However, there are lots of advanced performances in latest CAD technologies such as Pattern unwrapping, 3D to 2D reverse engineering to obtain patterns of pre-determined virtual 3D objects such as human body avatar, as fast fashion requirements of speed up mass scale productions and mass customizations. Also, CAD solutions are developed with advanced virtual options providing unlimited opportunities to unleash the creativity while improving productivity and efficiency (Sayyad, 2017). Mostly these CAD technologies are currently used to manage pre consumer waste in the apparel industry as sustainable practices. However, rare to find evidences of applying CAD technologies in managing post-consumer waste such as SHC in the fashion industry (Parthasarathi, 2019). Moreover, there are varied undiscovered potentials with these CAD software in order to establish the circularity

in the fashion industry such as virtual refashioning of SHC, over fast fashion practices (Sayem, Kennon, & Clarke, 2010).

Other than traditional brick-and-mortar retailer systems, companies have focused on tailor made products through e-customization. Online size measuring, customized tailoring, on demand manufacturing were key activities. For an example, a Japanese company ZOZO, expanded their business to western markets enabling customized clothes through a 3D body-scanning suit with "ZOZO mobile app". Also, well-known brand Gap introduced the "Dressing Room app" allowing customers to try on garments in augmented reality. The world's largest e-commerce company Amazon patented the "augmented reality mirror" for emote body scanning. M-Tailer also uses an app to consumers' size measurements and delivers the finished garments within five weeks. With such applications of digital technology, it is possible to avoid the waste of unnecessary productions and encourage customers for meaningful purchasing while promoting circular productions such as refashioned SHC. Further such technologies may lead to a higher speed to merchandise and build stronger relationships between seller and buyer with the means of On-demand manufacturing, and customized production that fits in a sustainable future where less unsold stock is destroyed. Further it would empower consumers to demand what they want, instead of consuming whatever supplied by the producer (Hoen, 2019; Segura, 2019).

The descriptive details of 3D virtualization permit to obtain more realistic depictions of body/ garment contours and colours. Moreover, the advanced tools in CAD systems allow to operate digital fabric and trim libraries and digital trend recognising systems (Papachristou et al., 2019; Spahiu et al., 2014). Therefore, the need of physical prototyping of garments could be skipped from the apparel production process in order to reduce waste and speed up the production process. Well-established fashion brands such as Hugo Boss have already using virtual 3D prototyping technology to shorten the product development time (Hugoboss.com, 2019). Apart from above, advanced technologies such as Blockchain technologies and Internet of things (IOT) technology is being used in the fashion industry in order to trace retails, and observe products' life once they are sold. The Table 4.10, in section 4.2.2 describes about such CAD technologies and their potentials for Circular Fashion.

2.6.2. "IOT" The Internet Of Things

Since the fashion retail world is much complex, the "Internet of Things" (IOT) technology helps to string all the fashion together invisibly, linking physical garments with its "digital twin". The digital system called "circular aid" which empowered by IOT, enables the products to communicate consistently while sharing information readily and openly itself. Therefore, it stores the records and reveals each product data from production to first sale, resale, rental, recycle, etc. Further, the IOT technology links the "things" of the actual world with the virtual world. This technology connects anything, any time at anywhere while allowing the retail industry to identify right customer at the right time (Vermesan, 2009). The six basic principles of IOT (as mentioned in Figure 2.5, bridge the gaps of information in retail industry and align today's needs of retail industry.

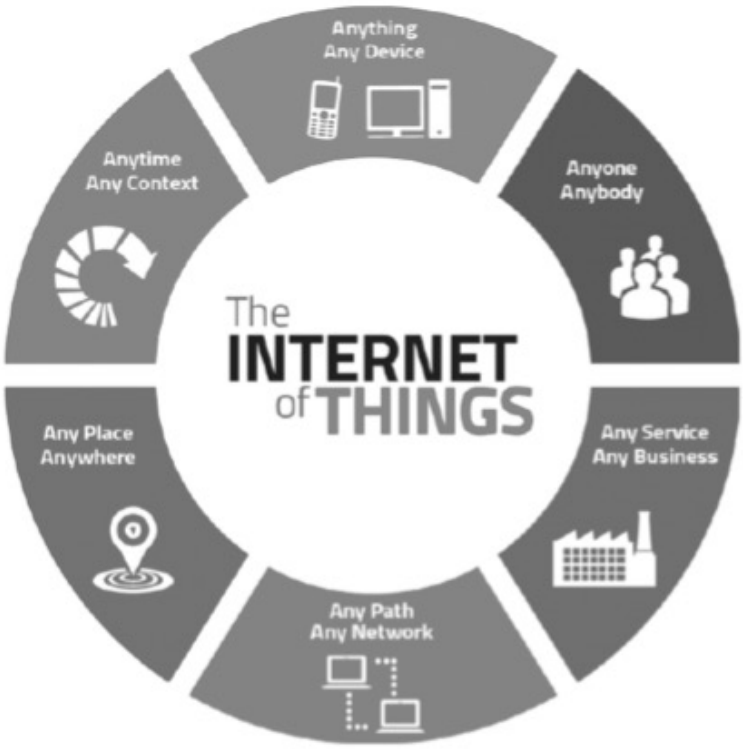


Figure 2-5: Principals of IOT

Source:(Patel, 2016)

According to Natasha Frank, the founder and chief executive officer of Eon, this adoption of digital identification technology along with the circular fashion concepts, accelerates the transition of retailors in to more circular business models with improved transparency, efficiency and productivity (Roshitsh, 2019). Therefore, the

IOT is essential for identification and managing productions and sourcing materials in a circular economy. It challenges the traditional structures of retail supply chains which mucked in secrecy, by improving the product life cycle with “measurement,” “accountability” and “transparency” (Connect-fashion.com, 2019).

2.6.3. Blockchain Technology/ Distributed Ledger Technology (DLT)

Since the fashion industry remained exploited and controlled by different stakeholders in the apparel supply chain, it demands much more change and positive evolution where a “demand chain” is employed with more customer influence. The DLT and Blockchain technology integrate all the stakeholders on the supply chain with the means of greater transparency, auditability and traceability. The DLT is a system, which records transaction details in multiple places at the same time. It requires no central administration functionality. The Blockchain is also a kind of shared database having more focus on a supply chain. Even though, these are multiple industry-wide applications, there are numerous possibilities for the fashion industry with it, to maintain decentralized and widespread data management systems rather than traditional intimate ledgering methods (Agrawal et. al., 2018; Roeck et. al., 2020).

Since these digital technologies still in their introductory and growth stages, they are mostly used in forward linkages in the apparel supply chain. However, there is more room to use those technologies vastly in different forms of production stages in the industry. Specially in SHC related productions, Blockchain technology gives massive opportunities to trace the early life of the SHC and obtain required data at the right moment from the right stakeholder. Therefore, SHC producers have to think ahead and position themselves strategically in the industry, to integrate with the technology.

3. METHODOLOGY

This chapter outlines the overall design and approach of the research. It explains the research design and methodology in terms of how to achieve the defined three (03) research objectives mentioned in Chapter 1, section 1. 4. Moreover, this chapter elaborates the sampling methods, survey instruments and method of analysis pertaining to each objective in each phase.

3.1.Research design

Mixed multiple research methods were utilized in this research, in order to accomplish three research objectives. Basically, qualitative research approach is considered with qualitative interviews using an open-ended, semi structured questionnaire and systematic review of literature of published scholar articles. Further, few case examples to provide a context to the analysis of first and second objectives of the research. Afterward, experimental research approach is planned to achieve the third objective (RO 03) of the research.

The research is planned to be conduct in three phases to achieve three research objectives. The first and second phases were planned targeting first and second research objectives, which focused on qualitative research methods and qualitative data analysing methods such as content analysis, thematic analysis. Further Nvivo software was used for text search queries, word clustering and quantifying qualitative data. Additionally, Strategic Factor Analysis Summery (SFAS) matrix was used as a tool to analyse qualitative data.

The third phase of the research is planned for an experimental research approach to achieve the third objective of the research. The main intention of this phase was to test the applicability of CAD technology for the suggested business model, which concluded in first and second phases. Figure 3.1 illustrates the design of the research for achieving each research objective.

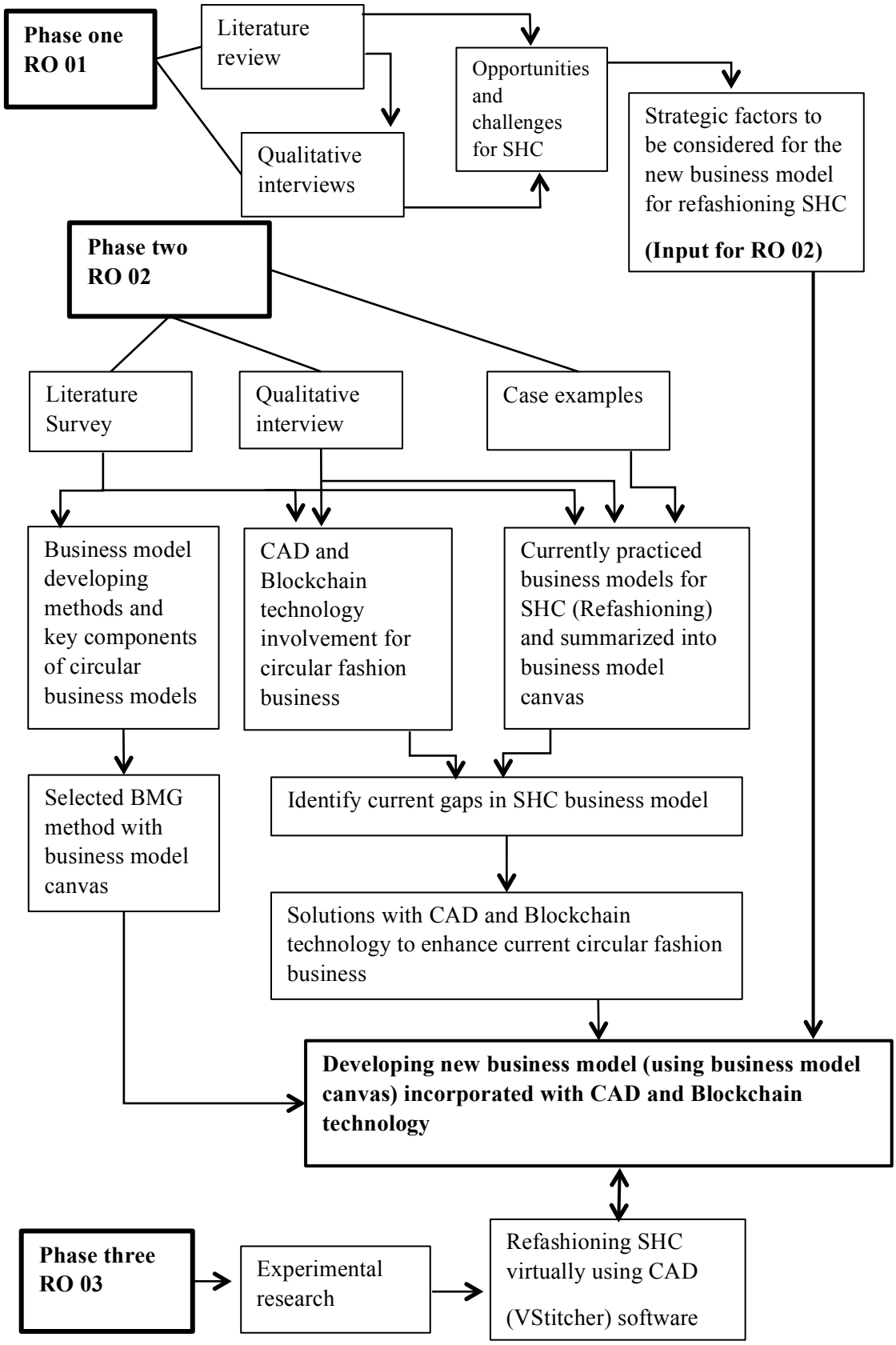


Figure 3-1: Research design

3.2. Methodology for RO1: To explore the potential opportunities in circular fashion industry with reference to the Second Hand Clothing

The objective one of this research is to explore the potential opportunities and challenges of circular fashion business in circular economy relating to second-hand clothing (SHC). A systematic review of literature and qualitative interviewing were used in the first phase, in order to achieve this research objective as summarized in below Figure 3.2.

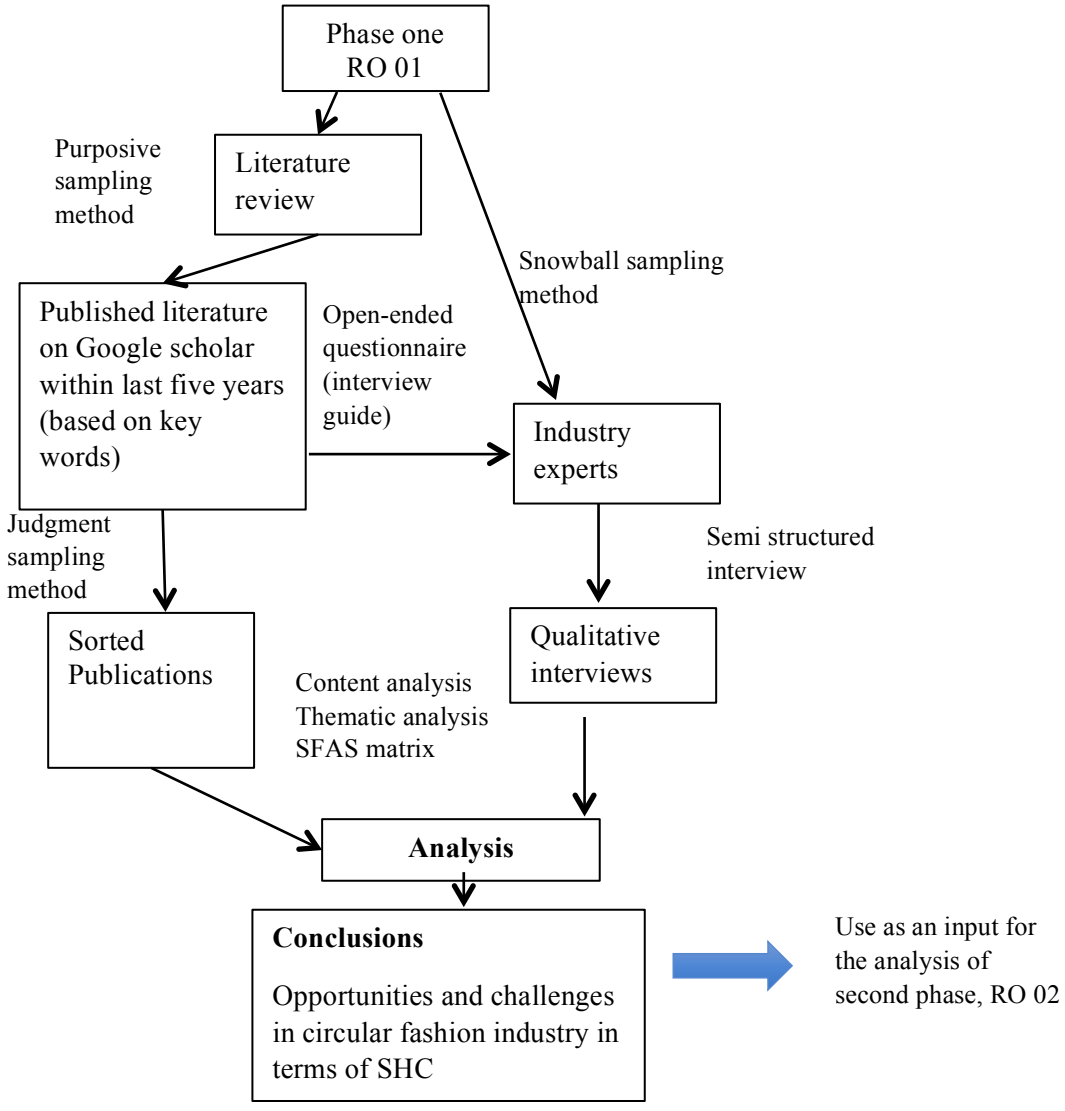


Figure 3-2: Summery of methodology for phase one, RO 01

3.2.1. Sampling method and survey instruments

The main sample for the literature review was based on publications published in Google scholar database within last five years (2015 – 2020), which are found through the key words of "Circular fashion" and "Second-hand clothing", or "Refashioning". Additionally, it was planned to limit the number of articles into manageable amount with the application of judgment sampling. The abstracts of the articles in the main sample were reviewed and then filtered out those are not directly relevant to this research based on the information availability. Here mainly the articles which consisted information recycling by down cycling and circularity on first-hand clothing productions were dropped and focused on selecting articles which consisted information about refashioning, remanufacturing of SHC, circularity on SHC.

In addition to above literature review, qualitative interviews were organized with the key industry experts in circular fashion and second-hand clothing. Snowball sampling method was used for selecting the experts of this research area for qualitative interviewing. It was planned to have professionals from three areas of design, retail and CAD in global context. First the sampling was initiated with the personal contacts of the researcher who expertise on design, retail and CAD. Then sample expanded with the known contacts and suggestions of those initial experts till the required level of information is achieved. Semi-structured interviews with an open-ended questionnaire (interview guide), which is developed based on findings of literature review, were used to gather qualitative information from industry experts. The interviews were tape recorded in order to capture the information accurately. The semi structured, open-ended questionnaire (Annexure 01) is developed based on the findings of the literature review of phase one, and additionally few questions were added to the questionnaire with the purpose of obtaining information for the phase two (RO 02) of the research. Therefore, same interview sheets were used for both first and second phases of the research.

3.2.2. Data analysis methods

Both the literature survey results and qualitative interview results were planned to analyze using a content analysis and thematic analysis. Further, the Strategic Factor Analysis Summery (SFAS) matrix also applied to identify true opportunities and key

challenges as strategic factors for SHC in circular fashion industry. The NVivo 11 software was used to record, analyze and visualize the results.

It is identified that there are opportunities as well as challenges for refashioning (SHC) industry while in the content analysis of both literature survey and qualitative interviewing. Therefore, both opportunities and challenges are extracted from selected literature and coded eight themes of opportunities and six themes of challenges for the thematic analysis. Likewise, the information obtained through the qualitative interviews (semi-structured) also analysed for same themes of opportunities and challenges respectively. Nvivo 11 software is used for visualising the devotion of coded themes (narrative analysis), and word frequency queries[5] (with synonyms) and text search queries[6] are done further for pictorial summaries.

Further due to contrasting results from literature review and qualitative interviewing, SFAS matrix is also used to identify true opportunities and challenges for refashioning SHC. Here all themes are considered as strategic factors for the analysis. The application of SFAS matrix is further described below with Table 3-1.

Table 3-1: Application of SFAS matrix

Strategic factor	**Weight** [7]	**Rate** [8]	**Weighted Rate** [9]	**Comments**
Themes of opportunities and challenges are considered as strategic factors	The % value (from published literature) is converted into a value out of 1	Allocated rate 4 for the highest % value. Then calculate the rate (out of 4) for each theme % value. Then rounded the figure in to one decimal place	**Weighted rate = Weight * Rate**	Identified the strength of the strategic factor (theme) based on the value of weighted rate for each theme. Highest valued theme/ factor has more strength and lowest valued theme is least strong.

[5] Frequency queries will provide the most frequent key words in a given content through a Word Cloud visualizing the size of words according to their frequencies.
[6] Text search queries will provide words associated with a given search term in a selected content through a word tree diagram. This is useful in identifying key messages reference to the search term in a large content.
[7] In SFAS matrix weight is decided by the relative importance of the factor and assign a weight that ranges from 0.00 to 1.00 for each factor. More importantly the sum of all weights must be 1.00
[8] The rate is assigned to each factor from 4 (outstanding) to 1(poor) scale.
[9] Rate is multiplied by weight for weighted rate

Calculation of Weight (% values are from literature survey results analysis)

$$Weight = (\%\ of\ each\ theme) \times 1$$

Calculation of Rate (% values are from qualitative interview results analysis)

$$Rate = \left(\frac{4}{Highest\ \%\ value}\right) \times (\%\ value\ of\ each\ theme)$$

Calculation of Weighted Rate

$$Weighted\ Rate = (Weight) \times (Rate)$$

The findings of the phase one (RO 01) were used as an input for the phase two (RO02).

3.3. Methodology for RO2: To propose a new business model to implement refashioning SHC, by utilizing 2D / 3D CAD and digital technologies in the circular fashion industry

The second research objective intended to introduce new circular fashion business model with CAD and digital technologies to employ refashioning SHC, by addressing the opportunities and challenges of current circular fashion industry, which are identified in the first research objective. Initially, the BMG method with business model canvas is identified to develop the new circular fashion business model and then the applications and advancements in the CAD technologies were identified further through the review of literature and qualitative interviews. Additionally, international case examples were studied to identify current practices of circular fashion. The steps of phase two are summarised in Figure 3.3.

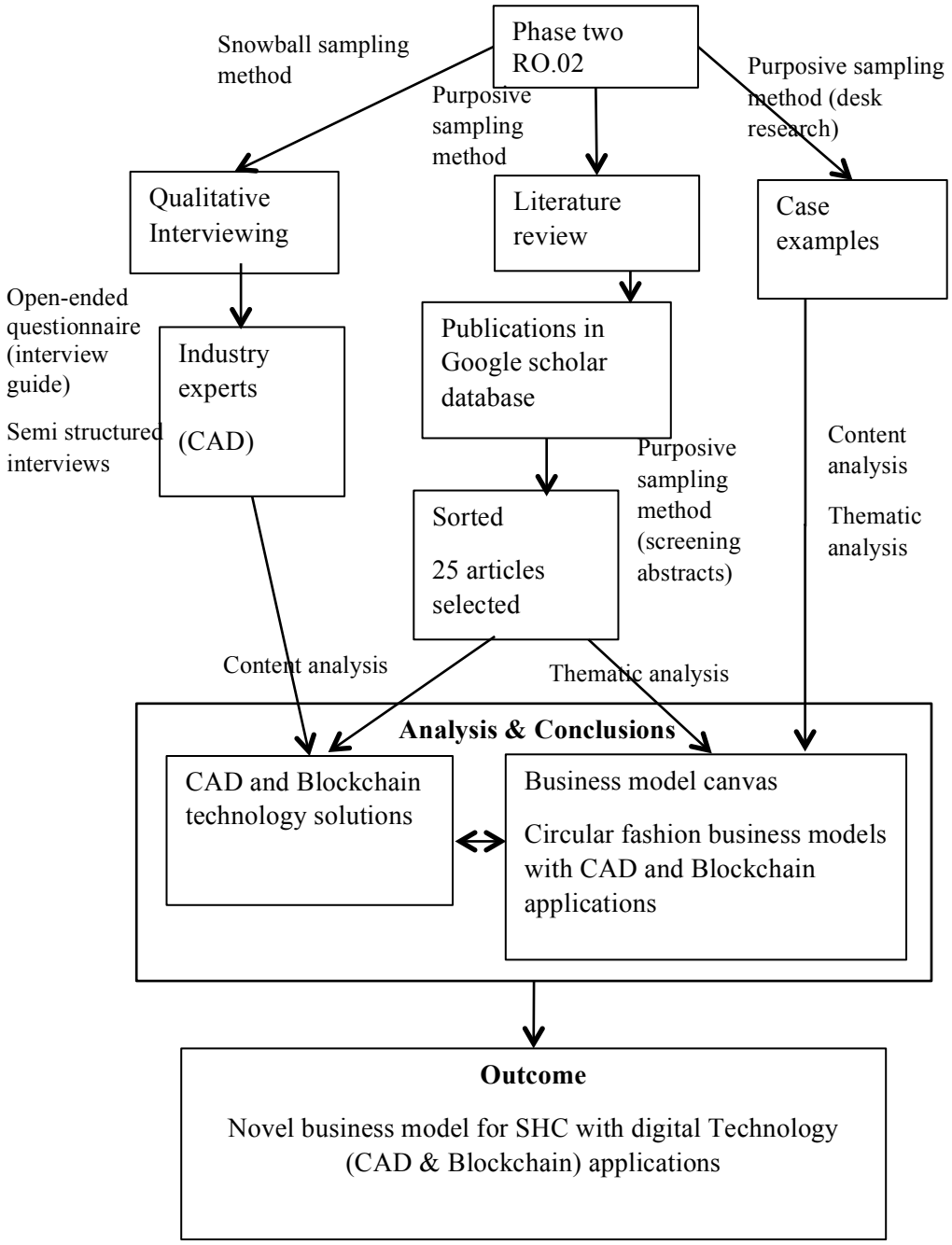


Figure 3-3: Summery of phase two, RO02

3.3.1. Sampling method and survey instruments

The sample included with selected publications from Google scholar database, international case examples on refashioning SHC, and a selected group of experts in fashion industry with knowledge of CAD technology.

Research publications were found through the search terms of "Circular fashion business models", "CAD technology", and "Refashioning". To limit the number of findings into manageable amount, most relevant publications were filtered in using purposive sampling procedure by scanning abstracts. International case examples were found though the review of published literature and a desk research on key research areas such as refashioning SHC with Blockchain technology, CAD – virtualization technologies and circular fashion business models. For the qualitative interviews, the same group of experts as in the phase one, RO 01 was involved, because of the use of same semi-structured open-ended questionnaire to cover both the objectives.

3.3.2. Data analysis methods

Analysis methods of published literature

Analysis of selected literature, case examples and interview recordings were based on the content analysis and thematic analysis. It intended to identify the most suitable business modelling method first through literature survey, and analyse case examples according to the components of the selected business modelling method with a thematic analysis. Initially, a systematic review of literature is done in order to identify and explore circular business models and applications of digital technologies for refashioning through content analysis and thematic analysis. Nine components of the business model canvas were considered as themes for the thematic analysis. The nine (09) themes are partners, activities, resources, value proposition, customer segments, customer relations, channels, cost structure, and revenue streams.

Analysis methods of case examples from the industry

Selected international case examples were analyzed using content analysis and thematic analysis. The analysis consisted with same nine (09) themes as in the components of the business model canvas.

As the output of the second research objective, a new business model and a framework were developed in order to implement CAD and digital technologies for refashioning SHC.

3.4. Methodology for RO3: To test the applicability of CAD technologies in extensions of circular fashion business models.

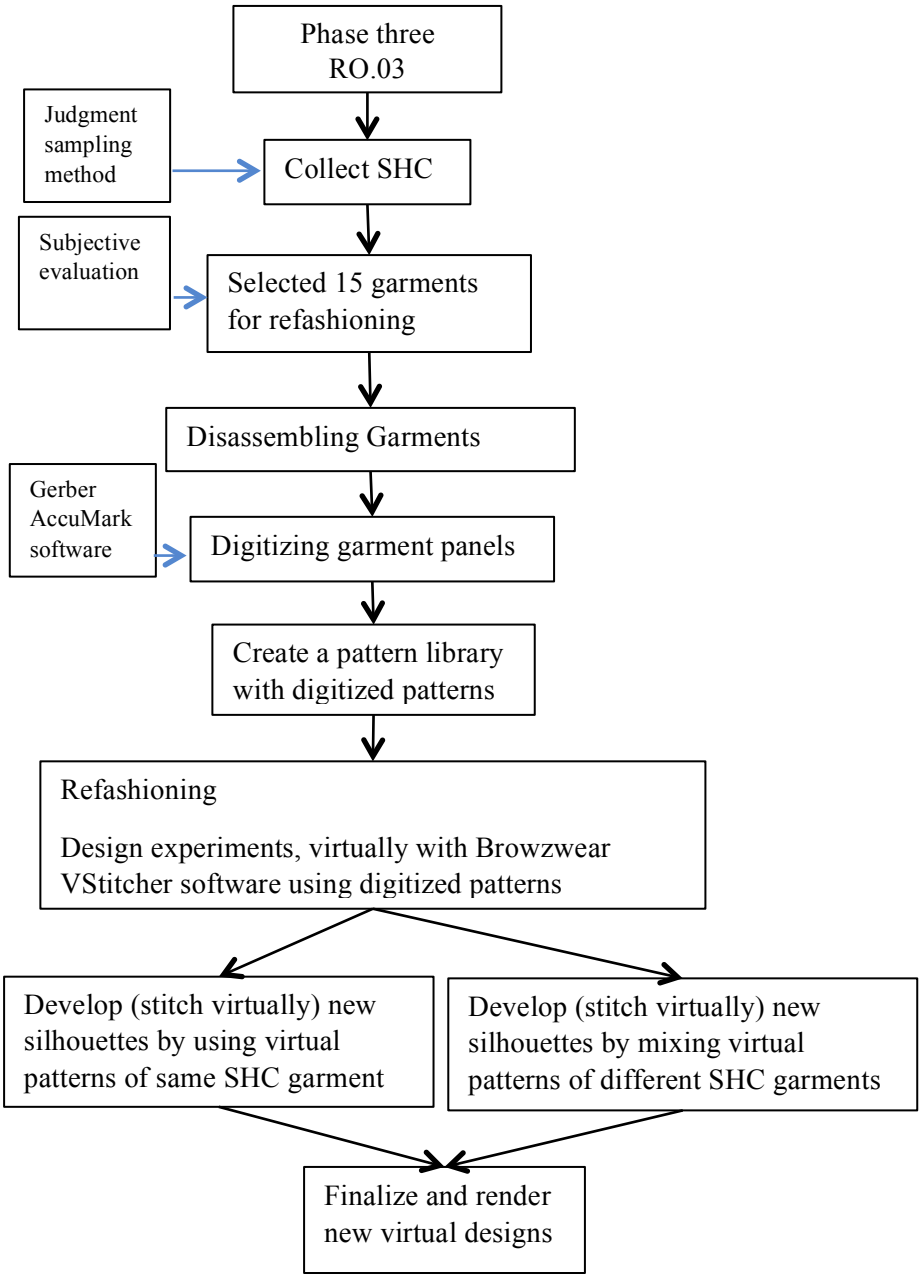


Figure 3-4: Summery of phase three, RO 03

The third objective was planned to test the applicability of CAD patternmaking and 3D virtual prototyping software for proposed technological solutions for circular fashion business model in RO2. Basically this research objective adopted an experimental research approach as illustrated in Figure 3.4.

3.4.1. Sampling method and survey instruments

The sample was based on formal/ office women's wear categories through judgment sampling method based on average lifespan of different garment categories, identified through literature review in section 2.3. The judgment criteria are described in below Table 3.2.

Table 3-2: Judgment criteria for selecting SHC for refashioning

Judgement criteria	**Description**	**Justification**
Season	Spring / Summer	Due to colour and material variety of the Spring summer clothing over autumn winter clothing
Category	Office/ formal/ Smart casual women's wear	Based on the expected lifespan of these garment categories/ styles (around 4-6years) And The basic pattern shapes (garment panels) being used in these garment styles, will be advantageous for the research purpose (refashioning)
Styles	Shirts (blouses), slacks and blazers, dresses, skirts, pants	
Size	(UK) Size 12/ medium size	Based on the availability in the market
SHC category	Grade A/ Branded SHC/ Cream	Assuming the material quality is high due to high ranking of these SHC, and suitable for refashioning into new silhouettes
Current condition of the SHC	SHC with no damages and SHC with minor damages	Since the refashioning process disassembles the garment to obtain the usable material area, the damages could be omitted. Therefore, using both conditions (with and without damages) could expand the range and variety of raw materials

3.4.2. Methodology

The collection of SHC and research experiments are done in five (05) stages.

1. Sourcing SHC

SHC are sourced through online platforms, and by visiting SHC retailers in global context. Then selected 15 garments to be refashioned by subjective evaluation of collected SHC.

2. Manual disassembly

Garments are disassembled and panels were labelled separately

3. Digitising

Garment panels were digitised using Gerber AccuMark software. Here any damaged areas such as cigar burned, colour faded, stained or pilling occurred are marked on the pattern piece virtually while in the digitising process.

4. Recording

Information such as original style, area of the pattern shape, colour and type of material (composition, construction and range of weight, surface texture – based on the availability of information) were planned to feed into the digital information sheet at this stage. Further these data are recorded in a manner of data bank as in the below Figure3.5.

	Garment before disassembling				Disassembled pieces										
Item No	Style	Size	Picture of the style	Special details)	Shape	Picture of the panel	No of pieces available	Area (Cm^2)	Composition	Construction	Weight of the material	Colour	Print details	Other special details	Place stored
1															
2															
3															
4															

Figure 3-5: Suggested format for the data bank

5. Refashioning

In this stage it is planned to develop new silhouettes and styles using virtual pattern pieces. Browzware VStitcher software is used for refashioning. Experiments are planned for refashioning same second-handed garment and mixing panels of different second-handed garments in order to develop new silhouettes. Finalised silhouettes are rendered as new a refashioned women's wear range.

3.5. Ethics and Limitations

This research will conceptualise a new business model and a framework for circular fashion to establish refashioning with CAD and Blockchain technology. Due to difficulties in accessing primary data, such as operating system of retail companies, the research is limited into secondary information in some areas.

Additionally, due to the time limitations, the research tapered in to limited design experiments regarding the RO 03.

4. ANALYSIS, RESULTS AND DISCUSSION

The analysis, results and discussion chapter provide discussion around main findings under the three phases for the three research objectives as mentioned in the methodology. Accordingly following three sections will summarise the outcomes of those three research objectives.

4.1. Phase one

To explore the opportunities in circular fashion industry with reference to the SHC (as mentioned in RO 01), phase one consists with the analysis of literature survey and qualitative interviewing.

4.1.1. Sample characteristics of phase one, RO 01

Sample characteristics of published literature

Total of 56 results emerged in Google scholar database for the selected key words and selected period. Even though it was intended to select only the journal papers for the sample, the selection consisted of three (03) books (Han et al., 2017; Pensupa, 2020; Radhakrishnan, 2020), one (01) report (Von Bahr et al., 2019) and five (05) thesis (Arzaga, 2017; Brink, 2018; Elias, 2020; Fjeldstad, 2017; Putilin, 2019) and eleven (11) journal papers (Casey, 2019; Dissanayake & Sinha, 2015b; Dominique, 2016; Goossensen, 2019; Manshoven, 2019; Norris, 2019; Pal & Gander, 2018; Paras & Curteza, 2018; Richard & Atsuo, 2019; Robbins, 2019; Vehmas et al., 2018) which were selected by screening abstracts and content.

However, it is noted that out of 20 selected articles based on key words, ("Circular fashion" and "Second-hand clothing" or "Refashioning") most of the articles were published recently. It reveals an inclining trend in this researching on this refashioning SHC, as in Figure 4.1. Therefore, it could be noted that this research area is a novel and trendy research area, which will explore the circular fashion industry constructively in future.

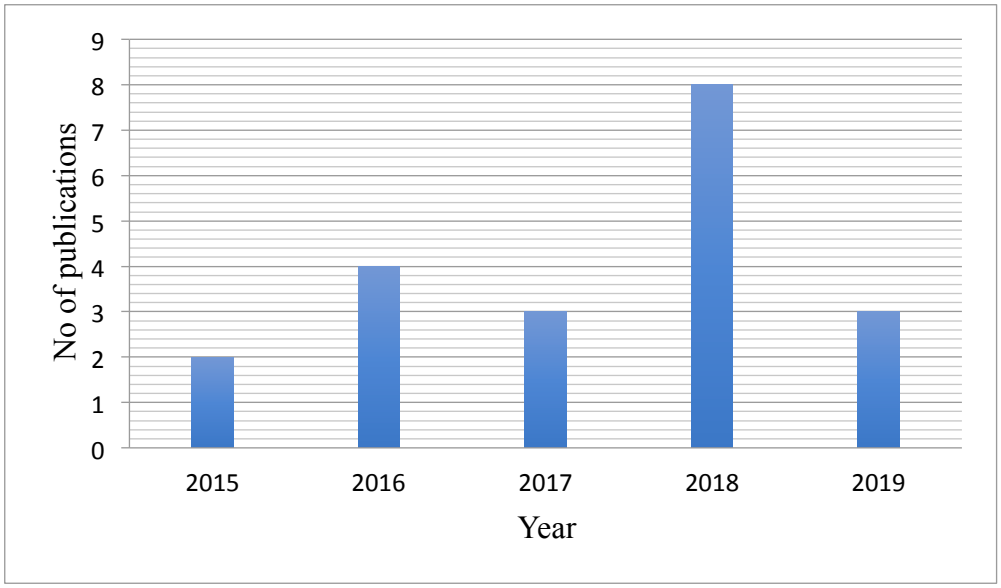


Figure 4-1: No of selected publications for each year

Source: Qualitative data analysis

Further the selected 20 papers were clustered based on the word similarity of those publications as in Figure 4.2, and it revealed that most of the publications were focused on parallel research areas without spreading. That means those papers have discussed much similar topics.

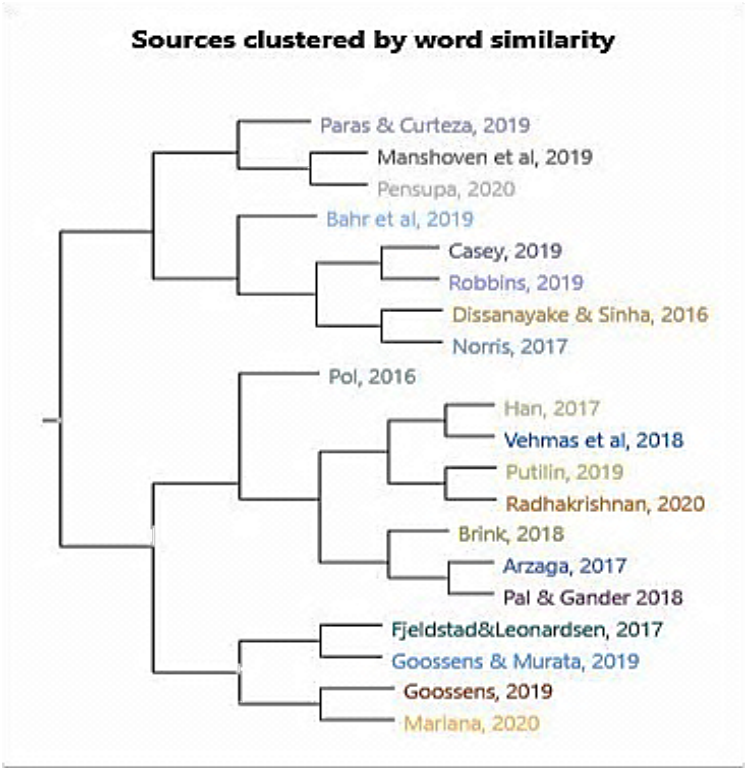


Figure 4-2: Selected 20 journal papers clustered by the word similarity for RO 01

Source: Qualitative data analysis

Sample characteristics of qualitative interviewing

The sample is selected based on snowball sampling method and consisted of 10 professionals from three (03) expertise areas; design, retail and CAD expertise areas in the fashion industry. Importantly, some professionals were expertise in more than one of selected areas as described in below Table 4-1. The same sample was used for the qualitative interviewing in phase two.

Table 4-1: Expertise areas of selected industry experts for qualitative interviewing

Respondent	**Expertise area in Apparel industry**			**Special notes**
	CAD	**Retail and merchandise**	**Designing**	
1	✓			International based business
2	✓			International based business
3	✓			Local and International based business
4	✓		✓	International based business
5		✓		Local and International based business
6			✓	International based business
7		✓		Local and International based business
8		✓	✓	Local and International based business
9	✓		✓	Local business
10		✓		Local business

4.1.2. Analysis of RO 01

4.1.2.1.Opportunities in circular fashion industry for SHC (RO1)

There was much information published about circular fashion concept within last few years as this concept became pervasive in recently. This trending concept within circular economy is identified as an umbrella concept, which covers multitude areas, and creating enormous opportunities for sustainable practices to address social, environmental and economic pressures within fashion industry.

Figure 4-3: Word cloud for word frequency query of coded opportunities in literature

Source: Systematic review of literature

The above word frequency analysis (Figure 4.3) reveals that most of published literature has pay more attention about “recycling” “circular fashion” “waste” as those words are mentioned more frequently, but less attention is paid for applications of, research, novel technologies (CAD/ Blockchain/ IOT) related to SHC industries. Therefore, it could be identified that there is a gap in terms of CAD and other digital technology applications for SHC in existing circular fashion business.

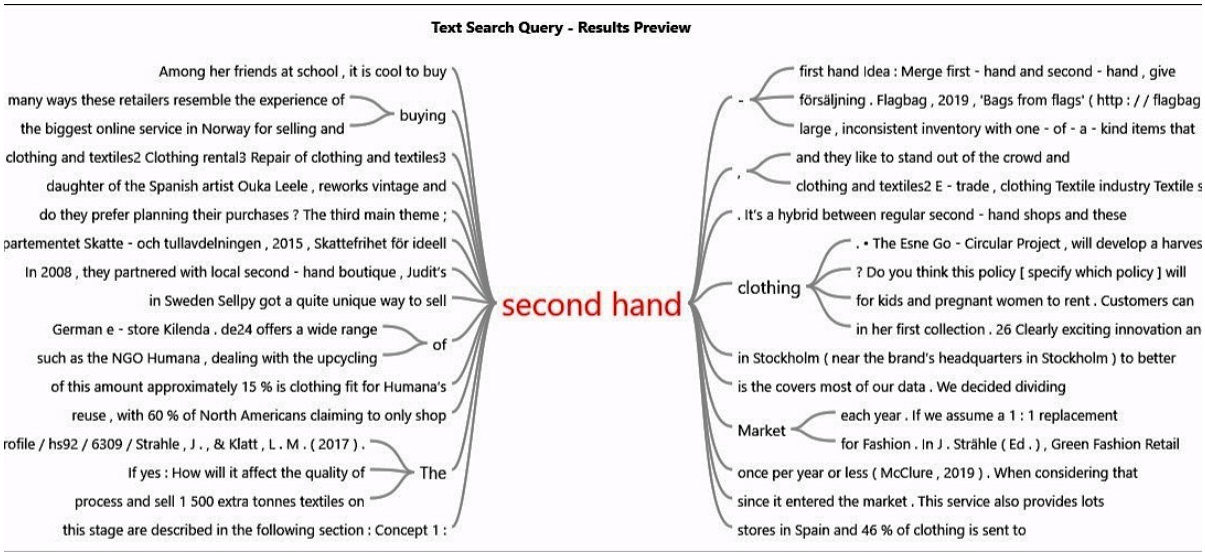


Figure 4-4: Word exploration for "second hand" in published literature

Source: Systematic review of literature

The text search query results as shown in Figure 4.4 and Annexure 2- Figure 1 visualise the content of selected publications regarding SHC, in the circular fashion industry.

Table 4-2: Eight thematic areas for opportunities

Opportunities for SHC within circular fashion (thematic area)	
Theme1	Market expansion with alternative options for SHC related products and new business models
Theme 2	Resource recovery and environmental benefits of circular fashion through recycling SHC
Theme 3	Research and technological advancements focused on circular fashion
Theme 4	Initiatives and trends by fashion industry towards CE and SHC
Theme 5	New employment opportunities in the circular fashion industry (economic factors)
Theme 6	Legislative support towards circularity to encourage SHC businesses
Theme 7	Changing consumer behaviour and attitudes towards circular fashion and second-hand products
Theme 8	Cost effectiveness of the circular fashion options

The information further analysed thematically in to eight themes of opportunities in this chapter. The above Table 4-2 summarise the eight (08) themes of opportunities for SHC in circular fashion industry. And each theme further described based on the information obtained from literature survey and the qualitative interviewing.

Theme 01 - Market expansion with alternative options for SHC related products

This includes opening up new markets and expansion of existing markets for SHC with different strategies and innovative business models within circular fashion industry. Majority of the selected publications were consisting of circular fashion concepts and strategies with more weight and evidencing the global transition into circularity with recycling both post and pre consumer waste. However, there were some circular strategies, which could be expressed as opportunities and drivers for SHC related productions within the disfavoured linear fast fashion strategies. In such strategies, all the stakeholders in the production process will be offered with a strategic value (Alkemade & Suurs, 2012; Berkhout, 2006). Accordingly, the literature review found such strategies i.e. domestic circular economy, slow fashion-followed by local approach, on shore/ near shoring productions and transparent production systems, elongated product lifetime (designing, material selection and production), co-designing, half-way products, modular structures, product take back with rewarding systems, open- source fashion and user centred-service design such as Product Service Systems (PSS) and Product As A Service (PAAS), clothing libraries as new and expanding market opportunities for SHC. At the same time, literature highlights the prevailing options of SHC such as reusing by reconditioning, refurbishing, refashioning or fibre-to-fibre recycling. Further there are other proficiencies such as downcycling with remanufacturing, bundle dyeing, felting, creating yardage, patchwork, making garments from garments. Other than those there are consignment and vintage stores, online re-commerce platforms, renting and leasing, and clothing libraries, subscription schemes, sharing and online garment exchange stocks as shown in the text search query results in Figure 4.5.

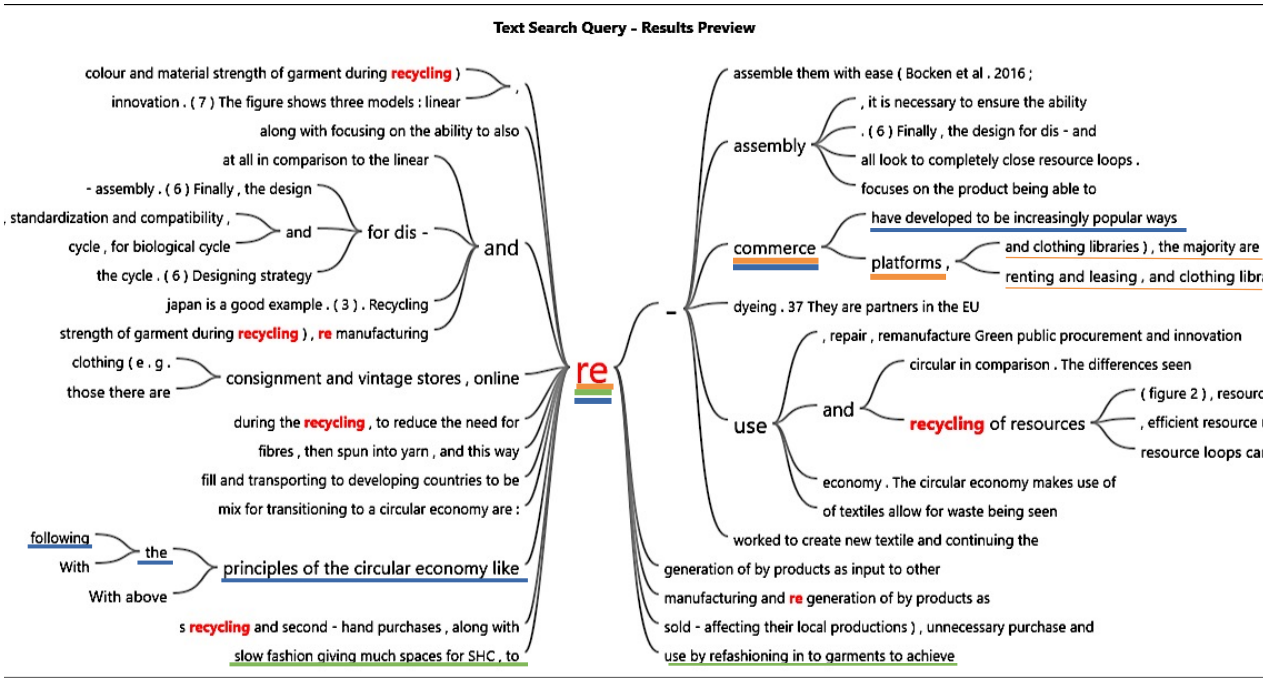


Figure 4-5: Word tree word exploration for Re-services in SHC industry in published literature

Source: Systematic review of literature

Additionally, qualitative interviews also revealed that it is a must need of expanding and uplifting existing approaches and explore new strategies for SHC over the traditional recycling systems by downcycling and exporting to developing countries. Further experts disclosed that the industry is rapidly moving towards circularity from linearity, and there will be new market segmentations and product categorizations prioritising SHC. They further explained existing strategies of SHC categorizations (sorting and grading) for reselling to different market segments, and alternative options such as downcycling into non-wearable products such as rags, braids, cleaning wipes. Also, it has emphasised the fibre-to-fibre recycling too.

Business model innovation (BMI)

Business model innovation (BMI) is another key area identified through publications. Circular economy highly relies on business models that reduce, reuse, recycle and recover materials (Kirchherr et al., 2017). Since fashion is a highly fragmented business there are many innovative and strategic options available for the industry to apply in each level and every aspect to achieve higher competence (Annexure 2- Figure 2).

There are well-known business models currently practised in circular fashion business for SHC. Both the literature and qualitative interviews mentioned those models, such as clothing service based models, subscription models (Nielsen & Gwozdz, 2018), close loop, slow loop and reverse supply chain, vertical integration to access the second life value of their products, PAAS and triple layered business model canvas presented by Joyce & Paquin (2016). However, it seems there are four main strategies that would probably improving SHC businesses i.e. providing a luxury service, localization, a mix of online and offline channels, and partnerships.

Further it is noted that the use of technology applications is boosting the circularity in fashion industry. But, according to the literature, 3D CAD and other digital technologies are limitedly applied in SHC related productions and supply chains. However, both the qualitative interviews and published literature reveal the proficiencies of those technology applications for SHC related business models such as digital supply chains, improved traceability through Blockchain technology and virtualization.

Theme 02: Resource recovery and environmental benefits of circular fashion through refashioning SHC

Environmental soundness of the circular fashion industry has brought attention of many parties such as consumers, government, environmentalists and researchers towards circularity of fashion industry. The review of articles indicated the disfavouring and unsustainable practices of fast fashion such as inappropriate disposal (burning of stock/ land fill and exporting to developing countries to be re sold, which is harming the local productions of those countries), unnecessary purchase and dispose before intended life of the garment, pollution in the backward linkages of the supply chain (Ex - use of pesticides in cotton farms intensive water requirement during the textile production process, and the chemical usage in the textile production process)and carbon footprint of transportation of raw material and garments.

In contrast the socio-economic benefits of recirculation of garments include reduction of use of water, energy and chemicals in the production processes, reduce waste landfilling and greenhouse gas emissions, drawing public attention to promote SHC industry.

The published literature highlighted that the textile waste generally composes of natural fiber, synthetic fiber, and accessories such as plastic and metal scrap. In this context circular fashion employs techniques such as 9R (Refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover), down cycle, resource optimization, loop system (slowing down resource loops, closing resource loops,–and the narrowing of resource loops), circular supply chain, recovery and recycling, building products to last longer, sharing platform and PAAS, allowing for creation of circular growth (Esposito et al. 2018).

In addition to the literature, industry experts also emphasized the current practices of the apparel industry such as green initiatives, waste management systems to avoid harmful environmental impact occurred by the fast fashion. Not only the post-consumer waste, but also pre consumer waste such as dead stocks, off cuts and waste accumulated throughout the production process of fibre to garment and the pollution occurred while in productions should be controlled for a more sustainable and circular fashion future. Further, the policies related to environment protection are summarized in theme six (06).

Theme 03: Research and Technological advancements focused on circular fashion

Research and technology play important role in executing the new visions of many business models in the circular economy. The technology will enable the traditional linear supply chain to become cyclical, with consumers urged to become active participants by providing the raw materials back to businesses. At the same time, since today's customers are very informed, data and information are very essential to make them work toward recirculation of fashion. The literature highlights the need of research and technical inventions for insight in the transition to CE in the fashion industry Figure 4.6 and Figure 4.7. Further, the availability of technologies that facilitate resource optimization (textile sorting and fibre recovery technologies), research on recycling and reuse (preserving the qualities like colour and material strength of garment during recycling), re manufacturing and re generation of by products as input to other processes, green chemistry to elongate material lifecycles and technologies to create more durable materials, development of sharing solutions with superior consumer experience and convenience (Jesus & Mendonça (2018)), digital platforms, and industrial automation technologies are important.

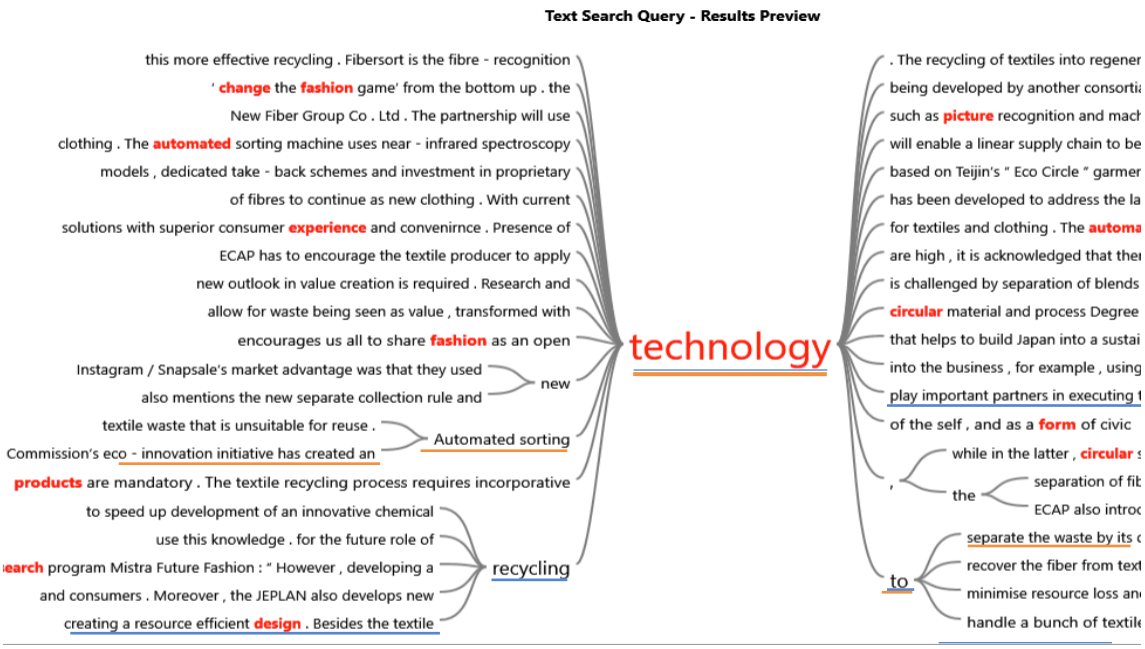


Figure 4-6: Word tree word exploration for "Technology" in published literature

Source: Systematic review of literature

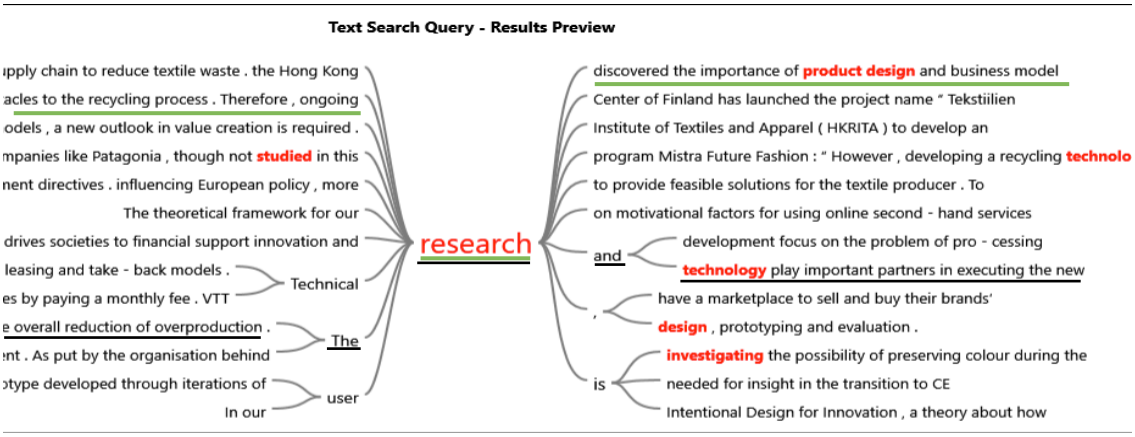


Figure 4-7: Word tree word exploration for "Research" in published literature

Source: Systematic review of literature

The availability of technologies that facilitate resource optimization (textile sorting and fibre recovery technologies), research on recycling and reuse (preserving the qualities like colour and material strength of garment during recycling), remanufacturing and regeneration of by products as input to other processes, green chemistry to elongate material lifecycles and technologies to create more durable materials, development of sharing solutions with superior consumer experience and convenience (De Jesus & Mendonça, 2018), digital platforms, and industrial automation technologies are important in circular fashion business.

Specially industry experts highlighted the importance of the technology applications such as 3D virtualization, CAD, digital supplier relationships to increase the production efficiency while reducing all kinds of waste in the apparel industry. Further they highlighted the prioritised use of CAD technology to manage pre consumer production stages and limited applications in management of post-consumer waste such as refashioning SHC. However, it is revealed that SHC industry is using digital technologies such as mobile apps, e-sales and social e-media for sourcing, retailing and promotions. Therefore, novel technology becomes a critical factor along with consumer and consumption changes to implement the circularity to diminish the traditional linear system.

Theme 04: Initiatives and trends (circular strategies) by fashion industry towards SHC

The duel business model system of Eileen Fisher for extending the existing margins of SHC business by refashioning is one of the best initiatives seen in the industry. Other than that, there are number of brands such as MIA, Re/Done, Christy Dawn, Antiform; arising based on Europe for upcycling by refashioning SHC in niche scale. And also, some mass scale brands like H&M, Patagonia, MUD Jeans, Levi's and Zara are also introduced some approaches like Product take- back, and return rewarding systems to encourage consumers to be mindful towards SHC in circular fashion industry.

The majority of textile and apparel industry today is supplier driven business, hence the industry has a significant role in uplifting the circularity than any other. Both the literature and industry experts discussed the importance of initiatives such as bold marketing and branding, perceived behaviour controls (provide additional information on life span of the garment, environmental benefits, number of washes the garment will take and yet look good, ethical acceptability of product, etc.), branded clothing rental services, post-customer product recycling, introduction of alternatives for cotton such as plant-based biopolymer, marketing sustainability and ecological footprint, innovative chemical recycling technology, incentivize recycling, upcycling with open source platforms (Ex- Pamoyo), and development of retail platforms like eBay and Amazon.

In order to get rid of the negative sentiment of SHC, strategies are suggested such as transparency through the whole loop giving facts and using terms like, “reborn”, “nextile” or the more humoristic “reincarnation” of an old garment. Other aspects to promote circular garments included high quality; some even suggested marketing them as luxury items of the future. In addition, “limited edition” or “priority buying” campaigns were brainstormed to boost interest towards circular clothing. At the same time qualitative emphasized the importance of motivations for people wanting to become part of the cycle and choosing circular garments accordingly such as product take back systems, awareness programmes and (Do It Yourself (DIY) workshops conducted by some brands like Anthropologie.

Theme 05: New employment opportunities in the circular fashion industry (economic factors)

In addition to general roles involved in fashion industry (designers, merchandizers, retailers, seamstresses, etc.), SHC within circular fashion has generated enormous opportunities for new small and medium enterprises to develop in its backward and forward linkages. This range from textile and clothing waste collection, cleaning, sorting, source libraries, e-trade platforms, software development, and textile engineering. However, there are criticisms stating that the popularity of circular fashion will threat the jobs of people engaged in fast fashion. On the other hand, it creates new opportunities in employments and other aspects to incorporate post-consumer waste effectively.

Theme 06: Legislative support towards circularity to encourage SHC businesses

Monitoring and enhancing the system with transparently and effectively functioned systems, careful resource and waste management with planning of product design strategies and resources used become essential. Sustainable development goals, policies by European Union, Green certification, Closing loop action plan by European Commission, zero landfill bound textile in USA, Community Used Clothes Recycling Bank scheme in Hong Kong, and ban of importation of textile waste by China and developing countries in Africa are major movements discussed in the literature and qualitative interviews.

Theme 07: Changing consumer behavior and attitudes towards circular fashion and second-hand products

The social awareness on the ecological footprint of fast fashion has motivated people to use the resources in a sustainable manner. At the same time branding circular fashion as luxury, eco-friendly, sustainable, green and organic products have shown some success (ex - second-hand luxury). Hence the sustainability become as a top concern among generation Y and Z, they affluently tend to reuse SHC and go for alternative options over discarding their SHC. And also, consumers are awaked by the initiatives created by the industry (discussed in Theme 04) towards re-services of SHC.

Theme 08: Cost effectiveness of the circular fashion options

As per the literature cost effectiveness of the circular fashion is because of its energy efficiency and resource optimization characters. It has generated multiple types of values i.e. economic, environmental, social, customer and informational. In addition to that, industry experts highlighted the fact that reusing SHC as a raw material would lessen the fiber-to-fabric production process, where the waste, and pollution occurs mostly.

Narrative analysis of opportunities

The eight (08) themes of opportunities consist the summary of both literature survey and the results of qualitative interviews. However, the devotion/ weight for each theme given by the literature was differed from the qualitative interviews. Therefore, the information obtained from both methods were further analysed using "Nvivo" software. Below Figure 4.8 and figure 4.9 narrate the devotion to each theme by the selected literature and qualitative interviews respectively. Therefore, the literature prioritizes the Resource recovery and environmental benefits of circular fashion through refashioning SHC and Market expansion with alternative options for SHC related products as top opportunities for refashioning SHC. In contrast, the qualitative interviews highlight the Initiatives and trends (circular strategies) by fashion industry towards SHC, Market expansion with alternative options for SHC related products and additionally Research and Technological advancements focused on circular fashion as better opportunities refashioning SHC.

However, due to this contrast, these themes are further analysed with SFAS matrix as in Table 4.3. As discussed in section 3.2.1, the eight (08) thematic areas of opportunities for refashioning SHC are considered as strategic factors. Based on the weighted rate values, strong opportunities are selected through Likert scaling. Factors, which have higher values, are considered as very good opportunities and then good, average and poor opportunities are labelled for factors while the value depreciating gradually.

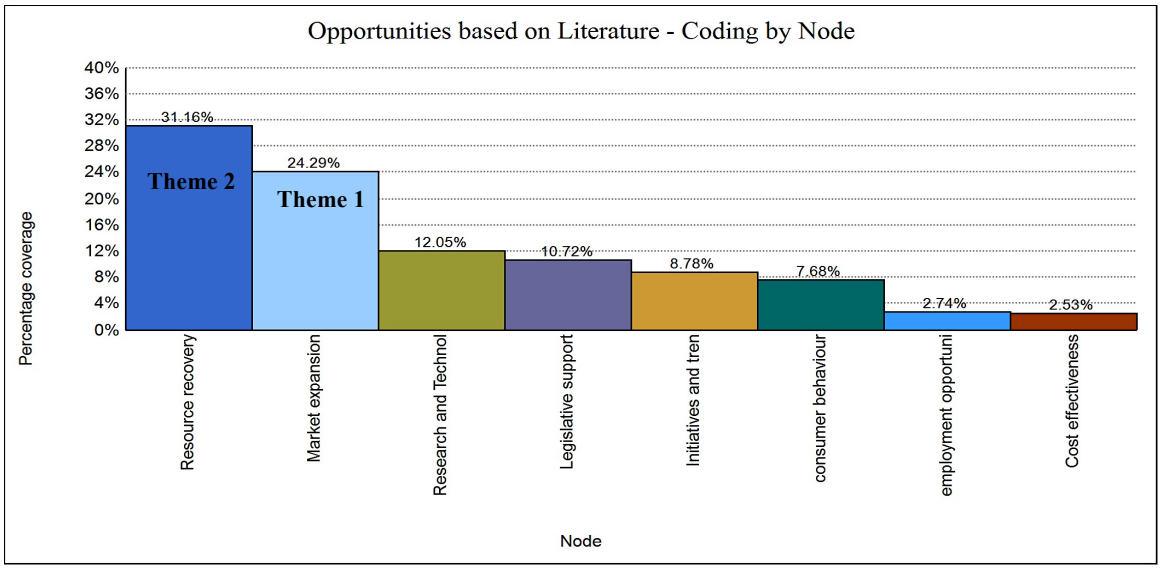


Figure 4-8: Allocated devotion towards (out of all opportunities) each theme of opportunities by published literature as percentage value

Source: Systematic review of literature

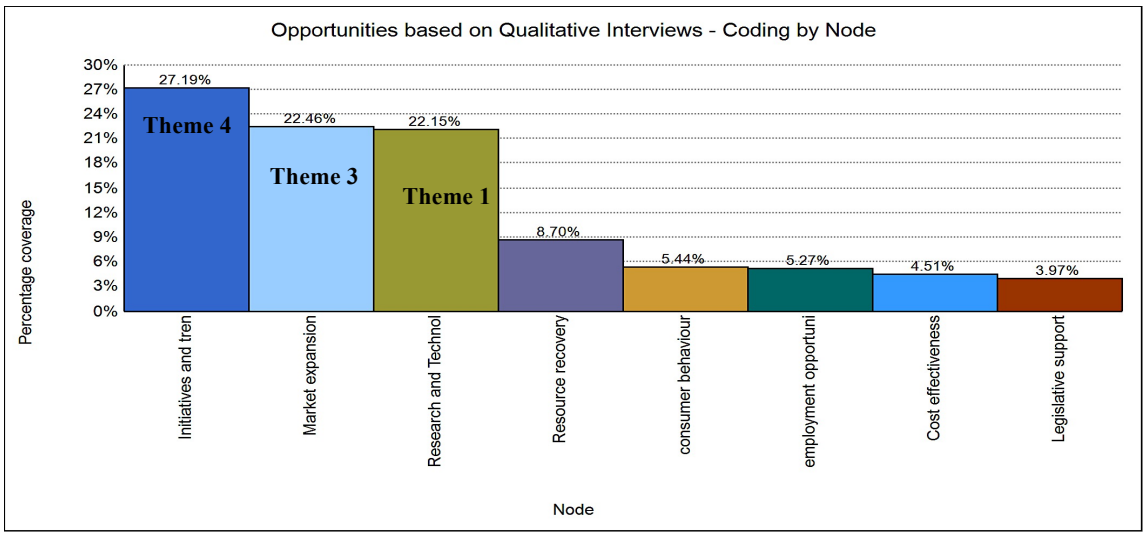


Figure 4-9: Allocated devotion towards (out of all opportunities) each theme of opportunities by qualitative interviews as percentage value

Source: Systematic analysis of qualitative interview results

Table 4-3: Application of SFAS matrix for identified opportunities

Strategic factor	Weight	Rate	Weighted rate	Comments
Market expansion with alternative options for SHC related products and new business models	0.24	3	0.80	Very good opportunity
Resource recovery and environmental benefits of circular fashion through recycling SHC	0.31	1	0.40	Good opportunity
Research and technological advancements focused on circular fashion	0.12	3	0.39	Good opportunity
Initiatives and trends by fashion industry towards CE and SHC	0.09	4	0.35	Average opportunity
New employment opportunities in the circular fashion industry (economic factors)	0.03	1	0.02	
Legislative support towards circularity to encourage SHC businesses	0.11	1	0.06	
Changing consumer behavior and attitudes towards circular fashion and second- hand products	0.08	1	0.06	
Cost effectiveness of the circular fashion options	0.03	1	0.02	
	1.00			

4.1.2.2. Challenges for SHC

In parallel to above analysis on opportunities for SHC, the challenges for SHC in the circular fashion industry also identified through both literature survey and qualitative interviews. That information is further analysed with word frequency queries and thematic analysis using Nvivo 11 software. Figure 4.10 visualise the word frequency of challenges for SHC in circular fashion industry.

Figure 4-10 : Word cloud word exploration for coded challenges in published literature

Source: Systematic review of literature

Accordingly, there were six (06) main challenges, identified by analysing the content of literature and qualitative interview records, which are summarised below in Table 4.4.

Table 4-4: Summery of challenges for SHC within Circular Fashion

Challenges for SHC within circular fashion (thematic area)	
Theme 1	Raw material related challenges regarding SHC
Theme 2	Limited use of technology for production processes of SHC
Theme 3	Competition from fast fashion (virgin clothing)
Theme 4	Limited government and regulatory support
Theme 5	Customer attitudes towards refashioning and reuse SHC
Theme 6	Economic feasibility

The challenges for SHC in circular fashion industry are further explained below under each theme.

Theme 01 –Raw material related challenges regarding SHC

Compared to fast fashion, circular fashion industry got several challenges in sourcing its raw materials. Literature discusses about the quality issues such as impurity, defects, wear & tear, blended fibre along with use of too many seams, trims and material complexity of SHC. Additionally, qualitative interviews highlighted difficulties in bulk sourcing and limited availability as raw material related challenges for refashioning SHC at the moment**.**

Theme 02 –Limited use of technology for production PROCESSES of SHC

The waste management of the textile product is different from other materials because the textile waste is a unique substance. The varied combination of the content requires a separate process of recycling. Because of these complexities, the textile waste management has little attention from the manufacturer and consumer. Specially there are research and development need in applications of current technologies in recycling and resource recovery. Further technical improvements or novel technologies are required for infrastructure for recycling textile waste, upcycling processes, automated sorting systems, communication and transportation in the supply chain, and virtual designing. On the other hand, even though there are many

provisions of current CAD and digital technologies for SHC related creations, it seems less attention of applying those technologies for SHC over virgin or mass clothing productions. In addition to that, CAD experts disclose the potentials of digital technologies to increase efficiency of SHC refashioning in multiple areas such as open-source patterning systems, virtual designing and stakeholder relationships through Blockchain technology.

Theme 03 –Competition from Fast fashion (first-hand clothing)

The dominance of fast fashion with its advance technology applications, cost effectiveness, speed, quick responses to fast moving fashion trends, automated mass production systems and massive supply chains has contributed for mass clothing consumption and increase the demand for fast fashion. China and Hong Kong and the developing countries such as Bangladesh, Sri Lanka, and Vietnam produce a massive amount of low-priced apparel, as an alternative way of creating waste. Further industry experts emphasized the threat from already established fast fashion industry and their endless strategies to provide attractive options to reach customers with new and freshly baked clothing.

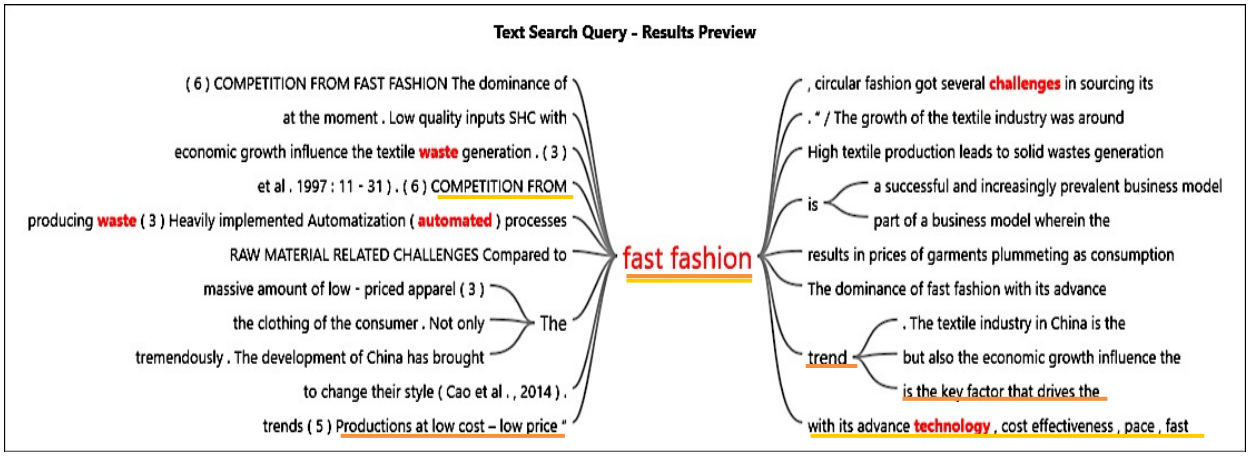


Figure 4-11: Word tree word exploration for "Fast-fashion "challenges in published literature

Source: Systematic review of literature

Theme 04 –Limited government and regulatory support

To encounter the textile waste problem requires the collaboration between the central government, regional government, private sector, consumers, and other. Particularly there is a need for initiatives such as regulations and standards on textile

waste to encourage those who involved in reusing and recycling textile, regulatory action that classifies textile waste as a resource, incentives more brands and retailers to participate in product take-back, reproductions and resale, and easier development of reverse supply chains. Further, by regulations of first-hand clothing manufacturing (i.e. considering material longevity in design stage) is also beneficial for SHC industry.

Theme 05 –Customer attitudes towards refashioning and reuse SHC

Although it is not possible to have complete circularity in today's fashion industry, consumer awareness raising and attitude changes are necessary for its expansion. Literature review shows that consumers' behaviour (preferring novelty and low costs over quality and sustainability, rigidity, and attitude and behavioural gap), negative attitudes (cultural factors, and trust), and misconceptions (cost, health concerns, and not trendy) are limiting the possibilities of circular fashion as well as the SHC.

Theme 06 –Economic feasibility

In terms of economic feasibility reviewed articles have discussed issue due to lower economies of scale (produce less in quantities make average unit cost high), high cost in the recovery process and recycling, high labour intensive nature and cost in collection, transfer and sorting of used clothing, large capital requirement and uncertain return, cheap virgin materials, lack of confidence among the producers, information asymmetry, and pre-mature markets.

Narrative analysis of challenges

Below Figure 4.12 and Figure 4.13 narrate the devotion to each theme of challenges by the selected literature and qualitative interviews respectively. Therefore, the literature prioritizes the "Economic feasibility" and "Limited technological support" as major challenges for refashioning SHC. In contrast, the qualitative interviews highlight the "raw material related challenges", "competition from fast fashion" and also "Limited technological support for SHC related productions" as greater challenges for refashioning SHC.

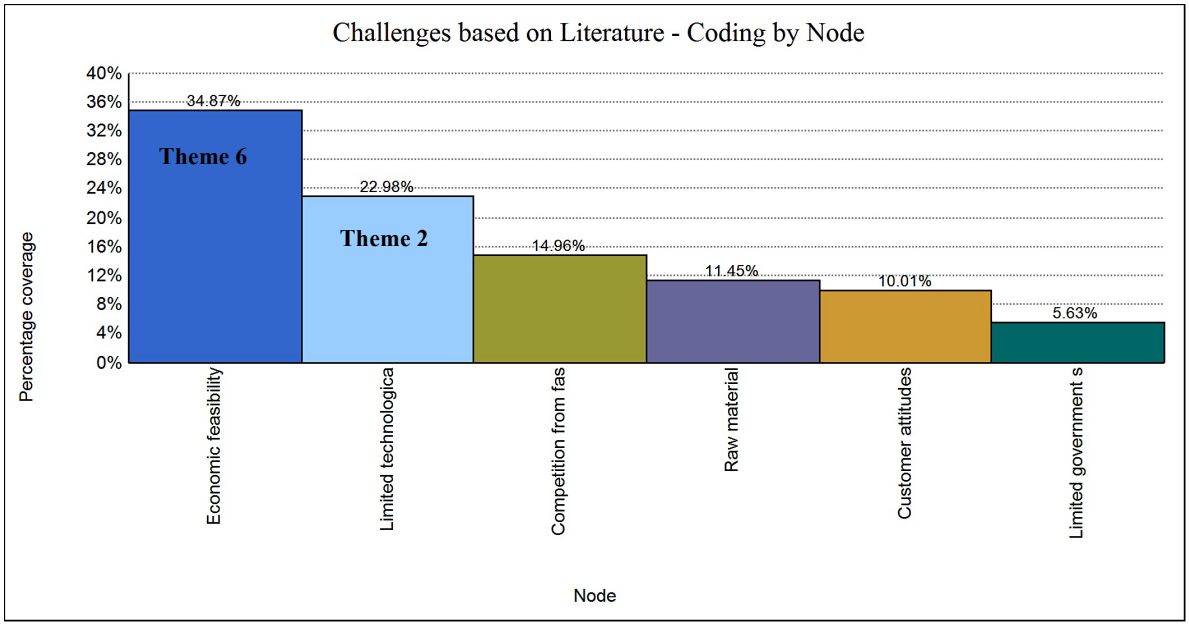


Figure 4-12: Allocated devotion (out of all challenges) for each theme of challenges by published literature as percentage value

Source: Systematic review of literature

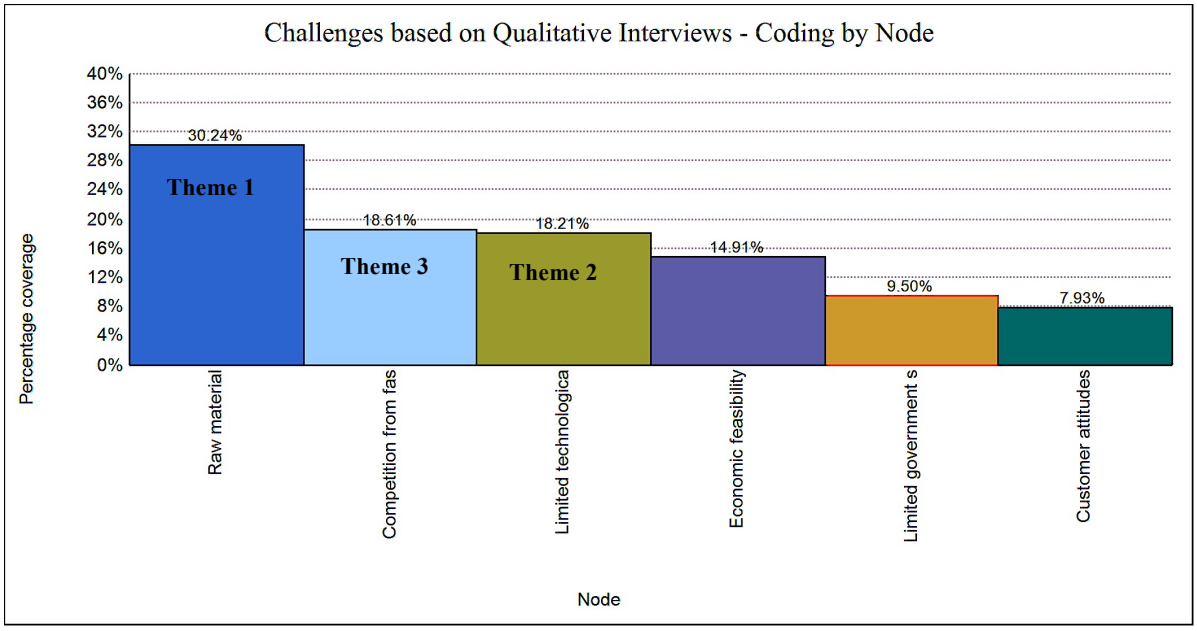


Figure 4-13: Allocated devotion (out of all challenges) for each theme of opportunities by qualitative interviewing as percentage value

Source: Systematic analysis of qualitative interview results

Due to this disparity, these themes are further analysed with SFAS matrix in Table 4.5, as explained in section 3.2.2. The six (06) thematic areas of challenges for refashioning SHC are considered as strategic factors. Based on the values of weighted

rating, key challenges are identified through Likert scaling. Factors, which have higher values, are considered as greater challenges less valued factors are identified as less challenging factors.

Table 4-5: Application of SFAS matrix for identified challenges

Challenges for SHC within circular fashion (thematic area)	**Weight**	**Rate**	**Weighted rating**	**Comments**
Raw material related challenges regarding SHC	0.11	4	0.46	Significant Challenge
LIMITED USE of technology for production PROCESSES of SHC	0.23	2	0.55	Significant Challenge
Competition from fast fashion (virgin clothing)	0.15	2	0.37	Challenge
Limited government and regulatory support	0.06	1	0.07	
Customer attitudes towards refashioning and reuse SHC	0.10	1	0.10	
Economic feasibility	0.35	2	0.69	Greater Challenge
	1.00			

4.1.3. Summary of Phase one, RO 01

Based on above SFAS matrix, four (04) strategic factors for opportunities and four (04) strategic factors for challenges are identified, to be addressed for enhancement of refashioning SHC in circular fashion industry, as summarized in below Table 4-6.

Table 4-6: Identified strategic factors to be catered with the technology

Opportunities	+ Market expansion with alternative options for SHC related products and new business models + Resource recovery and environmental benefits of circular fashion through recycling SHC + Research and technological advancements focused on circular fashion + Initiatives and trends by fashion industry towards CE and SHC
Challenges	− Economic feasibility − Raw material related challenges regarding SHC − LIMITED USE of technology for production PROCESSES of SHC − Competition from fast fashion (virgin clothing)

Through the thematic analysis of literature and qualitative interviews, it is noted that current explorations of refashioning of SHC in the circular fashion businesses are

limited in comparison with the actual existence of such opportunities (Figure 4.14). To bridge that gap, CAD and other technologies could be used profusely as explored in section 4.2.2, Table 4-10.

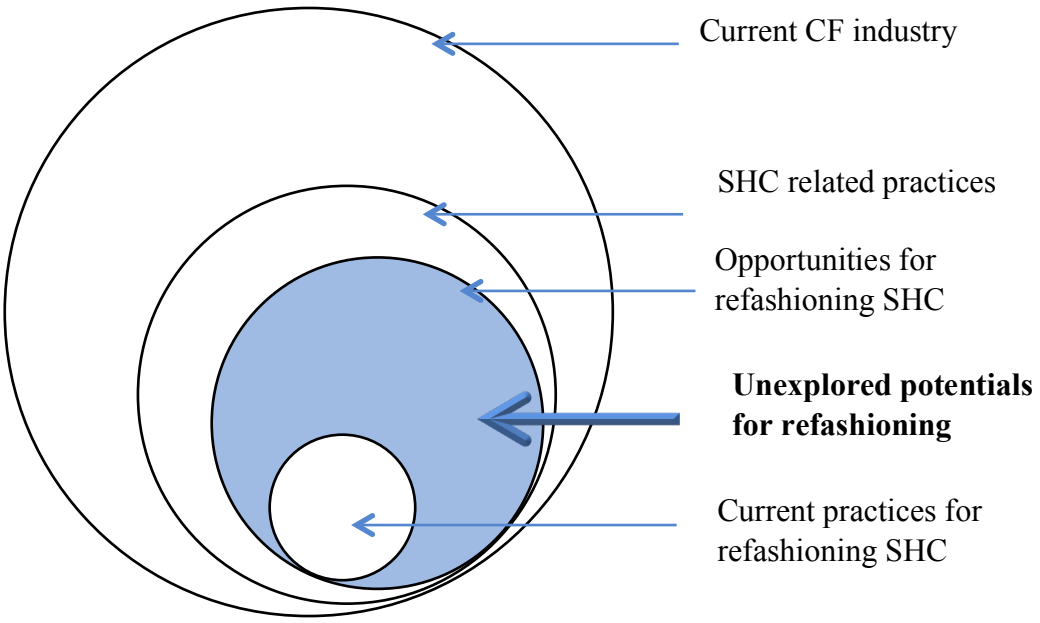


Figure 4-14: Current gap of SHC refashioning practices

4.2. Phase two

Phase two of this research is planned to achieve the second objective "To propose a new business model to implement refashioning SHC, with adaption to circular fashion by enabling digital technologies". Initially, a systematic review of literature is done in order to identify and explore circular business models for SHC. Here, general characteristics of the current circular fashion business models are thoroughly studied. The Business Model Generation (BMG) method with the business model canvas is used as a tool to analyse and summarise information in order to understand all the aspects of current circular business models. Moreover, international case examples for refashioning are followed to gather information and analysed thematically with nine (09) elements of the Business Model canvas, as mentioned in section 4.2.2. Since both literature and case examples reveal lack of technological adoptions in to the SHC refashioning business, section 4.2.3 discusses the possible applications of 2D /3D CAD and other digital technologies, concerning the identified strategic factors, which are identified in phase one, to enhance SHC industry by

enabling such technologies for refashioning. The valued ideas provided by industry experts, were also summarized in this section. Lastly, conceptualise the new business model in section 4.2.3 for a new SHC refashioning business model with explanation to each of the nine components.

4.2.1. Sample characteristics of phase two, RO 02

Sample characteristics of published literature

Total of 155 results emerged in Google scholar database for the selected key words. The refined sample contained 25 publications about circular fashion business models, and CAD and other digital technologies for apparel industry (Bakker et al., 2019; Huisman et al., 2014; Barquet et al., 2013; Berning & Venter, 2015; Haggar, 2010; Jong, Engelaer, & Mendoza, 2015; Joustra, De Jong, & Engelaer, 2013; Lacy et al., 2013; Laubscher & Marinelli, 2014; MacArthur, 2013; MacArthur, 2015; Mentink, 2014; Van Ostaeyen et al., 2013; Parlikad2003; Planing, 2015; Van renswoude et al., 2015; Robinson et al., 2014; Sassower, 2015; Schulze, 2016; Scott, 2017; Sheu, 2014; Subramanian & Gunasekaran, 2015; Talukder, 2017; Tukker, 2004; Tukker & Tischner, 2006).

Sample characteristics of qualitative interviews

The same sample, which used for Phase one for RO-01, is used.

Sample characteristics of case studies

Total of four (04) case examples in refashioning SHC, were selected for the study as described in below Table 4-7. Further Annexure 03 describes about those brands in detail.

Table 4-7: Content analysis summery of selected four case examples

Case Examples in the Industry	Speciality
1. Eileen Fisher	USA based international fashion brand, specialised for selling both new and second-handed/ refashioned clothing of their brand. The brand is practising two business models, one is for selling first-hand clothing for higher prices and the second is for collecting used clothing (of their brand) and resell after refashioning for lower prices. Therefore, the brand sells the same product twice to two different customer segments

2. MIA by Mia Nisbet	Malawi based African fashion label specialised for refashioning SHC for international market. The brand use SHC, which are exported to Africa, as raw materials for its collections with a touch of traditional African crafting techniques. That method harmonises the western impact of imported SHC and local industry with traditional craftsmanship.
3. Beyond Retro - reworked	Vintage retailer with its own up cycled label to refashion SHC. The India based brand produce brand-wise refashioned ranges such as Reworked Nike, Reworked Adidas, Reworked Ralph Lauren, Reworked Disney fir international market
4. Armadio Verde	Online platform for refashioning children's clothing based in France, focusing on technology to enable the drivers of sustainable innovation.

4.2.2. Analysis of Phase two, RO 02

4.2.2.1. Business model development methods

There are diversified methods available for creating business models such as Business model generation (BMG) with business model canvas (Osterwalder & Pigneur, 2010), STOF method (Bouwman et al., 2008), Circular Economy Toolkit (Evans, 2013) etc. However, the mostly practiced method by is BMG with business model canvas as it is a powerful tool, which could be applied in diversified business backgrounds to cover all the stakeholders (Talukder, 2017).

Business model components of the circular business model

The BMG method describes nine components as building blocks of a business model through the business model canvas. The structure of the BMG- business model canvas and detail explanation of each component is mentioned in Annexure 04. Further the characteristics and circular value of each component are summarised in Table 4-8.

Table 4-8: Exploration of nine building blocks of BMG method

Business model component	General characteristics	Application of values of circular economy	Contributing literature
1. Partners	• Cooperative networks • Collaborations with forward and backward supply chain • Relationships with community partners in recycling	• Share • Loop	(Haggar, 2010; Joustra et al., 2013; Renswoude et al., 2015; Robinson et al., 2014; Scott, 2017; Sheu, 2014)
2. Activities	• Optimizing performance • Lobbying • Remanufacturing • Recycling • Technology exchange • Product Design	• Regenerate • Optimize • Loop • Virtualize	(Haggar, 2010; Joustra et al., 2013; Lacy et al., 2013; Laubscher & Marinelli, 2014; Renswoude et al., 2015; Sassower, 2015; Scott, 2017)
3. Resources	• Better-performing materials • Regeneration and restoring of natural capital • Virtualization of materials • Retrieved resources	• Regenerate • Optimize • Loop • Technical cycles	(Haggar, 2010; Planing, 2015; Renswoude et al., 2015; Scott, 2017)
4. Value proposition	• Product-service systems (PSS) • Circular product • Virtual service • Incentives for customers in Take-Back System	• Share • Loop • Optimize • Virtualize	(Bakker et al., 2019; Bakker et al., 2014; Haggar, 2010; Jong et al., 2015; Lacy et al., 2013; Laubscher & Marinelli, 2014; Parlikad et al., 2003; Planing, 2015; Renswoude et al., 2015; Scott, 2017; Tukker, 2004; Tukker & Tischner, 2006)
5. Customer segments	• Identify possible customers • Change or move in to new customers • Educate customers or prior changes of customer habits and behavior	• Optimize	(Bakker et al., 2019; Corvellec & Stål, 2019)
6. Customer relations	• On demand manufacturing (customized options and communication) • Post retail responsibilities • Customer vote and feedbacks • Customer awareness workshops	• Share • Virtualize	(Lacy et al., 2013; Renswoude et al., 2015)

	• Social-marketing strategies		
7. Channels	• Virtual communication and virtual design channels • Near shore production facilities	• Virtualize	(MacArthur, 2015; Scott, 2017; Talukder, 2017b)
8. Cost structure	• Evaluation criteria • Value of incentives for customers • Guidelines to account the cost of material flow	• Regenerate • Optimize • Loop • Exchange	(Barquet et al., 2013; Berning & Venter, 2015; Laubscher & Marinelli, 2014; Mentink, 2014; Subramanian & Gunasekaran, 2015)
9. Revenue streams	• Input-based • Availability based • Usage-based • Performance-based • Value of retrieved resources	• Share • Loop	(Ostaeyen et al., 2013; Renswoude et al., 2015; Tukker & Tischner, 2006)

4.2.2.2. Case examples for circular fashion

Four (04) international case examples have been conducted on companies/ brands, which are engaged in upcycling SHC by refashioning in the circular fashion industry. Mainly the business structure of these brands, were explored through business model components as summarized in below Table 4-9.

Table 4-9: Key characteristics of SHC related CF business models of different companies

Business model components	**Brands**			
	Eileen Fisher	**MIA by Mia Nisbet**	**Beyond Retro - reworked**	**Armadio Verde**
1. Partners	• Collaborations • Partnerships	• Partnerships with SHC agents	• Strategic sourcing partnerships	• Collaborations
2. Activities	• Virgin cloth productions • Collecting and reselling SHC • Recycling by refashioning	• Sorting • Cleaning • Refashioning	• Resell • Sorting, deconstruction and reconstruction	• Exchange • Resource recovery • Technological innovations
3. Resources	• On shore and Near shore production facilities • Retail network	• Local crafting techniques • Local producers • E- platforms	• Trained employee • Production facilities • Clothing crating techniques	• Technology

4. Value proposition	• Environmental sustainability, human rights, women and girls empowerment	• Harmonizing the disfavored imported SHC dominate with local crafts by refashioning	• Brand wise reworked collections with meaningful refashioning	• Take back system • Customer education
5. Customer segments	• Premium segments • Affluent young segments	• Ethical, affluent, sustainability conscious customers all over the world for women's wear	• Ethical, affluent customers who seeks value for money	
6. Customer relations	• Post retail responsibilities • Customer reward systems	• E- channels for customer relationships while educating customers	• Proper communication and providing easy access to production process through the website for a sense of transparency	• Collaborations • Memberships
7. Channels	• Supplier and retail networks • Customer network for take-back programme for used EF clothing	• Retail network • E-platforms	• E-platforms • Worldwide retail network	• E-platforms
8. Cost structure	• Dual business models for virgin products and recycled products	• Sourcing, sorting and production costs • Cost of skilled workmanship and time	• Sourcing, sorting, storing costs • Logistics and transportation costs • Production cost	
9. Revenue streams	• Sells products twice (virgin product and same product as SHC)	• Price setting for higher level of workmanships • Revenue reinvesting for employee training and infrastructure	• Lower price setting for reworked, yet branded collections	• Direct sales of sustainable products

4.2.2.3. Current Circular fashion business model

Summarizing existing SHC businesses in to business model canvas and identifying technology related limitations

Based on the literature review and case examples, current practices of global SHC industry were summarised into general structure and presented with in the business model canvas in below Figure 4.15.

		Designed for:	*Designed by:*	*Date:*	*Version:*
Business Model Canvas					

Key Partners	**Key Activities**	**Value Propositions**	**Customer Relationships**	**Customer Segments**
• SHC collecting agents • Loyal customer base for SHC take back system • Sorting and cleaning firms • Local producers (sewing, crafting)	• Inspection • Sorting / cleaning • Stocking • Disassembling • Reproducing • Valuation and pricing • Retails • Awareness and DIY workshops	• Customers can get unique designs, branded items for lower prices • Zero, minimum waste processes and minimum environmental impact • Way of keeping SHC away from burning or landfilling • Encouraging consumers towards circularity • Empowering local mini scale producers	• Websites for easy access and communication • Maintain loyalty, rewarding systems • Attract affluent young crowd by offering second-hand, but luxury	• Price conscious ethical consumer segments • Environmentally concerned segments • Affluent young segments • Adults in luxury customer segments who have disposable money and fashion freedom
	Key Resources		**Channels**	
	• Employees – skilled workforce • Couture crafting techniques • Local production houses		• On line through websites with home delivery • Offline through flagship stores • Advertising through social media, fashion shows	

Cost Structure	**Revenue Streams**
• Raw material cost (SHC) • Sorting, cleaning, stocking, other logistics and transporting costs • Cost of higher level of workmanship • Cost of training, research and building infrastructure	• Pricing with profit margins • Donations

Figure 4-15: Summarizing general structure of current business models in circular fashion

It revealed the gaps and shortages in application of CAD and other digital technologies for each component of the business model and those identifies gaps are summarized in Figure 4.16.

Identified gaps of current SHC business models in terms of CAD and Blockchain technology

<table>
<tr><td></td><td></td><td>Designed for:</td><td>Designed by:</td><td>Date:</td><td>Version:</td></tr>
<tr><td colspan="2">Business Model Canvas</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Key Partners</td><td>Key Activities</td><td>Value Propositions</td><td colspan="2">Customer Relationships</td><td>Customer Segments</td></tr>
<tr><td rowspan="3">• Lacking long term/ well established strategic partnerships for virtual sourcing, productions.
• Poor post retail responsibilities- tracking records.
• Less traceability</td><td>• Prioritizing niche levels over expanding market with new technology to reach more customers
• Higher level of waste (time and material) due to manual operations
• Lack of virtual prototyping
• Less availability/ information in the market
• Poor reproducibility of products (designs) due to lack of virtual stocks/ records</td><td rowspan="3">• Value depreciating mindset of both producer and the customer</td><td colspan="2">• Lack of properly established network to maintain continuous customer relationships such as feedback systems, DIY awareness online workshops.</td><td rowspan="3">• Less attention/ research to forming new customer segments over targeting luxury niche segments.</td></tr>
<tr><td>Key Resources</td><td colspan="2">Channels</td></tr>
<tr><td>• Lack of new technology applications for expanded productions</td><td colspan="2">• Weak supplier network due to information limitations
• Less promotions</td></tr>
<tr><td colspan="3">Cost Structure</td><td colspan="3">Revenue Streams</td></tr>
<tr><td colspan="3">• Lack of technology applications in productions instead of hand crafting techniques</td><td colspan="3"></td></tr>
</table>

Figure 4-16: Identified gaps in technology applications in circular fashion business model

4.2.2.4. Existing CAD and digital technology applications for different stages of apparel productions

The literature review and the qualitative interviews of industry experts revealed current CAD and Blockchain applications and in different stages in apparel production process. Specially, industry experts explained the new possibilities of such technologies that could be applied in to refashioning process to enhance the circularity of the fashion industry. The current CAD applications and their potentials for refashioning SHC are summarized in Table 4-10.

Table 4-10: Categorization of CAD systems based on the usage

Stages of fashion production process	**Names of currently practiced CAD software**	**Current Use**	**Potentials of CAD towards circularity**
CAD for fabric design	• Adobe illustrator • Weave it • Tuka-Studio from Tukatech • Textronic • Pro weave from	• Surface (print, embroidery) designing and • Structural (weave and knit) designing • Plan complex weave structures, color compositions • Generate an infinite number of virtual design variations of fabric • Documentation	• Yardage (fabric) development from fabric/ trim waste
CAD for garment design	• Adobe Photoshop • Adobe Illustrator • Corel Draw • Auto CAD • Smart Designer • Modern High Tech • Telestia Creator • VStitcher by Browzwear	• Design and visualise vivid aspect of garments such as the shape, silhouette, colour, proportions of the garment etc. • Visualising embellishments • Varieties of looks (range planning) • Documentation	CAD applications for refashioning SHC
CAD for pattern making	• Lectra • Accumark Gerber • O/DEV by Optitex • Tuks CAD by Tukatech • Gemini CAD	• User friendly PDS • Digitizing, drafting and grading • Measurements by body scanning • Pattern unwrapping (from avatar) and 3D to 2D reverse engineering with higher level of accuracy • Print, embellishment placements through 2d/3d visual effects • Virtual fitting for problem	• Pattern Sharing Options for Post Production Operations (Refashioning) • Collaborative Pattern Library Options

		solving • Accurate marker marking options • Documentation	
CAD for Productions	• Integrated CAD by Gerber Technology • Modaris by Lectra • GT CAD software • O/PRO by Optitex • Smartmarket by Tukatech • Richpeace	• CAD synchronised with Automated Production Systems • Process Innovations • Documentation	• Physical garment to virtual pattern conversion options • Virtual disassembling of garments • Plan garment operation breakdown through CAD
CAD for Retail Promotions	• Dressing Room APP by GAP • 3D Mirror/ Virtual Mirror	• 3D simulations • Virtual stocks • Mass Customization communication and documentation	• Virtual sales • On demand manufacturing

Source: Literature review and Qualitative interviews

4.2.3. Developing new business model for refashioning SHC

Main outcome of this research is to introduce a novel circular fashion business model enabling digital technologies to strengthen the refashion business. Accordingly, research proposes suggestions enhance the circular fashion business model to a certain extent with the CAD and Digital applications. Table 4-11 below elaborates on how the digital technology can be applied into strategic factors identified in phase one, RO1. With the analysis in Table 4-12, the research proposes new additions to existing circular fashion business model in order to address technology related limitations identified in section 4.2.3. Finally, all the suggestions are summarized into business model canvas in figure 4.21, as a new business model. The suggested CAD applications will be tested through an experimental research in phase three, RO03.

Table 4-11: Suggestions to address key strategic factors identified in phase one - RO01, with digital technology

Impact	Strategic factor	Suggestions with CAD and Digital technologies
Opportunities	• Market expansion with alternative options for SHC related products and new business models	Enhance productions and upgrade business models with CAD and other digital applications
	• Resource recovery and environmental benefits of circular fashion through recycling SHC	Encourage and aware consumers towards cyclical use of goods and build/ maintain strong relationships with customers providing more traceability with Blockchain technologies
	• Research and technological advancements focused on circular fashion	New adoptions of existing technology (2D & 3D CAD) for refashioning SHC. Applications of digital technology (Blockchain) for supply chain managements and partnerships for SHC industry Use of advanced technology will skip the limitations in sourcing, sorting, storing as well as prototyping and virtualisation
	• Initiatives and trends by fashion industry towards CE and SHC	More transparency and obtain feedbacks from customers through Blockchain technology
Challenges	• Economic feasibility	Minimise production costs and waste with CAD Applications Expand productions and sales promotions with CAD and other digital applications
	• Raw material related challenges regarding SHC	Application of Blockchain technology to track SHC materials and source pattern of garment panels with barcode system
	• LIMITED USE of technology for production PROCESSES of SHC	More use of CAD and other digital applications for productions and retails
	• Competition from fast fashion (virgin clothing)	The main competition of fast fashion is the production cost and speed. But cost of productions could be reduced by substituting virgin textiles by SHC materials Offer multiple virtual choices to customer for on demand manufacturing, to reduce multiple types of waste instead of offering multiple productions to choose for fairly cheap quality. Assured durability and high quality crafting techniques instead of low cost productions Temporary owning concepts instead of filling personal wardrobe with unwanted stuff.

Table 4-12: Suggesting CAD and digital technology applications to address limitations current circular fashion business model

Business model component	**Applications of Technology (CAD /and other Digital)**	**Application of values of circular economy**
1. Partners	• Digital platforms (IOT and Blockchain Technology) for Cooperative networks, Collaborations and Strategic sourcing partnerships • E-platforms for sourcing/ open sourced patterns	• Share • Loop • Optimize
2. Activities	• 2D and 3D CAD applications in designing/ refashioning stages for virtualization of products • 3D CAD applications to maintain virtual stocks • Blockchain technology for sourcing SHC material • 2D and 3D CAD technologies to expanded, faster productions • Minimize waste by avoiding physical prototypes, overproduction and material waste • Offer customized choices for customers through 3D CAD and more transparency through Blockchain technologies	• Regenerate • Reuse • Share • Optimize • Loop • Virtualize • Exchange • Minimise waste
3. Resources	• 2D and 3D CAD technologies to replace manual processes such as sketching, patterning, prototyping) • Digital and CAD technologies to maintain virtual fashion libraries and material stocks of SHC related data • Digital technologies for advanced communication systems with suppliers and customers	• Optimize • Loop • Virtualize
4. Value proposition	• Digital Technologies to maintain communication systems for post sales responsibilities • Digital Technologies to consumer awareness programms and DIY workshops • 3D Virtual services for customized products • Incentives for customers in Take-Back System	• Share • Loop • Virtualize
5. Customer segments	• Target technology oriented customer segments such as millennial and Gen-Z • Segmenting and identifying potential customer segments through digital data recording.	• Optimize
6. Customer relations	• Develop user friendly Digital applications such as virtual mirror to convince the customer and to reach possible new customer segments	• Optimize • Loop • Virtualize • Share

	• Digital data management systems to obtain customer feedbacks and post retail relationships • Introduce new branding strategies such as "nextile" "Reborn"	
7. Channels	• CAD and Digital technologies to maintain virtual supplies such as SHC sourcing information, CAD patterns • E- platforms for custom orders	• Virtualize • Digitalize
8. Cost structure	• Improve production efficiency using CAD systems • Value addition through CAD technologies • Invest for advanced technology	• Regenerate • Optimize • Virtualize • Loop • Exchange
9. Revenue streams	• Value additions through virtualization	• Share • Loop • Virtualize

The above Table 4-12 elaborates, how CAD and other digital technology applications such as Blockchain could be applied in to the nine (09) components of the business model canvas in order to develop value added decentralized system for circular fashion industry, focusing on SHC. The suggested technology applications for each of nine (09) business model component are further described below.

- **Partners**

Cooperative networks play a vital role in SHC business, in order to source raw materials, obtain the digital patterns of SHC (without unraveling and digitizing SHC garment panels) and to obtain SHC details such as material composition, construction etc. It is possible to develop trade agreements with first-hand garment manufacturers to obtain CAD patterns and other required information of garments once they found as SHC. Further a barcode system could also be used as non-removable tags attached in to garments in their first-hand production stages, with the purpose of identifying garments and obtain required information in second-hand productions. Blockchain technology could be occupied in this context for tracing the history of garment. Out sourcing productions with the economies of scale, such as utilizing labor specializations in different countries for crafting, textile finishes etc., is another advantage that can manage through "strategic sourcing partnerships". Further this decentralized production system could be managed with Blockchain technology.

Collaborative partnerships among garment manufacturers as well as other relevant industries in the supply chain are also part of this new/extended business model. Particularly fashion industry needs to build collaborations with IT and logistic industry partners to manage virtual supply chains. E-platforms such as thrift, and e-bay could be useful here for material sourcing as well as retails. Further, better partnerships should be maintained with customers as suppliers of raw materials (SHC), and the process could be traced through Blockchain technology and IOT technology. Additionally, these digital technologies could be used to communicate with customers to educate and obtain feedbacks and for research developments.

- **Activities**

Using advanced technologies could enhance the current activities involved in the SHC production process such as sorting, storing, disassembling, prototyping. For example, collection and sorting of SHC materials could be enhanced by systematic methods with barcode systems as described in above. Use of CAD technologies for refashioning SHC in product virtualization, virtual designing and pattern making, and prototyping is advantageous in many ways to the industry. It will reduce the physical waste of defects (fitting and construction) and speedup the productions and postproduction activities as well. Further, on demand manufacturing and direct customer services systems are getting reinforced by the advanced technology.

- **Resources**

The 2D/ 3D CAD and Blockchain technologies will contribute the resource base of the circular fashion business model with virtualize designing and production environment (trial and error problem identifications) and well managed de centralized production systems. CAD technologies will use the virtual materials in best possible ways as substitutes to actual materials to reduce material waste and cost. At the same time, it provides numerous ways to differentiate and diversify products in an accurate and efficient way. Source libraries are another virtual resource comes with Blockchain technologies to maintain digital records for sourcing. Additionally, e-platforms will make all the communications in the production supply chain easy.

- **Value proposition**

CAD technology adoptions along with virtualization provides provisions to create unique designs and let consumers to own and experience value added products.

With the use of digital (Blockchain) technologies, the new business model will help the industry to maintain transparency of their entire production process which leads to fair trading, sustainability, and it will be beneficial to the company in marketing, customer subscriptions and expansion leads to profits. The massive environmental benefit by occupying apparel waste by creating second life cycle is highly accounts for the sustainability of the industry.

- **Customer segments**

CAD and digital technologies will extend the current customer base of the circular fashion business, which is limited to a niche scale. The options provided by CAD and Blockchain technologies will attract new diversified customers/ segments by promoting numerous design possibilities, sales options and by providing traceability of production process. Therefore, it is beneficial to identify potential market segments i.e. millennials who are trendy, sustainability minded or adults who have disposable money, willing to pay more for a new fashion experience.

- **Customer relations**

It is possible to maintain customer relationships with digital technologies to obtain feedbacks for product and process improvements. Virtualization of production processes will convince, communicate and educate customers. CAD technology applications like virtual mirror, and virtual dressing room will retain customers by facilitating their buying decisions. Further post retail responsibilities will maintain through Blockchain technology.

- **Channels**

Decentralized digital supply chains, maintained through Blockchain technology will skip physical stocks, storing and transportation costs. And increased traceability and communication through such technologies will expand and strengthen the forward linkages of the apparel supply chain.

- **Cost structure**

The new business model is prioritizing key aspects such as material optimization through CAD technology, replacing manual operations through improved production systems and supply chains, reducing physical waste (storing, transporting) by virtualization and digital supply chain. Accordingly, the product and

process value addition through Blockchain and CAD technology leads high quality output, which will impact on costing of final products.

- **Revenue streams**

The proposed technology applications will impair revenue streams if the business model in few paths,

  - Input based – use Blockchain technology for sourcing digital patterns of garment panels, and use of CAD/ virtualization technology for productions and sales promotions
  - Availability based – maintaining digital libraries/ digital supply chains
  - Demand based – on demand productions by prioritizing customers, educating and expanding loyal customer base
  - Performance-based – speeding up productions / sustainable practices/ substituting virgin materials
  - Value of retrieved resources – keeping used clothes away from waste/ land filling by re using them as raw materials for refashioning garments.

Conceptualizing new business model to enable digital technology for refashioning SHC

Based on the research finding and analysis in phase one and phase two, the novel business model has compiled with the business model canvas for refashioning SHC in circular fashion industry as in below Figure 4.17.

<table>
<tr><th colspan="5">Business Model Canvas</th></tr>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">• First-hand clothing manufacturers and brands for sourcing libraries
• IT / CAD software agents
• Customers for product returns and sales
• SHC agents for branded/ sorted clothing</td>
<td>• Inspection
• Sorting / cleaning
• Stocking
• Disassembling
• Reproducing
• Virtualization (productions/ sales/ marketing)
• Valuation and pricing
• Retails
• Awareness programmes and DIY workshops
• Research and training</td>
<td rowspan="3">• Customers can get unique designs, branded items for lower prices
• Zero, minimum waste processes and minimum environmental impact
• Way of keeping SHC away from burning or landfilling
• Encouraging consumers towards circularity
• Empowering local mini scale producers</td>
<td>• Websites for easy access and communication
• Maintain loyalty, rewarding systems
• Customer feedback systems
• Attract affluent young crowd by offering second-hand luxury
• Post retail responsibilities with increased traceability</td>
<td rowspan="3">• Price conscious ethical consumer segments
• Environmentally conscious segments
• Affluent young segments (Gen Z and Millennials)
• Adults in luxury customer segments</td>
</tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr>
<td>• Employees – skilled workforce
• Couture crafting techniques
• Virtual process from material to customer
• Digital supply chain</td>
<td>• Online merchandise through websites with home delivery
• Offline supplies through flagship stores
• Advertising through social media, fashion shows</td>
</tr>
<tr><th colspan="3">Cost Structure</th><th colspan="2">Revenue Streams</th></tr>
<tr><td colspan="3">• Raw material cost (SHC)
• Sorting, cleaning, stocking, other logistics and transporting costs
• Cost of higher level of workmanship
• Cost of training, research and building infrastructure</td><td colspan="2">• Pricing with profit margins
• Donations</td></tr>
</table>

Figure 4-17: Proposed new business model

4.2.4. Developing new framework for the new business model for refashioning SHC

Based on the new business model, new framework is developed for refashioning SHC as shown in Figure 4.18. Further, Figure 4.19 explains the involvement of CAD and other digital technologies for different stages of refashioning process in order to enhance circular fashion business for refashioning.

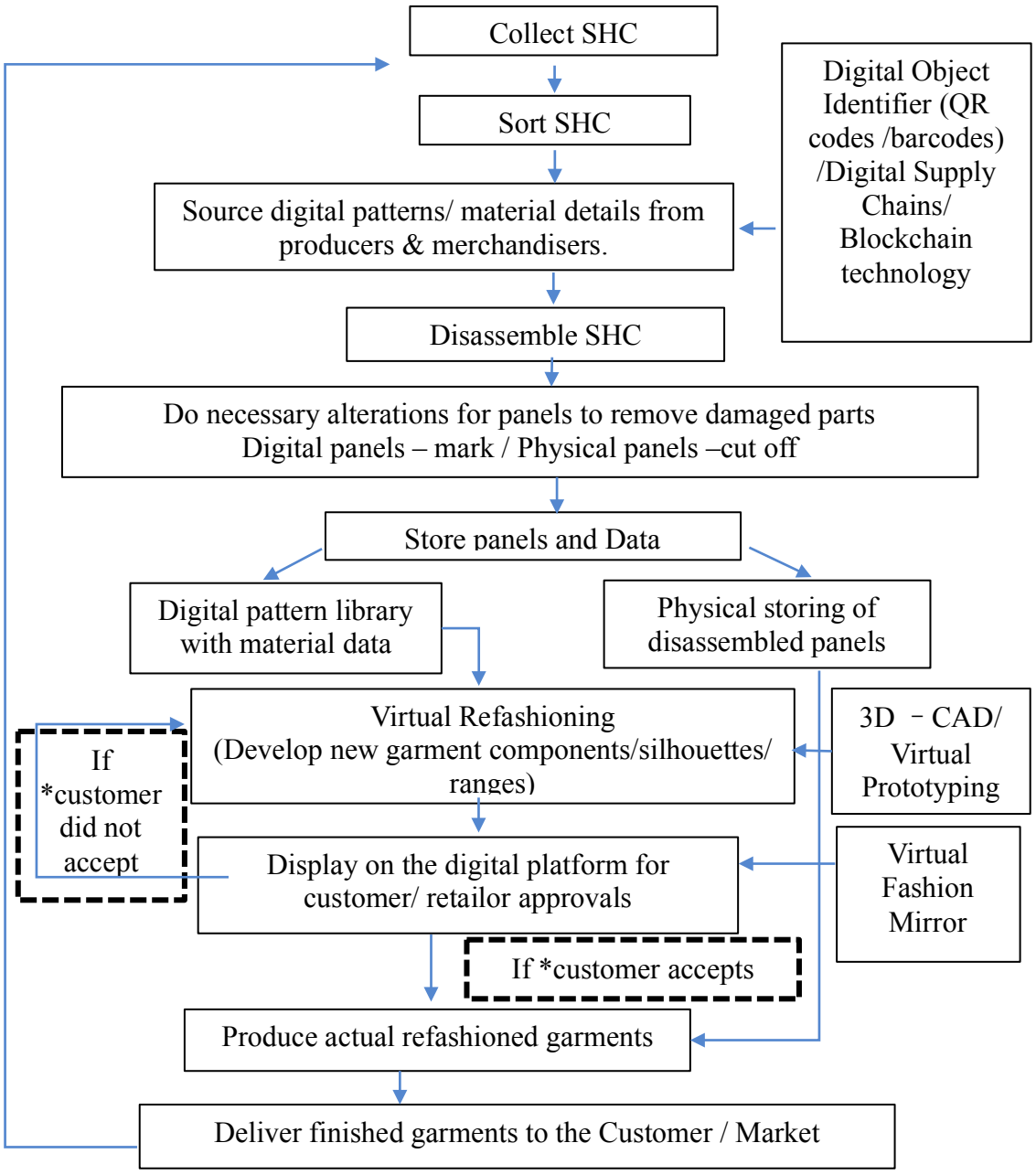


Figure 4-18: New framework for refashioning SHC

* Customer can be a consumer or a retailor

Each stage of the production process could be reinforced with the technology applications. By introducing Digital Object Identifier (DOI)s in the first life of garments, it is easy to trace the current position of the garment and obtain necessary material information through DOIs. DOI could be a smart sewing thread/ yarn inserted to the garment, barcode system or smart labeling system to track the garment at the end of their first life. With such information, it is possible to obtain data such as digital patterns, fabric information of SHC directly from their first-hand manufactures through digitalized supply chains. In this context, it is important to maintain strategic trade agreements among first- hand and second-hand manufacturers.

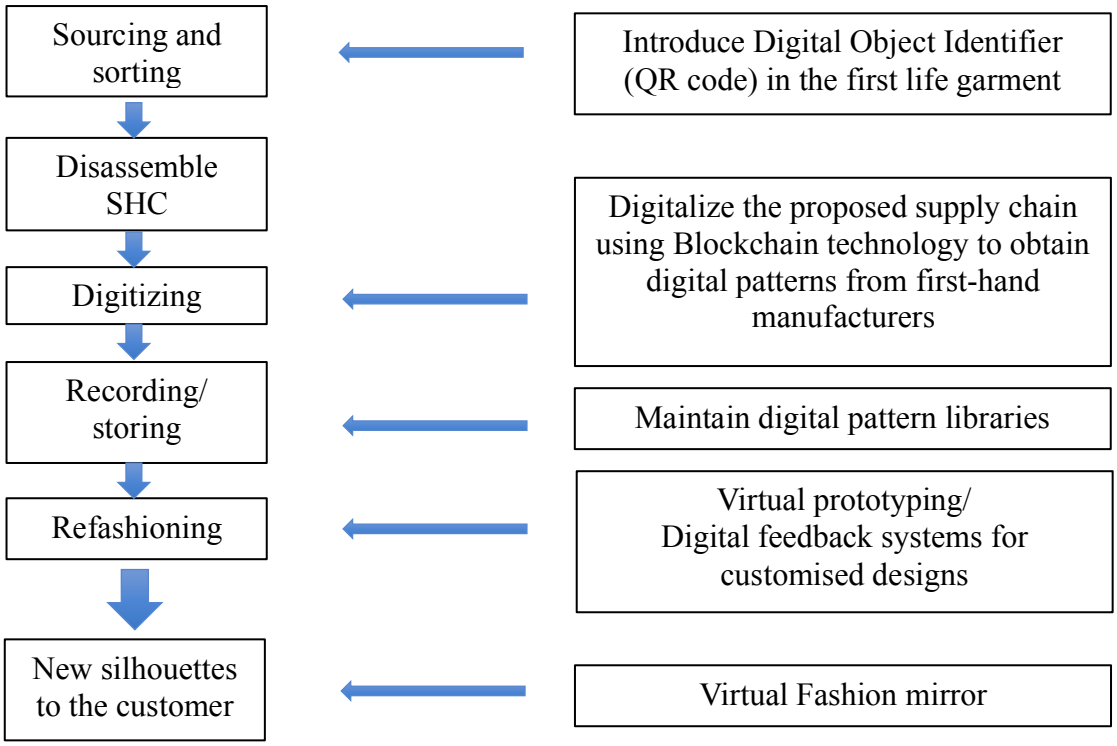


Figure 4-19: Suggest potential digital tools at relevant process stage, to enhance Circular Fashion business model

4.3. Phase three

The third objective of this research is to test the applicability of 2D and 3D CAD technologies in the implementation of new business model for SHC, in the circular fashion business. Accordingly, section 4.3.2. Provides the results of CAD experiments in the extended business model.

4.3.1. Sample characteristics for phase three, RO 03.

For the experimental research, the sample consisted of 12 used garments, which belonged to luxury brands in their first life. These garments were further evaluated by subjectively as summarised in below Table 4-13.

Table 4-13: Subjective evaluation of second-handed garments for experimental research

	Style	Material details	Subjective evaluation (Remarks)	Special details (Brand /Trims and accessories)
1.		• 100% polyester (synthetic material) • Heavy weight • Leopard print (AOP)	• The garment was in a good condition • Stain marks on the hem and neck facing	• Brand – Chanel • No lining • One Zipper
2.		• 100% cotton • Heavy weight • Check print (AOP)	• Good condition • Little colour fading at the back crotch area.	• Brand – Tibi • No lining • One Zipper • Self-fabric pocket bags
3.		• 100% polyester • Light weight • Plain coloured (off white)	• Good condition • Wear mark at the sleeve edge (hem)	• Brand – Burberry
4.		• Cotton/ wool crepe material • Medium weight • Navy blue	• Good condition • Ink mark on the sleeve	• Brand – Veronica Beard

5.		• 100% cotton • Medium weight • Printed (AOP)	• Good condition	• Brand – Zimmerman • Buttons
6.		• 100% polyester • Light weight • Plain coloured (black)	• Good condition	• Brand – Tommy Hilfiger
7.		• 100% cotton • Medium weight • Printed (pin stripes)	• Good condition	• Brand – Tommy Hilfiger • Buttons • Twill tapes
8.		• 100% cotton • Medium weight • Printed (stripes black, grey and white)	• Good condition	• Brand – Low Classic • Buttons • Twill tapes
9.		• 100% cotton material • Medium weight • Check (printed)	• Good condition	• Brand –Tibi
10.		• 100% cotton material (chambray) • Medium weight	• Good condition	• Brand – Low Classic • Buttons
11.		• 100% polyester • Light weight	• Good condition	• Brand – Argent
12.		• 100% polyester • Light weight • Plain coloured (off white)	• Good condition	• Brand – Burberry

4.3.2. Data collection and Analysis

There were few steps in experimental research process for refashioning SHC as shown in below Figure 4.20.

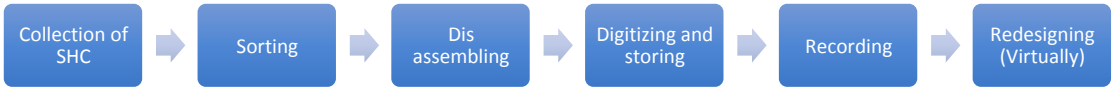


Figure 4-20: The process followed for refashioning SHC

Each step of the refashioning process is further analyzed based on the remarks, limitations experienced and suggested enhancements in Table 4-14.

Table 4-14: Analysis for each step of refashioning process

Collection of SHC		
Method practiced	**Remarks**	**Suggested enhancements**
Purchased SHC through E-platforms And by visiting SHC collection centres.	Limited information available about the SHC garment such as material composition, weight, construction of the material etc. Lacking tactile sensation of SHC before buying Uncertainty of the purchasing process Time consumption Fairly lower prices than virgin garments Could get a fair understand about the colour, volume and shapes of garment panels, trims and accessories being used through the information available on the website	Attach non removable detail tag (including composition, weight, construction etc.) in to garments in their first-hand productions, which would be helpful for sorting SHC Introduce a barcode system with recorded digital data, which could be used for further operations through Blockchain technology Maintain strategic partnerships with SHC collectors, agents, and consumers to collect SHC in a systematic manner. (Data Hub) Educate both consumers and collectors for sorting and segmenting SHC in returning and collecting process
Sorting SHC		
Method practiced	**Remarks**	**Suggested enhancements**
Subjective evaluation	Time and labour consumption	Obtain true information about the SHC while the purchasing through DOIs. (attach smart thread or a QR code etc. for each SHC garment as a digital birth certificate to track the history)

Dis assembling of garments		
Method practiced	**Remarks**	**Suggested enhancements**
Manually disassembled garment panels	Higher level of time and labour consumption	Use advanced technology for disassembling (use of special sewing threads which break the tensile strength with minimal force such as microwave heating etc.) and developments of new machineries for unravelling stitches. Use unskilled (cheap) labour to disassemble SHC Introduce new stitches for garments, which provide the ease to unravel after using the garment while maintaining seam the strength. (Ex: chain stitches) Mindful designs with special patternmaking techniques targeting refashioning in the second life of the garment. (Ex: designing with large garment panels, less style lines and less trims). Introduce new product category in to the first-hand market such as “garments with a second life” or “dual life garments” targeting refashioning

Digitizing, recoding and storing garment panels		
Method practiced	**Remarks**	**Suggested enhancements**
Digitised using Gerber AccuMark software and removed damaged areas from the garment panel virtually	Time consumption	Make trade agreements with different brands, producers to obtain digital patterns of SHC through the Blockchain technology to skip or reduce the time consumption in manual digitising process
Record digitised pattern information in a data bank (Figure 4.21)		Use digital technology to maintain pattern libraries
Store physical samples	Required physical store area	Speed up the designing process with CAD, therefore can avoid the stay duration of garment panels in the store

Designing the range		
Method practiced	**Remarks**	**Suggested enhancements**
Altered the existing (digitised) patterns for new designs and rendered using Browzwear VStitcher software For refashioning, three techniques were practised, refashioning same SHC, mixing panels of different SHC, and reproducing same new style with different SHC materials as mentioned in Figure 4.22, 4.23 and 4.24.	Limited data recorded in the action history (software)	Develop options to record the design developing process then it could be useful in developing the operation break down of the garment

SHC Before Disassembly					Disassembled panels								
Item No	Style	Size	Picture of the style	Special details)	Shape (Picture of the panel)	No of pieces available	Area (Cm2)	Composition	Construction	Weight of the material	Colour /Print details	Other special details	Place stored
1	Shift Dress	12 (UK)		Brand - Chanel/ metal zipper attached at upper CB	Sleeve 	2	88	100% polyester	Plain weave		Leopard print (AOP)		Lot A
2					Dress front 	1	578	100% polyester	Plain weave		Leopard print (AOP)		Lot B
3					Dress back 	1	615	100% polyester	Plain weave		Leopard print (AOP)		Lot B

Figure 4-21: Recording format of SHC data

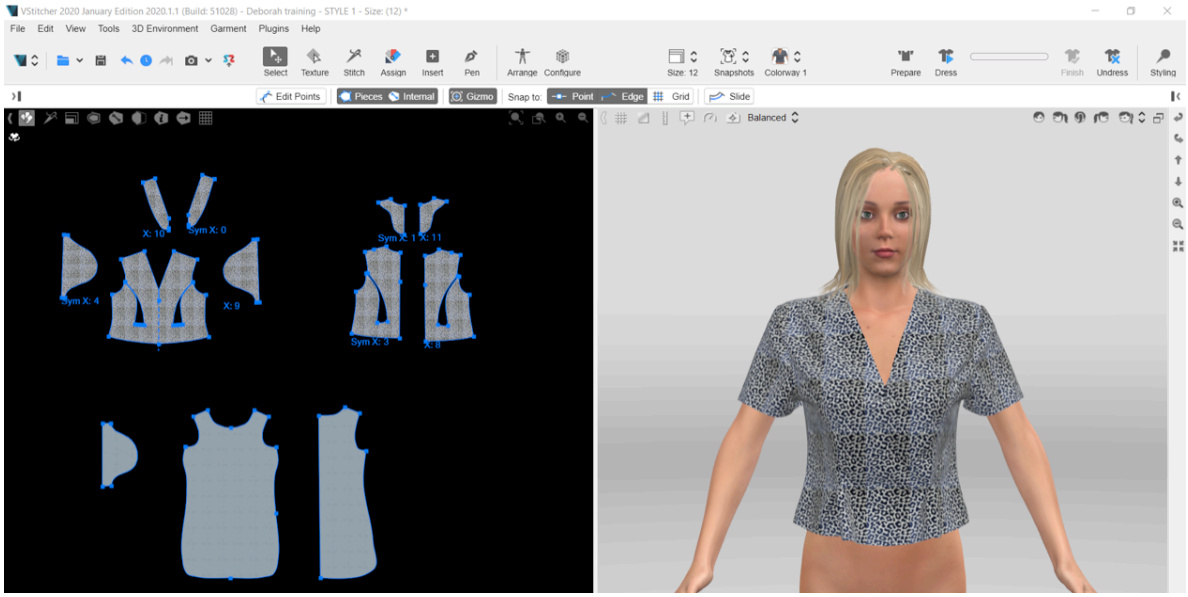


Figure 4-22: Virtual refashioning of same SHC garment panels

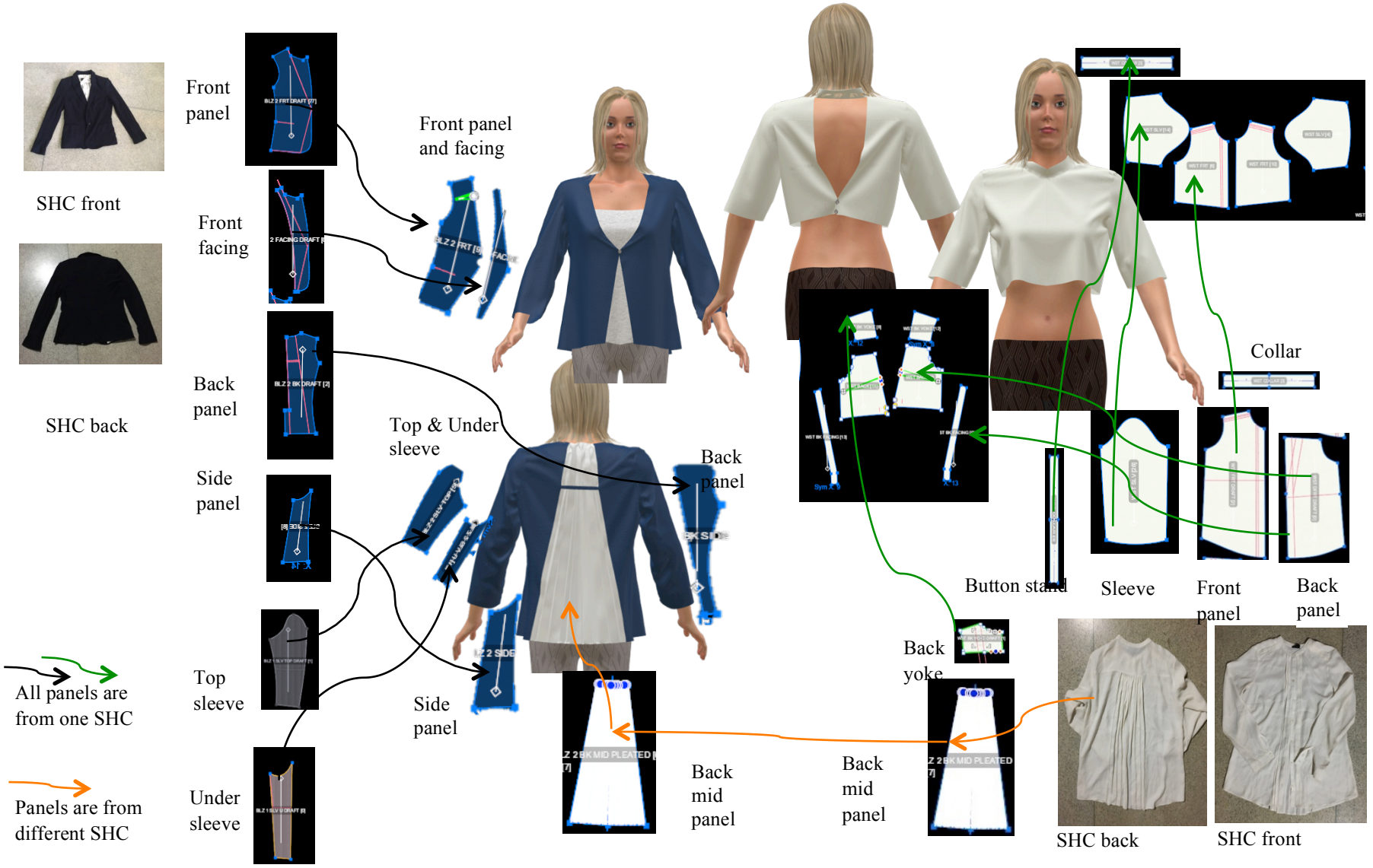


Figure 4-23: Refashioning garment panels from different SHC (mix and matching)

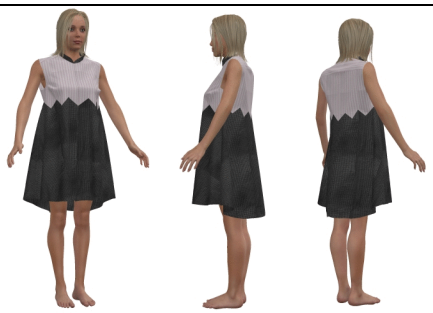
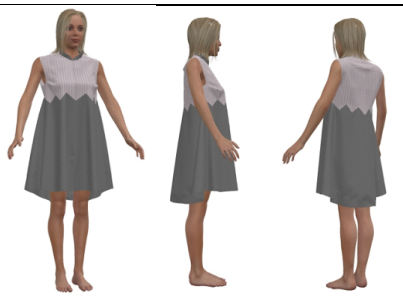
The new range of refashioned garments using SHC.

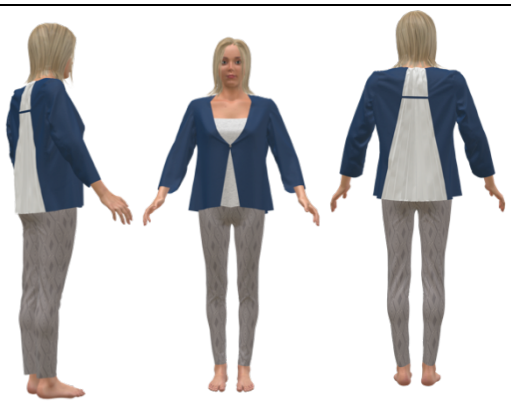
The refashioned range of garments with multiple silhouettes, colour, and material options are presented in below Table 4-15.

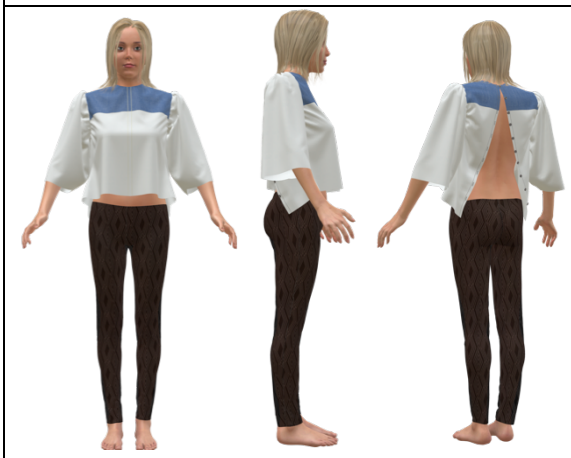
Table 4-15: New refashioned garment range

Style/ Silhouette	Refashioned garment	Comments
Look 01		Refashioned by mixing different SHC panels Provides colour/ material multiple options
		
Look 02		Refashioned by mixing different SHC panels Provides colour/ material multiple options
		

Look 03		Refashioned by mixing different SHC panels Provides multiple material/ colour options
		
		
Look 04		Refashioned by using SHC panels of same garment Provides multiple colour / material options
		

Look 05		Refashioned by mixing different SHC panels Provides multiple material/ colour and design options
		
Look 06		
Look 07		
		

Look 08		Refashioned by using SHC panels of same garment
Look 09		Refashioned by using SHC panels of same garment
Look 10		Refashioned by using SHC panels of same garment
Look 11		Refashioned by using SHC panels of same garment
Look 12		Refashioned by mixing different SHC panels

Look 13		Refashioned by mixing different SHC panels Provides multiple colour/ material options
		
		
		

Look 14		Refashioned by using SHC panels of same garment
Look 15		Refashioned by using SHC panels of same garment

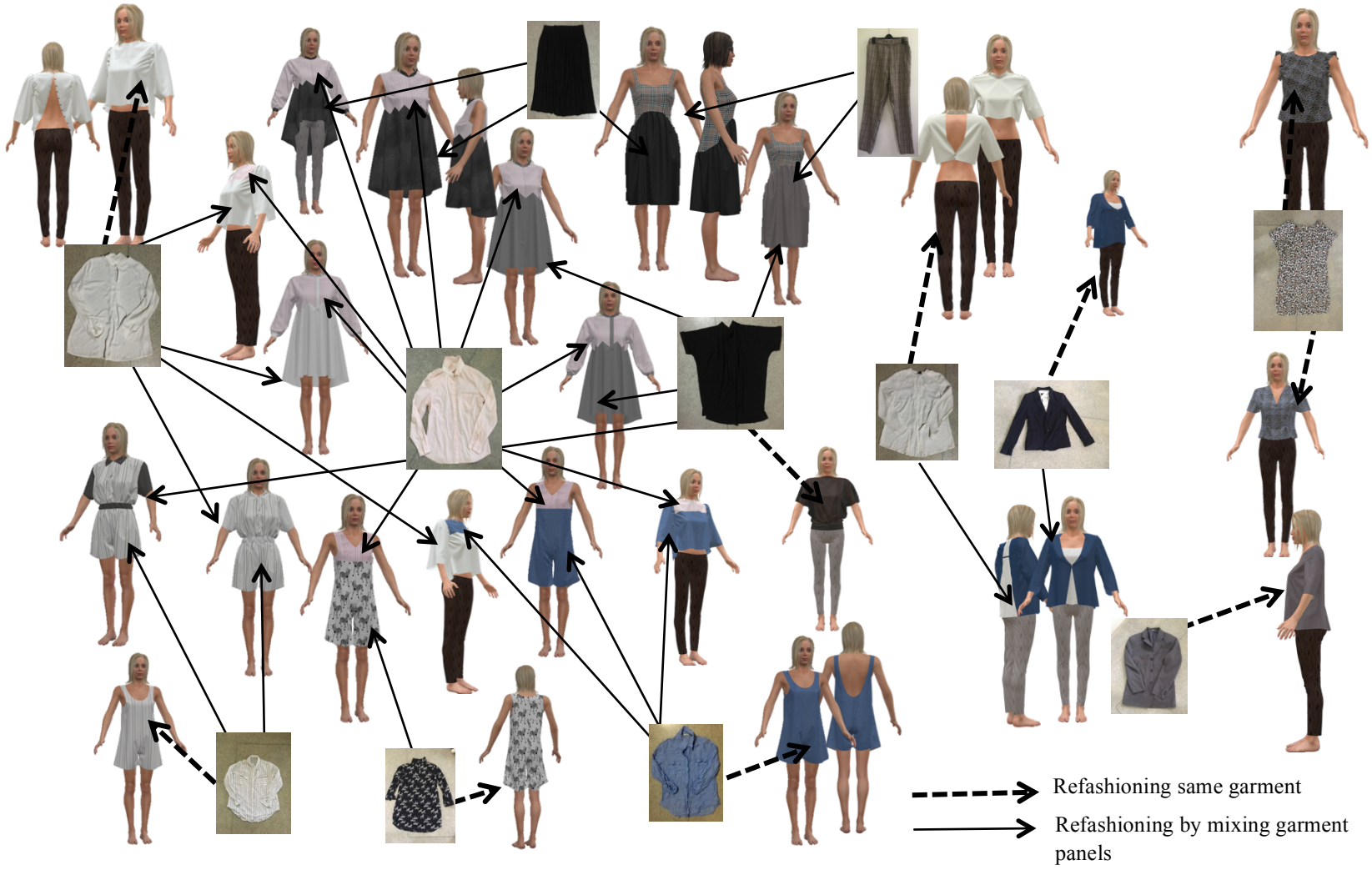


Figure 4-24: The refashioned range from SHC garments

5. CONCLUSIONS

This research intended to explore the adoptability of circular fashion (refashioning SHC) by enabling CAD and other digital technologies. Further it was divided to three (03) research objectives of exploring opportunities in circular fashion, proposing a new business model by enabling digital technologies and test the applicability of CAD technology for refashioning SHC.

The first research objective was achieved with a literature survey of 20 recently published articles on “Circular fashion”, “Second hand clothing”, “Refashioning” and qualitative interviews of apparel industry experts in CAD, designing and retails. The data were analysed using thematic analysis method. Accordingly, it was found market expansion with alternative options, environmental benefits through resource recovery, research and technological advancements, initiatives and trends set by the industry stakeholders as key opportunities for circular fashion with reference to SHC. Further, it revealed few challenges such as economic feasibility, challenges in raw material supplies, and limited application of technology for refashioning and huge competition from fast fashion. Further, it summarised that there is an undiscovered potential for refashioned SHC in the current fashion industry.

The second research objective attempted to generalize the current second-hand clothing business model and propose a new model to address challenges and opportunities in SHC industry identified in the first research objective. However, this particular research narrowed its scope only into CAD and Blockchain applications in developing the new business model. Importantly this research explored the potential applications of CAD and Blockchain technologies in to nine (09) components of the business model canvas of BMG method. In summary, a new business model and a framework is developed for refashioning of SHC.

The third research objective attempted to explore the operational aspects of the proposed SHC business model in the second objective. However, considering the time and other limitations of the research, sample of 12 used garments were used for refashioning experiments using Browzware VStitcher software. Accordingly, it was found that three (03) methods of refashioning; same SHC into new garment, refashioning by mixing panels of different SHC and produce same new silhouette

repeatedly by different SHC. Therefore, it delivers numerous possibilities of new designs/ silhouettes, colour blends and material blends to offer multiple options to the customer from refashioning SHC through 3D virtualization.

In summary this research explored the opportunities of CAD and digital technologies, in addressing challenges of SHC industry. Although this particular research only focused on possibilities from industry point of view, reducing textile waste is multi-stakeholder challenge, which needs committed involvement from the customers, government, producers, and other parties in the textile and clothing supply chains.

Recommendations

Since SHC and other apparel waste is becoming a global threat, the apparel industry should consider the elongation of the garment lifecycle over short-lived fast fashion. Furthermore, initiatives could be done in the design stage of fresh products, by adding sustainable design features such as less style lines, durable trims, high quality materials and stronger, yet easily unravelling stitches etc. therefore initial designing should be done with the second life of the garment in mind.

It is highly recommended to introduce a new garment category into the market for fresh clothes, which are designed to live longer to employ a second life after refashioning.

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ANNEXURE 01

Open ended questions for semi-structured interviews

	Theme		Probing questions
1.	Initiatives towards circularity regarding SHC	1.	What is your opinion about recycling/ Refashioning SHC in current circular fashion industry?
		2.	What are the best practised waste management systems (post-consumer waste, SHC) in the apparel industry?
		3.	What (current and future) initiatives are there towards circularity of the fashion industry regarding SHC?
2.	Opportunities of using SHC as a raw material (refashioning SHC)	4.	What do you suggest to expand/ uplift current SHC refashioning industry?
		5.	What are the unexplored possibilities are there for refashioning SHC in your expertise area?
3.	Challenges in circular fashion related to SHC as a raw material (refashioning SHC)	6.	What are the current issues challenges in the fashion industry (regarding SHC), when moving towards circularity?
		7.	What are the strategies do you suggest to implement/ extend circularity (SHC related) in your expertise area?
		8.	What challenges you would expect when implementing above strategies? And possible solutions?
4.	Initiatives towards circularity regarding SHC	9.	What is your opinion about recycling/ Refashioning SHC in current circular fashion industry?
		10.	What are the best practised waste management systems (post-consumer waste, SHC) in the apparel industry?

	What (current and future) initiatives are there towards circularity of the fashion industry regarding SHC?
5. Opportunities of using SHC as a raw material (refashioning SHC)	*11.* What do you suggest to expand/ uplift current SHC refashioning industry? What are the unexplored possibilities are there for refashioning SHC in your expertise area?
6. Challenges in circular fashion related to SHC as a raw material (refashioning SHC)	*12.* What are the current issues challenges in the fashion industry (regarding SHC), when moving towards circularity? *13.* What are the strategies do you suggest to implement/ extend circularity (SHC related) in your expertise area? What challenges you would expect when implementing above strategies? And possible solutions?
7. CAD and Digital technologies for circularity (refashioning)	*14.* What is the current involvement of CAD and digital technologies in the fashion industry? *15.* How possible is to use CAD and digital technologies to address the challenges in circular fashion? *16.* What are the challenges in above context? What is the future (un used) provisions of CAD and digital technologies to address the challenges in circular fashion?
8. CAD technology possibilities for refashioning (specially for CAD experts	*17.* What CAD software/s do you suggest for refashioning SHC? Any future (unused) possibilities of new CAD technologies for refashioning SHC?

ANNEXURE 02

Text search query results of literature survey

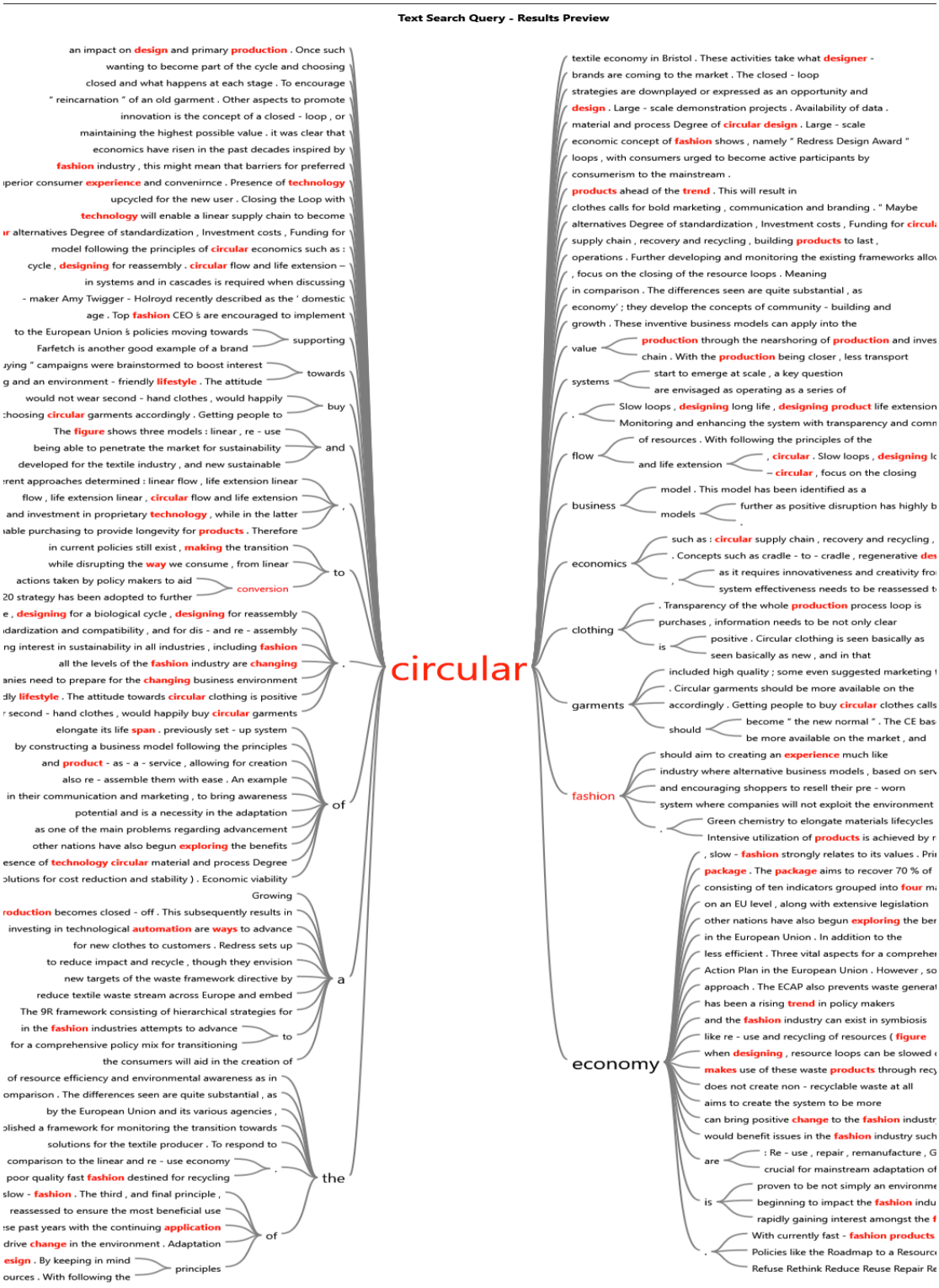

Figure 1: Word exploration for "circular" in published literature

Source: Systematic review of literature

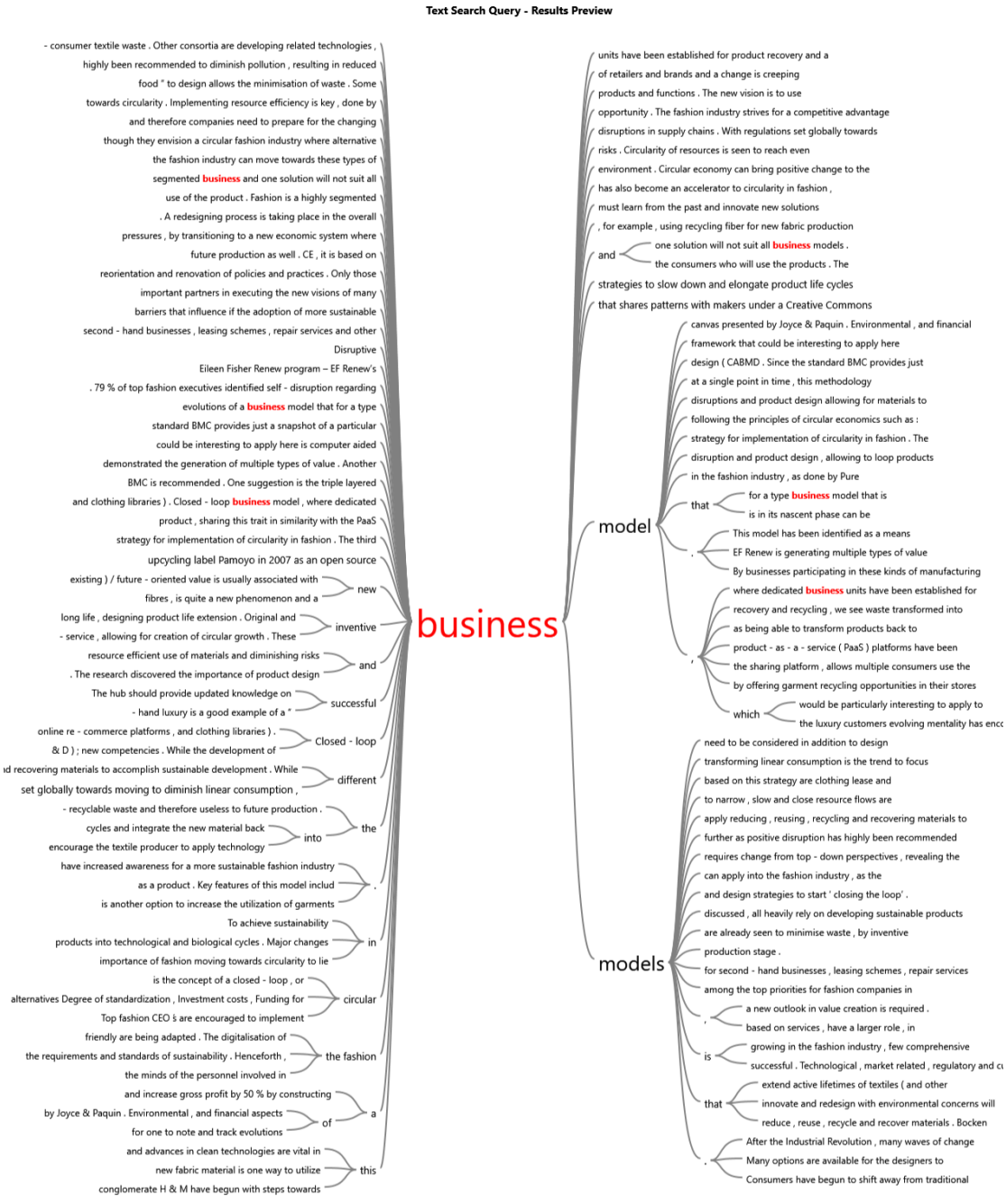

Figure 2: Word tree word exploration for Business models in published literature

Source: Systematic review of literature

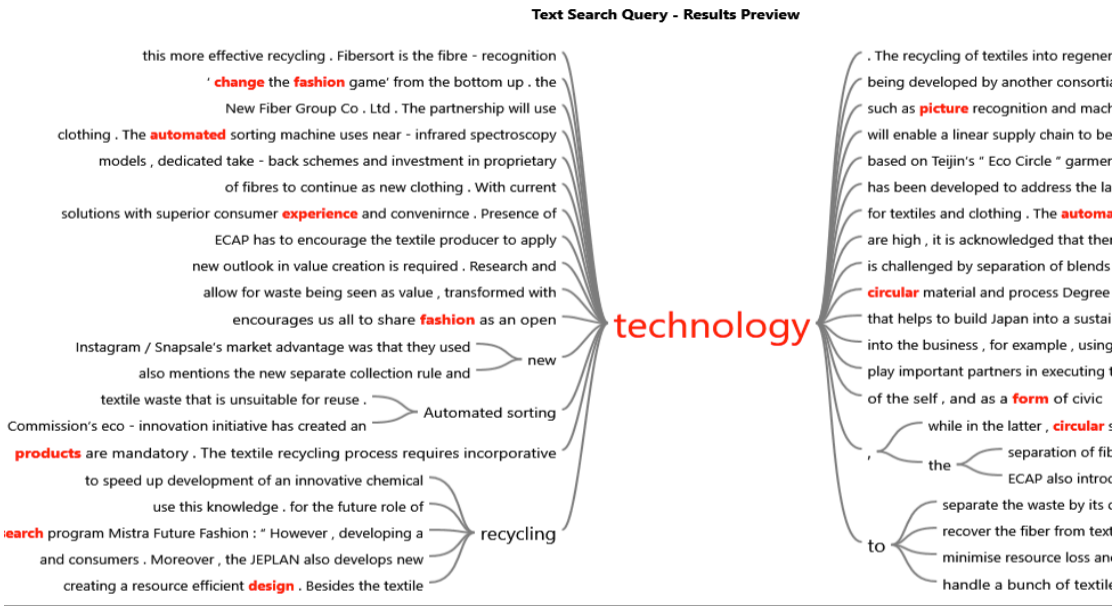

Figure 3: Word tree word exploration for "Technology" in published literature

Source: Systematic review of literature

ANNEXURE 03

Case examples for circular fashion (refashioning) in the apparel industry

Four (04) sample international case studies have been conducted on companies/ brands, which are engaged in up cycling SHC by refashioning in the circular fashion industry.

Case 01 – Eileen Fisher Renew

A pioneering brand for sustainability

Eileen Fisher, started in New York in 1984 as a luxury women's wear company (women's business and casual clothing as well as accessories and shoes), currently employing two circular business models. One business model targets its loyal luxury customer segment to sell their new clothing which are designed for product longevity. They use high quality materials, minimum accessories and trims with minimum number of seams with bigger garment panels keeping many provisions for disassembling and refashioning. The other business model focused on garment take-back system for used EF clothing and reselling after refurbishing or refashioning. The second model specially targets affluent young customers who loves luxury products, but have less spending power. Therefore, the company sells its products twice as virgin clothes and resell the same product as second hand luxury.

The company committed to its values, such as environmental sustainability, human rights, women and girls' empowerment and have well established and refines supplier network from fiber to productions. Further it operates both onshore and near shore production facilities and invests vastly on research and innovation.

Case 02 – MIA by Mia Nisbet

MIA is a unique ethical African fashion brand in Malawi, which produces refashioned garments for international fashion markets upcycling SHC. Since the African countries including Malawi becomes the final destination of second handed clothing while damaging local textile industries, MIA has harmonized such imported modern second hand clothing with old Malawian traditional textiles through her refashioned clothing range. The specialty here is the innovative use imported second hand clothing with Malawian traditional touch by colours and bold African prints in order to create fresh and playful garment designs.

MIA use special tailoring techniques to refashion blazers, jackets, shirts, t- shirts and sportswear with their original logos such as Adidas, I "heart" NY while mixing African textiles to emphasize the contrast between African and Western fashion. Further this brand collaborates with local producers while investing on their training, infrastructure, production facilities and sustainable livelihoods.

Case 03 – Beyond Retro- reworked

Beyond retro is a vintage retailer with its own upcycled label called "Beyond Retro Reworked" to refashion unsold SHC stocks. Reworked collections are made only

from second hand fabrics, which are sorted, stocked and then redesigned for future fashion trends. The speciality is they forecast styles years in advance, to make with fabrics, which are years past. Particularly they produce brand-wise refashioned ranges such as Reworked Nike, Reworked Adidas, Reworked Ralph Lauren, Reworked Disney for a very affordable price range. Beyond Retro has worldwide retail chain with e- sales platforms. Their productions are done in India; reinforcing local producers with mindful manufacturing by low waste, low carbon footprint. Further the Waste & Resources Action Programme (WRAP) has certified that every year they save 608 tonnes of CO2e and 300,000m3 of water by recycling and up cycling SHC.

Case 04 - Armadio Verde

Armadio Verde is an online platform for children's clothing exchange that draws from the lowsumerism, second hand, and collaboration drivers. The company created a point-based exchange mechanism for donating and acquiring second-hand garments for newborns and children up to 16 years old. Focus on technology to enable the drivers of sustainable innovation. Fosters a new fashion experience, based on values such as high quality (all garments are controlled for quality and brand upon their receipt), sustainability, innovation, and sharing, saving both money, time, and resources.

By focusing on children, the start-up of the brand also has strong potential for promoting customer education. by donating used clothes, members can obtain credits to spend on other clothes made available through the platform, thus triggering engagement and collaboration.

Apart from above discussed cases, there are many other fashion brands such as Patagonia, Re/Done, Fabric For Freedom, Zero Waste Daniel , wardrobe surgery who are contributing to circular fashion by making SHC occupied further without accumulating waste (Huerlimann, 2020).

ANNEXURE 04

Nine components of the business model canvas (BMG method)

Partners - In order to enable resource optimization a key competence is required, which is the ability to keep track of products, components and material data.

Cooperative networks allow businesses to receive advantages from supplies, and support a company in research, product design, marketing, office support, supply routes, financial functions, production processes, and management Thus, collaboration enhances obtaining key resources and performing key activities. For instance, off-site recycling is done by other parties that recycle the industrial wastes at the post-consumer stage or recycle the specific wastes, which then are sold to other industries Collaborative production, based on the cooperation in the production value chain, allows the materials to circulate in a so-called closed material loop. The "butterfly diagram" developed by the Ellen MacArthur Foundation shows the key role of manufactures and recycling companies. Without collaboration, achieving circularity is hardly possible.

Activities - Products have to be made in specific processes, with recycled materials and specific resources, which may require not only specific capabilities but also creating reverse logistics systems and maintaining relationships with other companies and customers to assure closing of material loops. The change concerns the way products are designed and engineered to maximize high quality reuse of product, its components and materials.

The key activities, which directly or indirectly lead to creating, offering and delivering the value propositions, may apply the CE principles in several ways. Some are oriented on increasing performance, product design, technology exchange, and the other on remanufacturing, recycling or even lobbying.

Increasing performance can be obtained through good housekeeping, better process control, equipment modification and technology changes, sharing and virtualization. Good housekeeping and process control involve not only optimization of the process by elimination of any fault that would result in unnecessary losses, like spills, leakage, overheating etc., but also effective and efficient planning and regulating of

the process to ensure optimal conditions such as temperature, pH, pressure, water level, time, etc. This requires, for instance, continuous monitoring and management, a regular preventive maintenance program, raising staff environmental awareness, and incentive mechanisms, and is supported by lean thinking and lean management. Recently, another way of increasing performance has been introduced—the "bring your own device" model. It assumes that users bring their own devices in order to get the access to services, and thus the quantity of products required to meet market need is being reduced. An example is Citrix where employees are paid for bringing their own computers into the company to use on the company's network for work and home. Equipment modification and technology changes improve the production process or replace one with another, and in turn increase efficient utilization of raw materials, water, energy, reduce emissions and eliminates toxic materials from production. A good example is using 3D printing to produce what is needed. Increasing performance may be related also with sharing and virtualizing office space through flexible seating, desk-sharing, office hoteling, tele-working, audio and video conferences, the "internet of things", big data and machine learning.

Appropriate product design enables using less raw material or energy, to reduce emissions and toxic materials, prolonging product life, eliminating waste before resource-life extension, and to circulate the product, components and materials in a 100% closed material loop, according to the Cradle-to-Cradle concept.

Moreover, sometimes lobbying for the changes of legislation and political incentives to accelerate the circular economy is necessary. When a company is directly engaged in lobbying, then it becomes the key activity. Otherwise lobbying depends on third-party entities and is considered as an adaptation factor.

Resources - The assets required to create, offer and deliver value propositions via chosen channels, to build and maintain relationships and to receive revenue flows, correspond with the principles guiding the circular economy in two major ways. One is focused on input choices and the second on regenerating and restoring the natural capital.

The input choices are related to changing input materials and products. This can be done through so-called circular sourcing, which applies the principle of using only products or materials obtained from closed material loops along four circular flow. Another way to achieve this is direct substitution of resources with better-performing materials, which are "less harmful to the environment, more feasible to use and have

the same or better technical requirements". Next option is direct virtualization of materials, as for instance through digitalization.

Natural capital regeneration and restoring concerns using energy from renewable sources, land restoration or reclamation, saving water, operating in more efficient buildings, and choosing sustainable production locations like eco-parks.

Value proposition - Value proposition is composed of the products and services offered to the customer, the relievers of customers pains, and the creators of customer gains pertaining to the tasks and jobs he or she needs to accomplish with the assistance of the offered product or service.

In CFBM, products should become fully reused or recycled, which requires reverse logistics systems, or firms should turn towards product-service system (PSS) and sell performance related to serviced products. A shift from selling volumes of products towards selling services and retrieving products after first life from customers. Circular products, although ownership-based, have several specific features related to the CE principles. Circular products enable product-life extension through maintenance, repair, refurbishment, redistribution, upgrading and reselling. They are designed to enhance reusing, recycling, and cascading. This requires a modular design and choosing materials that allow cascading, reusing, remanufacturing, recycling, or safe disposal. Thus, such products are 100% ready to circulate in the closed material loops. Moreover, product design should allow using less raw material or energy or to minimize emissions. Circular products can be also dematerialized and offered not as physical but as virtual products. In a product-service system a company offers access to the product but retains its ownership. It is an alternative to the traditional model of "buy and own". This is a way of reducing customer pains, creating gains, and getting the jobs done through offering product-oriented services or advice, use-oriented services including product leasing, renting, pooling, and pay-per-service unit, or result-oriented services, comprising outsourcing and functional result. Some examples comprise: Philips pay-per light or Green Wheels' shared car use, hours of thrust in a Rolls-Royce, or "Power-by-the-Hour" jet engines.
Circular value propositions related to services may concern shifting their traditional form to a virtual one (e.g., virtual travel).

Collaborative consumption related to product sharing/renting or product pooling can bring cost savings, services tailored for customer needs, and additional benefits. For instance, Bla BlaCar offers not only cheap transportation possibilities and route connections unavailable by public transport, but also social gains (see blablacar.com). Some other sharing-based value propositions concern sharing residence, parking, appliances/tools sharing, office, and flexible seating, which may require some specially developed platforms.

Usually there are some incentives offered to the users/consumers: for example, buy-back programs like Vodafone—New Every Year/Red Hot. In this case, incentives are a source of value for the customer (part of value proposition), and products, components or materials collected back contain a value retrieved by the company.

The value proposition must be appropriate for particular customer segments, for specific types of customers.

Customer segments - selling "circular" products or services may require prior changes of customer habits or, if this is not possible, even changes of customers.

Customer relations - Building and maintaining relationships with customers can underlie the main principle of the circular economy—eliminating waste—twofold. Those two options encompass producing on order, and engaging customers to vote for which product to make. Additionally, a switch to recycling 2.0 may enhance social-marketing strategies and leverage relationships with community partners.

Channels - Turning towards the maximization of the recovery of own assets where profitable and to maximization of the use of recycled materials/used components in order to gain additional value from product, component and material flows. Virtual communication and virtual design channels can play an important role here.

Cost structure - The reviewed literature provided no good examples on how the cost structure can enhance implementation of CE principles. However, whenever a company decides to change the cost structure it might require further organizational changes, such as for materials, energy consumption, staff behavior etc., and in turn elicit more circular changes to the business model. This process could start with the analysis of the cost structure. In this regard, cost structure-related criteria can help to

evaluate efficiency of optimization policies. Cost structure is usually mentioned when the implications and potential benefits of CE are described. It may pertain to cost savings related to PSS or reverse material flow, production costs in agriculture, costs of product development, or investments.

Revenue streams - Revenue streams are essentially the ways in which a company makes money. There are several circular propositions, mainly associated with the product-service systems. The first is an input-based PSS, like pay per product or pay per service. The second is availability-based PSS, encompassing a subscription-based rental where, against a low, periodic fee, consumers can use a product or service; or a progressive purchase, where customers periodically pay small amounts before the purchase. The third is usage-based PSS like pay per use, which is a one-time payment to use a product or service. The fourth one is performance-based, like performance-based contracting. However, several performance-based Product Service Systems are possible, like solution-oriented (e.g., selling a promised level of heat transfer efficiency instead of selling radiators), effect-oriented (e.g., selling a promised temperature level in a building instead of selling radiators), and demand-fulfilment oriented (e.g., selling a promised level of thermal comfort for building occupants instead of selling radiators). Two traditional options of revenue streams concern selling pure products or pure services. Revenue streams depend on the value proposition.

Moreover, revenue streams may be related to retrieved value, generated from products, components and/or raw materials collected back. For example, product components, when collected back, are resold after they were restored to “as-new” quality, or remanufactured, or used to create a new product if they carry a high value. Despite how low or high the value, it must be sufficient to make the material loops economically reasonable. Retrieved value may also be related to energy captured from waste disposal.