Planning a Swedish Collection and Sorting Plant for Used Textiles

Feasibility Study

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re:textile

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Executive summary

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

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

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

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

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

Voluntary and subsidized work is essential for economic feasibility, and must be supported by legislation, occupational measures or general practice. 2. Increased prime quality in incoming material will raise the income level of sold fractions. There are ways to achieve this, of which one is to convince consumers of providing less used material for collection – perhaps at the cost of shorter first-hand use. Another possibility is a sharing agreement with the charities, which carry out the first-tier sorting. It involves also measures to enable consumers to make more educated decisions. A certification system may also be helpful to achieve better quality. New actors should be encouraged to join the market. 3. Increased productivity in the sorting centre. 4. Increased value of output can otherwise be achieved by innovative sorting,

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

Collection and Legislation for Used Textiles and Clothing

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

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

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

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

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

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

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

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

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

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

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

The critical success factors for distributed fashion redesign comprise material cost (which may vary widely), material usage, redesign process cost and lead time, and subsidies obtainable. The future potential for establishing distributed fashion redesign is likely dependent on creating a strong inter-connected network of suppliers and value-adders regionally. Educational efforts are needed, also primarily in circular product development and design, circular production processes, and in circular local flows and establishment of collaborative networks.

The critical success factors for PSS redesign-as-a-service are identified as direct process costs, overhead costs, customers' willingness to pay, and PSS lead time. The future potential here is in developing both the technical solution and improving the customer satisfaction in a larger retail setting, for example by direct-to-garment printing or fun features for customers, like artwork, 3D visualizations, customization features, etc.

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

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

Borås, 15 December 2019
The authors

Förord

Vi vill först tacka VGR för att vi fick möjligheten att arbeta fram denna rapport med den målsättning som fastställdes i projektansökan Re:Textile[1] (WP3). Som vi förstått under arbetets gång är denna genomförbarhetsstudie en av de få som adresserar affärsmässigheten i de olika stegen av värdekedjan begagnade textilier. Eftersom verkligheten förändras snabbt är rapporten utformad så att nya parametrar kan sättas in, och på så sätt kan resultaten användas för simulering av nya förhållanden.

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Rapporten innefattar en sammanfattning på svenska men är i övrigt skriven på engelska för att tillgodose ett internationellt intresse på det aktuella området.

Foreword

First we gratefully acknowledge the support from the Västra Götaland Region, giving us the opportunity to prepare this report with the objective set in the project application Re:Textile (WP3). As we understood during the work, this feasibility study is one of the few that address the commercial aspects of the different steps of the used textiles value chain. Because reality is rapidly changing, the report is designed so that new parameters can be inserted, and thus the results can be used to simulate the new conditions.

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The report includes a summary in Swedish but is otherwise written in English to cater to the international interest in the field.

[1] retextile.se

Sammanfattning

Studien belyser följande frågor:

- Finns det några realistiska förutsättningar att etablera en svensk sorteringsanläggning för insamlade textilier med hänsyn tagen till redan etablerade insamlingsstrukturer?
- Vilka ar de avgörande kritiska faktorerna?
- Hur ser framtiden ut?
- Hur kan en framkomlig väg se ut för att etablera en lämplig strategi för en cirkulär ekonomi avseende använda textilier?

Grundförutsättningar för studien:

Idag bedrivs den ordnade insamlingen av textilier huvudsakligen av välgörenhetsorganisationer som Myrorna, Röda Korset, etc. Av en total konsumtionsvolym på ca 13 kg/capita i Sverige (omfattande kläder och hemtextil) samlas 3-4 kg in av mestadels seriösa operatörer genom direktöverlämning eller genom insamlingscontainrar. Vissa butiker/varumärken har också kommit igång med mottagning av använda textilier, t.ex. H&M, Hemtex, KappAhl m.fl. Övriga kvantiteter (8-10 kg) har vi inte exakt kännedom om, men troligen hamnar de förr eller senare i containrar för brännbart.

Motivet för de seriösa insamlingsorganisationerna att bedriva denna verksamhet är dels att skapa finansiella resurser för att kunna bedriva sin hjälpverksamhet, dels att skapa sysselsättning för en växande kader av personer i arbetsträning och liknande. Detta innebär att verksamheten i stor utsträckning bedrivs av volontärer samt av subventionerad personal vad avser arbetskostnader. Samhällsnyttan som skapas genom detta är mycket stor och bör inte äventyras av förändringar i denna struktur. I regeringsuppdraget 2014 till Naturvårdsverket angående hantering av textilier framhålls detta också som en förutsättning.

Den sorteringsverksamhet som bedrivs av dessa organisationer syftar till att sortera ut de bästa produkterna, som har förutsättningar att säljas genom egna butikskanaler. Ungefär 20 % av volymerna tar denna väg, och dessa har en helt avgörande ”värdeuppväxling”. Övriga 80 % exporteras till avsevärt lägre värde än de första 20 procenten.

Eftersom välgörenhetsorganisationerna utför denna första fas på ett utomordentligt kostnadseffektivt sätt, samt därigenom skapar samhällsnytta som också är mycket kostnadseffektiv, kan vi inte se något som helst motiv att ändra på detta förhållande utan kanske istället förbättra möjligheterna att utveckla deras värdefulla arbete.

För en regional/nationell sorteringscentral återstår alltså en potential bestående av exportkvantiteterna samt de volymer som hamnar i ”brännbart”.

De beräkningar vi har utfört baseras på en sorteringsanläggning som bedrivs efter normala affärsbetingelser, dvs. avtalsenliga löner, marknadsmässiga hyror och avskrivningar samt rådande finansiella kostnader.

Den kritiska volymen för en sådan anläggning har beräknats till en kapacitet om 40 ton/dag motsv. ca 50 anställda. Denna kapacitet motsvarar ca 40 % av totalförbrukningen (13 kg/capita) i Västra Götaland eller ca 170 % om insamlingsnivån ligger på nuvarande ca 3 kg/capita.

För att nå erforderlig volym krävs alltså:

– Utökat geografiskt upptagningsområde
– Maximerade marknadsandelar
– Större insamlad volym per capita.

Beaktande dagens kostnadsläge för en effektiv anläggning om 40 ton/dag samt de marknadsmässiga priser/intäkter som idag är för handen avseende "2nd choice" kvantiteter är projektet inte ekonomiskt försvarbart. Kostnads/intäktsförhållandet ligger på ca 7,80 SEK/kg mot ca 6,50 SEK/kg.

De faktorer som påverkar detta förhållande är följande:

– Andelen förstasortering i fraktionerna (andelen är noll i vårt exempel)
– Totalvolymerna
– Kvalitetsfördelning. Bärbara plagg i förhållande till icke bärbart, dvs. kvantiteter för re-cycling etc.
– Produktiviteten
– Lönekostnaderna
– Låga marknadspriser på framförallt material till recycling samt "rags" (putstrasor)
– Teknologi för hantering respektive potentiell sensorteknologi för automatisk sortering avseende främst förekomst av skadliga kemikalier samt fiberinnehåll
– Recyclingsteknik för återvinning av använda fiber till nya fiber; inte kommersiellt tillgänglig ännu
– Vertikal integration (insamling-sortering; recyclingprocesser/second hand-retailing)

Dessa förhållanden kan självfallet förändras och ändra bilden av konceptets realism.

Slutsatser avseende marknadsutveckling:

Beaktande att framtidens fiberbehov om mer än 200 miljoner ton/år (från nuvarande ca 90 miljoner ton/år) huvudsakligen genereras genom befolkningsökning och ekonomisk tillväxt i utvecklingsländer som utgör dagens exportmarknader, får detta till följd att dessa marknader blir självförsörjande avseende bärbara second hand-kläder. Alltså: våra exportmarknader mins- kar betydligt.

De tekniker och marknader som måste utvecklas i strävan mot en lönsam cirkulär ekonomi utgörs följaktligen av

– **Sorteringsteknik som kan detektera och sortera på skadligt kemiskt innehåll respektive fiberinnehåll. Dessa två sorteringsförutsättningar är grundläggande för säkra och lönsamma produktinnovationer.**
– **Nya tekniker och processer för utveckling av nya innovativa, värdeskapande produkter från både mekanisk, kemisk och termisk recycling.**

Dessa båda områden är centrala för att värdet på insamlade textilier kan öka vad avser både volym och priser.

Förslag till fortsatt arbete; ett diskussionsscenario:

Förslaget är att skapa en flexibel öppen struktur, baserad på tre grundkomponenter:

1. Bygg upp **regionala sorteringscentra** som ger grundförutsättningar för insamlingsorganisationerna att bedriva sin verksamhet på ett effektivt sätt. En bra samlad sorteringsvolym (summan av varje organisations insamling och sortering) ligger lämpligtvis på ca 40 ton/dag. Vissa gemensamma funktioner kan utvecklas som t.ex. balning/packning, intern transportlogistik etc. Detta skulle ge skalfördelar utan att påverka varje organisations egna affärsprocesser. Det bör kunna vara självfinansierat genom hyror respektive sålda logistiktjänster.
2. Skapa en **agentur eller liknande** med uppgift att sälja exportkvantiteter på uppdrag av insamlingsorganisationerna. Motivet skall vara att bättre kunna optimera en kundsamman- sättning som ger en optimal mix av EKONOMI – EKOLOGI – ETIK. Genom att den totalt genererade volymen blir större borde en professionell organisation kunna nå bättre totalt utfall avseende de tre E:na. Erfarenheter från vår empiri ger vid handen att det finns pot- ential för bättre utfall. Den borde också kunna vara självfinansierad genom t.ex. provisionsintäkter.
   OBS. Om förutsättningarna förändras enligt vår studie kan en fysisk sorteringsanläggning strukturellt etableras och ersätta agenturen.
3. Ovanstående punkter ger förutsättningar för att bygga upp en **testbädd** som är inriktad på att kunna serva företag, forskningsorganisationer etc. med kapacitet att köra betatester, som är ett nödvändigt inslag i produktutvecklingsprocessen. Eftersom Sverige saknar en infrastruktur för både subindustriell produktion av fiber och recycling av textilier är detta en viktig förutsättning för utveckling av de produkter/processer som ligger till grund för värdeutvecklingen av använda textilier.

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1. Introduction

1.1. Motivation

Based on the presentation ReDesign from 2014 and the experience during the ongoing project ReDesign (2015) it has become apparent that the development of a national (Swedish) structure is a very important development step into the future, which must manage a number of critical issues:

1. Being a leading nation (region) in the development of a structure (and technical details) towards a real circular economy
2. Create jobs
3. Provide job training facilities for a new workforce generation, i.e. effects of migration etc.
4. Create a new industry section
5. Initialize new unconventional products and services

1.2. Questions

The original aim regarding feasibility of a national sorting structure corresponds to the following questions:

1a. Is there any feasibility in establishing a Swedish sorting facility for collected textiles, taking the present and probable near-future structural situation into consideration?
1b. Consequently, what are the main critical success factors for such an investment, also considering the present-day/near-future view?
2a. What would be a viable future structure in terms of logistics, technology and business models?
2b. How to develop a roadmap for a success scenario promoting a circular economy for used clothes?

The aim of the study is to highlight these issues and provide some conclusions and recommendations accordingly.

1.3. Methodology

We have focused our study on observing the present actions in the value chain from collection to actual end market conditions and the ensuing economical results.

The data for the study was obtained from:

1. Open sources (reports, homepages, etc.)
2. Study visits and interviews at both charity-driven organisations and business-driven companies and groups
3. Financial reports
4. Experience from our previous activities in this area
5. Scientific conferences
6. Ongoing projects. By observation of future products and business offices we have studied some of the ongoing R&D projects, for instance categorized in an SAC report (Sustainable Apparel Coalition).

The structures and business applications (as well as the role in social issues) of the total redesign area are very complex. Sometimes it has been difficult to interpret information to workable facts, but where appropriate we have checked facts from different angles and if decent

correlations are identified our conclusions are deemed supported. However, as always in stud- ies like this, one has to apply the approach that:
It´s better to be approximately right than definitely wrong...

2. Description of products and services

2.1. Background – existing structure of collection and sorting

This sub-section is structured under the following sub-headings.

A. Per capita clothing consumption and disposal
B. Structure of collection, main actors, and collected volumes
C. Structure of the used clothing network

2.1.1. Per capita clothing consumption and disposal

The per-capita yearly consumption of clothing and textiles in Sweden is about 15 kg (of which about 9 kg is clothing)[2]. However, when it comes to recycling and reuse, a much lower volume is recorded. Carlsson et al. (2011) suggest that each individual disposes about 8 kg of clothing and textiles into the garbage (ending up for energy recovery), while roughly 3 kg are reusable and collected by charities, and the remaining 4 kg either accumulate (e.g. in a closet or wardrobe) or are handled through other means of waste management (e.g. recycling centres)[3]. However, this calculation is underpinned by the assumption **"in = out"**[4].

2.1.2. Structure of collection, main actors, and collected volumes

Channels and actors

The collection system for used clothing in Sweden is highly fragmented with many actors, who engage with collection via various channels:

1. *Traditional street collection and kerbside containers:* maintained by various organiza- tions, like charities (e.g. Human Bridge, Stadsmissionen, Red Cross) through collaboration with municipalities, NGOs and some small enterprises. Campaigns are also organized to collect from people's homes. Unfortunately, there are many informal collectors currently operating, some of them illegal.
2. *In-store collection systems:* Several second-hand retailers like Myrorna and Emmaus, also collect used clothing through their stores.
   Several fashion retailers like H&M or KappAhl in collaboration with global sorters, like I:CO, also engage in collection activities. Some fashion brands, like Filippa K, Nudie Jeans, Haglöfs, also take back their own brands from the customer. This deposition of used clothing is generally conducted by providing discount coupons to customers, which may be used for the next purchases.

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[2] Carlsson, Annika, Kristian Hemström, Per Edborg, Åsa Stenmarck, and Louise Sörme (2011), Kartläggning av mängder och flöden av textilavfall. SMED på uppdrag av Naturvårdsverket [Mapping the Amount and the Flow of Textile Waste. SMED on Behalf of the Swedish Environmental Protection Agency], Report No. 46. Norrköping, Sweden: Sveriges Meteo- rologiska och Hydrologiska Institut [Swedish Meteorological and Hydrological Institute]
[3] Palm, Improved waste management of textiles, Project 9: Environmentally improved recycling, Report No. B1976 (April 2011)
[4] i.e. assuming the amount of waste reaches the amount expended during the year, although it is not the same garment. For further details on its advantages and disadvantages, see Carlsson et al. (2014). ReDesign kläder: Förstudie [ReDesign Clothes: Prestudy]. Borås, Sweden: (VGR),
http://epi.vgregion.se/upload/Studio%20ReDesign/Rapporter/ReDesign%20Kl%C3%A4der%20%20F%C3%B6rstudie.pdf (January 2015)

3. *Recycling stations:* At designated recycling stations operated by the regional municipalities, often in cooperation with charities.

Volume

Second-hand retailers and charity organizations are by far the largest collectors of reusable clothing in Sweden accounting for a yearly per-capita collection of nearly 1.8 kg. This accounts for nearly 16,000 tons of clothing being collected yearly by the ten largest second-hand retailers and charities in Sweden.

A small portion is also collected by fashion retailers through their recent engagement with in- store collection activities. H&M, for example, one of the largest collectors among them, col- lected just over 3,000 tons of used clothing (worldwide) in 2014[5]. Unsold clothes are also sent to the charities (<0.1 kg per capita yearly).

More details on some of the major actors' collection volume are found in the table below:

Organisations	Amounts yearly*	Collection points
Emmaus Björkå	3100 tons**	✓ Bins in public sorting stations and recycling centres ✓ Pick-up trucks ✓ Events
Human Bridge	7700 tons**	✓ Bins at municipal recycling centres and recycling stations ✓ Kerbside bins ✓ Household garbage rooms ✓ Retailers ✓ Private second-hand shops.
Myrorna	8000 tons	✓ Own second-hand stores ✓ Bins in municipal recycling centres ✓ Own events ✓ Retailers
Swedish Red Cross	5000 tons	✓ Their own 280 second-hand stores ✓ Workplaces and schools

Table 1. Collection volumes and locations.
** The numbers are approximate*
*** The numbers are for 'original collection' and can include other things than clothing.*

2.1.3. Structure of the Swedish used clothing network

A commercial chain for used clothing requires several steps for value generation, viz. collection and sorting, refurbishing (e.g. repairing, washing etc.) and redesigning. Fashion businesses run all these reverse value chain activities, either single-handedly by arranging both take-back of used clothes followed by reselling them through various retail formats, or by getting involved in collaborative networks with a number of other partners to carry

[5] http://fashionista.com/2014/01/hm-launches-denim-line-made-from-used-clothing (November 2015)

them out[6]. The figure below highlights the diverse actors operating in the Swedish network, their associated reverse logistics activities and generic flows[7]. The major ones are charities, clothing brands and rede- sign brands.

Collection system

Mapping of the flow reveals various actors involved in the collection process and through multiple channels (as mentioned above). The charities are the largest collector, as they collect material directly from consumers through multiple channels or through donation partnerships with retailers and clothing brands.

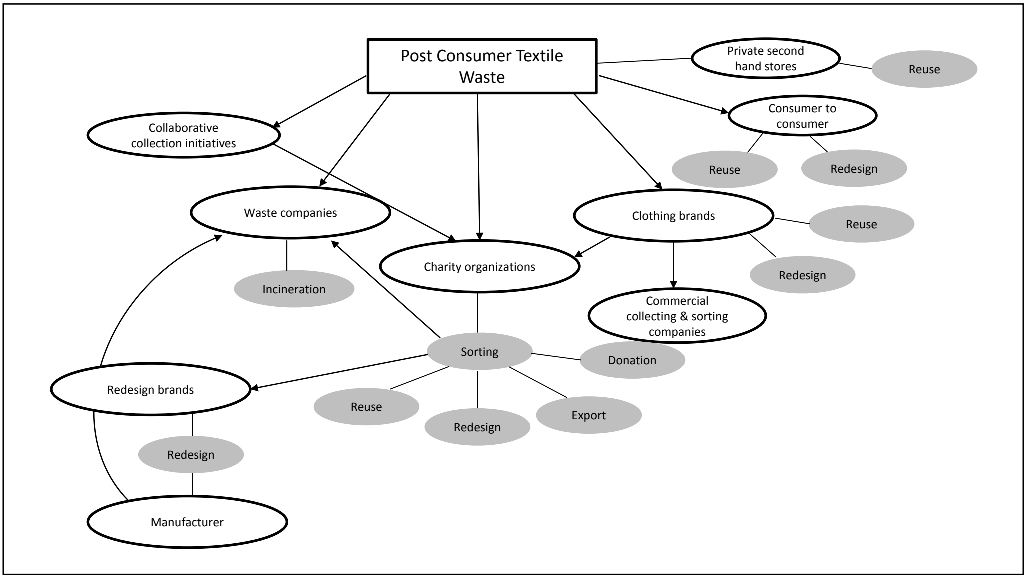


Figure 1. Mapping of used clothing network in Sweden

Clothing brands also engage in collection of used clothes through their own shops. Some clothing brands and retailers act as middlemen between consumers and commercial collection and sorting companies, and hence the clothing is not sorted but directly sold/donated (e.g. H&M and KappAhl's collaboration with the global sorting company I:CO). Others are selective about which garments they accept, due to internal processing for new value creation through reuse and/or redesign (e.g. Boomerang, Nudie, Filippa K).

Recycling stations, waste and energy companies: Recycling stations are a key nation-wide collector of textile and clothing through sack and bin-waste collection system. The majority of this is used for energy recovery at recycling centres. Material recycling is not conducted in Sweden at a commercial level. Large scale industrial recycling of textiles occurred in Sweden until 1992. Since 1992, only recycling has been of discarded rags as industrial wipes.

[6] Hvass, K. K. (2014). Post-retail responsibility of garments – a fashion industry perspective. Fashion Marketing and Management, 18(4), pp. 413-430.
Ekström, K. & Salomonsson, N. (2014). Reuse and Recycling of Clothing and Textiles – A Network Approach. Journal of Macromarketing, pp. 1-17.
[7] Johansson, E. and Nyström, M. 2015, Textile Waste is only matter out of place: Antecedents of value creation in reverse textile value chains, Master's Thesis, University of Borås, ID: 2015.16.03

Sorting system

The collected material is sorted by the charities and second-hand retailers in own facilities to take out the top quality garments which are generally resold "as they are" in Sweden, while the rest is exported. The sorting generally takes place in two phases, initial and fine, to end up with ~10-20 different SKUs, defined by:

1. Section (men's wear, women's wear, kids' wear, accessories)
2. Basic category (t-shirts, trousers, denims, jackets, ...)
3. Season (summer, spring, autumn, winter)
4. Price range

Depending upon the in-house sorting capability, export amounts range between 55% (in case of Stadsmissionen) and 73% (in case of Myrorna) for the largest actors, with Poland and the Baltic countries as the major destination markets[8]. Both sorted and unsorted goods are exported to the various markets at different prices, packed in bales or big bags and sold at kilo price. Hence, export provides lower incomes compared to selling the garments for reuse in Sweden.

Some charities work with redesign in small-scale projects, but not regularly. However, they do provide material to small redesign brands, both sorted and unsorted. Studio Re:design[9] was such an initiative, funded by Västra Götalandsregionen (Region of West Sweden). Generally the redesign brands receive material from charities with whom they (sometimes) collaborate in projects. The redesigned products are manufactured by third parties, e.g. criminal wards, aimed mainly at creating jobs for the marginalized section of the society.

Appendix III further provides a comparative study of the existing structure of collection and sorting in six countries, viz. Denmark, Germany, France, United Kingdom, Switzerland and Canada.

2.2. Business motivation for second-tier sorting in Sweden

The business motivations for developing a second-tier sorting facility at the national or regional level in Sweden, along the triple bottom line of economic, social and environmental perspectives, can be identified as follows:

1. Economic motivation:

a. **Profits:** Establishment of a second-tier sorting location in Sweden would facilitate the retention and selling of used clothes left after the major collectors have collected and cherry-picked the items (~20% of the collection volume). Presently, this volume is ex- ported outside Sweden by the charities at a very low cost (1-2 SEK/kg). Competitive trading of these used clothes in the export market instead would give a better price (~4-5 SEK/kg), hence profitability to all involved actors engaged with the network, compared to what the charities currently sell for. Connected to down-cycling or remanufac- turing this can be a rather unique business idea in the Swedish context.

b. **New products:** Establishment of a second-tier sorting location with associated research and development (R&D) could help to development novel and innovative products, like

[8] Interviews with Emmaus and Myrorna (2015)
[9] hhttp://epi.vgregion.se/studioredesign/ (June 2015)

non-woven and semi-processed materials with multiple technical and functional uses (mentioned in detail in the section "Products and services"). Commercialization of these products can be profitable in the long-run. Currently, Sweden does not have any remanufacturing plant or facility, thus representing a white space for new product innovations.

2. *Social motivation:*

a. **Job creation:** A second-tier sorting facility can create many job opportunities regionally. Further, realization of subsequent down-cycling or remanufacturing can boost development of domestic production, also resulting in additional job creation. This is in particular a positive aspect amid increasing migration of refugees in Sweden.

b. **Regional upgradation:** A second-tier sorting facility can motivate the development of vocational programmes and schemes to educate the newly created workforce, of various disposition and remanufacturing activities. This can enhance the knowledge intensity over time, resulting in development of a regional "smart specialization".

3. *Environmental motivation:*

a. **Resource efficiency** (moving up the EU waste hierarchy): Development of a second-tier sorting facility is expected to appropriate a sufficient amount of used clothes, which otherwise would end up for incineration or perhaps even landfill, which forms the lowest level in the EU waste hierarchy. Second-tier sorting can improve the scope of re-manufacturing, which can result in attaining higher resource efficiency, hence lower utilization of virgin materials.

3. Technology considerations

3.1. The state of the art in collection and sorting technology

3.1.1. Collection techniques

Collection may be considered as one of the salient processes in the closed-loop supply chain. The future of the close-loop supply chain largely depends on the quantity and quality of col- lection. Contemporary methods used to collect textile scrap are namely manual method and container collection.

Manual: Manual method includes direct hand-over of scrap to the second-hand shops or charity organizations by consumers. The charity organizations selflessly collect waste as well as create awareness amongst consumers to donate the used material. However, several brands have taken initiatives by asking consumers to return or donate textile products after use at their outlets. In lieu of those donations, consumers get discount coupons for a new purchase from their store. The extant awareness has caused several private players to enter in this domain.

Containers: Placement of containers or bins provided by charities or recycling organizations can be appraised as one of the main sources of collection[7]. The size of containers varies with location. In general, smaller containers are located near market places, while larger ones are placed near recycling stations.

3.1.2. Sorting techniques

Extraction of value from waste involves subjectivity. This may be because the process is heavily dependent on the decision-making ability of workers[10]. Currently, decision-making regarding sorting of textile products is manual. However, there have been several attempts to automate the material handling process. On this basis, sorting can be classified as:

Manual: In this process material handling as well as sorting is carried out by humans. The collected textile material is spread on a table, where all non-textile materials, like shoes, plastics bags etc., are separated. Later, depending on the type and condition of material, they are sorted into different categories and put in separate boxes. This kind of practice is very common at small and medium-sized charity organizations. The reason that can be attributed is that these organizations do not get collection in bulk.

Conveyor belt: Commercial and charity organizations handling large amount of waste use conveyor belts to simplify material handling. With the help of an automatic lift system, collected material is fed via a conveyor belt. At the first stage all non-textile materials are separated. Later on, depending upon quality, type and requirements, textile products are segregated.

They are either kept in containers or disposed into a duct. These ducts guide material into different areas for further operations.

Sorted materials are baled in different sizes with baling machines. The size of bales depends on the requirement and destinations. Currently, specialized technologies are not common in practice used for sorting. Recently, practitioners and academicians have emphasized the importance of innovative technologies for segregation of heterogeneous material.[11] Therefore, we expect technological advancements in this sector to have a high potential in the near future.

3.1.3. Recycling technique

Products which have lost their functional value generally tend to form part of material left for recycling. These products are sorted based on colour and fibre composition. All kinds of trims (zippers, buttons, etc.) are taken out from the clothes before extracting fabric or yarns. Mechanically, clothes are cut or shredded to make wipers and rags.

To extract fibres and energy, chemical and thermal recycling, respectively, is made. In some cases even mechanical recycling is made to generate fibres out of used textile. However, more than one technology is used to make non-woven products like carpeting and composites.

[10] Botticello, J. (2012). "Between classification, objectification, and perception: Processing secondhand clothing for recycling and reuse." Textile: The Journal of Cloth and Culture 10: 164-183.
[11] Tojo, N., B. Kogg. N. Kiörboe. B. Kjaer & K. Aalto. (2012). Prevention of Textile Waste..TemaNord 2012:545, Nordic Council of Ministers.

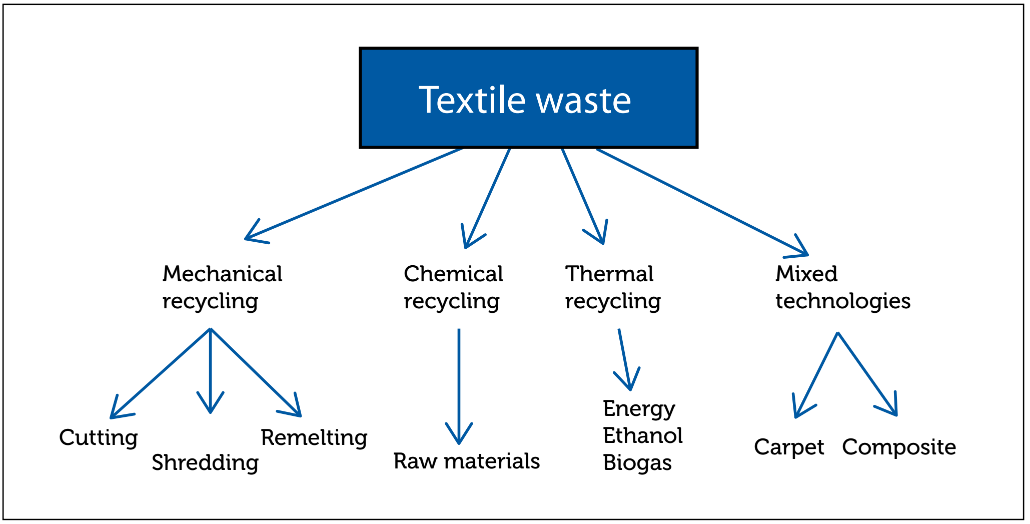


Figure 2. Types of recycling

3.2. Prospective new technologies

3.2.1. Collection techniques

Every company is trying collect best quality of products. In order to do this, they use various innovative techniques. Few important initiatives are as follow:

Postal/Courier Service: To enable better reach to consumers, postal or courier services are also used to collect unused clothes to second-hand factories directly.[12] The bag for postage can be collected from the retailer or a nearby post office. However, internet websites can be used to order postage bags or bar codes for free postage.[13] But, still this practice is not very common.

Mobile App/Websites: The advent of internet technologies has further simplified the collection process. Many charity organizations are providing facilities on their websites to register for pickup service. For example, Excess Access[14] provides an opportunity to consumers to upload the image of unused products, which can be picked up by charity organizations. Also, there are a few companies which send shipping labels by mail. This can be used for mailing bags free of charge.

3.2.2. Sorting techniques

The use of technology is prevalent in sorting material in forwarded supply chain. But its use in sorting plastics and other materials in close loop supply chain has recently being recognized. Few of the attempts are mentioned below:

[12] Palm, D., M. Elander, D. Watson, N. Kiørboe, H. Salmenperä, H. Dahlbo, S. Rubach, O.-J. Hanssen, S. Gíslason and A.-S. Ingulfsvann (2015). A Nordic textile strategy: Part II: A proposal for increased collection, sorting, reuse and recycling of textiles, Nordic Council of Ministers.
[13] North, Amy (2014). Textile recyclers target used clothing via website, accessed on 26 November 2015: http://www.letsrecycle.com/news/latest-news/textile-recyclers-target-used-clothing-via-website/
[14] Excess Access, Accessed on 27 November 2015: http://excessaccess.org/

Bar code: This method is extensively used in almost all sectors. For instance, a London-based company uses bar codes to check productivity of workers, who work in sorting. However, a few other companies based in Oslo and Norway use bar codes after sorting. Bar code-enabled price tickets are printed out for different products, based on the type and condition. But still the use of this technology has a huge untapped potential.

RFID: Use of radio-frequency identification devices is considered as a robust technology in retail stores and warehouse management in forward supply chains. However, this technology can be used with containers and bags for ease of access. Reusability of RFID tags multiple times makes this a promising technology in future.

NIR: Optical Near Infra-Red (NIR) technology is extensively used in plastics recycling. This technology sorts the material based upon composition and colour. The Textile 4 Textile[15] project has developed similar technology for sorting products on the basis of fabric composition and colour. However, use of this technology at industrial level is very limited. Besides this there is a need of sensors to detect toxicity in used textile. This will facilitate infection-free reuse or recycling of used textile.

Robotics: Robotics is always considered a fascinating technology, which has the capability to replace human beings. An attempt has been made to develop a robot under the project CloPeMa[16] funded by EU. The 8 feet robot has a capability to make sorting decisions on the basis of quality, colour and composition. This robot can also fold sorted clothes.

3.3. Examples of technology development in Sweden

Sweden has always emerged as a leader in the development of new technologies and innovations. A mobile application, Cirqle[17], has been developed, which tells consumers about the nearest location of a charity organization and retail store, which collects used textile products. In similar notion, the Swedish fashion brand "Uniforms for the Dedicated" have developed THE RAG_BAG[18]. The bio-degradable shopping bag can be made into an envelope by turning it inside out. A proper postage stamp with the address of the charity organization helps consumers to easy donations. A new initiative has been taken to develop a national test centre for textile recycling[19] at Vargön, Sweden. The laundry industry in Sweden has also initiated advanced sorting technology together with for instance Jensen Group. University projects have started with the purpose of developing new sensor technology for identifying toxic additives and fibre contents in textiles.

[15] Alkazam (2013). "Textile Science & Engineering Automated Sorting Technology from T4T Can Help Improve Recovery and Efficiency." J Textile Sci Eng 3(3): 3-5.
[16] CloPeMa - Clothes Perception and Manipulation, access on 27 November 2015: http://www.clopema.eu/
[17] Cirqle, accessed on 27 November 2015, http://www.cirqle.se/
[18] The Rag Bag, accessed on 27 November 2015: http://www.theragbag.se/
[19] Wargon Innovation, accessed on 27 November 2015: http://www.wargoninnovation.se

4. Market perspectives

4.1. Products and Services

Description of the conventional markets in terms of available products is as follows:

1. TYPE I: Reusable clothing

Sorted used clothes provide a proper response to demand of both resellers and remanufacturers as a raw material. Unlike original used clothes they can be beneficial to resellers and recyclers, who are seeking for a specific type of fibre composite (e.g. polyester or cellulose based fibres) or stock keeping unit (white T-shirts), etc. Depending upon various collection schemes these reusable clothes can be classified into various categories by the global sorters. However, the generic schema is the same in most cases, as highlighted below:

a. "Very good, hardly worn, fashionable clothing" is classified as *Quality Extra or Europe quality.*
b. "Good, wearable clothing" is classified as *Quality Nr. 1 or Export 1 quality.*
c. Remaining material is sold as *Quality Nr. 2/3 or Export 2.*

2. TYPE II: Non-woven products

This group of products is manufactured through mechanical recycling (cutting, shredding and melting of clothing and textile waste). Some of the renowned companies working with mechanical garment recycling are: Wilson Knowles & Sons (UK)[20], Dell'Orco & Villani (Italy); Textiles Techniques Chaudières Appalaches (Canada).

There is a diverse range of products which can be made with this procedure, e.g.:

– Industrial towels/wipes, building materials (e.g. Dafecor[21] is a Finnish company producing these items through mechanical carding of used textiles).
– Insulating tapes
– Barrel-protection mats
– Oil-stops and other materials for managing harmful substances
– Acoustic, thermal insulations[22], e.g. ISOA's (France) cotton wool flakes, Buitex's (France) Isonat cotton wool flakes, Soprema's (Canada) drainage panels, etc.

3. TYPE III: Semi-processed raw materials

This group of products includes shredded and cut fabric and fibres which can be sold to other manufacturers. Recycling producers, car manufacturers and furniture producers illustrate ex- amples of the prospective buyers.

Various consumer goods are also produced by using these shredded materials like:

a. Rags
b. Cushioning and filling materials
c. Stuffed toys, insoles, bags
d. Recycled denims (with recycled yarns), e.g. G-Star (Netherlands) is making jeans out of 50% recycled material.

[20] http://www.wilsonknowlesandsons.co.uk/, http://www.dellorco-villani.it/, http://www.ttc-a.net/ (December 2015)
[21] http://www.dafecor.fi/ (December 2015)
[22] http://www.isoa.fr/isolation-naturelle/, http://www.buitex.fr/, http://www.soprema.ca (December 2015)

The table below shows the typical composition of the collected assortment of few well-known sorters and second-hand retailers. The composition indicates the how the actors sort out the reusable products (TYPE I) from the rest. The ones which cannot be reusable are either shred- ded (for both industrial and consumer products: TYPE III) or are recycled for mainly industrial applications (TYPE II).

<table>
<tr><th>FWS: a German sorter[23]</th><th>LMB: a British sorter</th><th>Gebotex: a Dutch sorter[24]</th></tr>
<tr><td rowspan="3">Re-usable clothing, 50%
No longer Re-usable, 50%

<u>Re-usable clothing</u>
Quality EXTRA, ~3% Quality Nr. 1, ~4%
Quality Nr. 2, ~38% Quality Nr. 3, ~4%

<u>No longer Re-usable</u>
Raw material for cloth manufacture, ~16.5%
Raw material recycling process, ~21%
Raw material (for quilt manufacture), ~2.5%
Waste, ~10%</td><td>50% re:use, 50% recycling
On recycling, approx. 50-50 split between wipers and shredded material</td><td rowspan="3">Reusable clothing and recycled product, 90%

Europe quality, ~9%
Export A, ~24%
Export B, ~16%
Rags, ~17%
Recycling, ~21%
Shoes, ~6%
Refuse, ~7%</td></tr>
<tr><td>Myrorna: a Swedish 2nd hand retailer[25]</td></tr>
<tr><td>Reusable clothing (at own shops), ~20%
Export, ~73% Reuse,
~79% Recycling,
~19% Landfill,
~2%
Energy Recovery, ~7%</td></tr>
</table>

Table 2. Composition of collected textiles

4.2. Geographical stratification

Geographically the destination of the various reusable or remanufactured products is diverse.

Myrorna, a Swedish second-hand retailer, reports a somewhat different flow of its collected clothing. Nearly 70% goes to Eastern Europe, Central Europe and the Baltic States (Poland being the biggest destination with over 55% of the imports)[26]. The rest of the clothing goes to Asia (Iraq and Pakistan), accounting for over 25%. The global sorters are in contrast very global with a broader sales market. In general, a much lower volume, ~40% of the total col- lected reusable clothing are resold in the country of collection and in other Western European countries. The next destination is Eastern Europe (~20%) followed by exports to Asia-Africa (~40%)[27, 28]. This changed picture of the destination markets can be assigned to two reasons:

1. a major part of the clothing received by global sorters are from the second-hand retailers, which have already been cherry-picked, thus having lesser potential to be resold in Western Europe, and
2. in most cases they do not have second-hand stores of their own.

[23] http://www.fws.de/EN/sortieren.html (November 2015)
[24] http://www.gebotex.nl/en/products/ (November 2015)
[25] http://myrorna.se/wp-content/uploads/Myrorna_insamlingsrapport_20141.pdf (November 2015)
[26] http://myrorna.se/wp-content/uploads/Myrorna_insamlingsrapport_20141.pdf (November 2015)
[27] http://www.fws.de/EN/sortieren.html (November 2015)
[28] http://www.gebotex.nl/en/sales-market/#!prettyPhoto[150]/1/ (November 2015)

However, the finest quality of reusable clothing is mostly resold by the sorters, either in the country of collection or in other Western European countries (~70%), while the poorer quality is either resold in Eastern Europe or in the developing nations of Asia and Africa (50-100%).

On the other hand, the part of the collected goods which cannot be reusable as clothing any longer, mostly finds itself being recycled or down-cycled and has 100% sales market in Western Europe.

4.3. Future perspectives for products and services.

The profit of the 80 % residual textiles after cherry-picking will be reduced, as it is export- based, and as a consequence of development in the receiving countries, they will successively generate second-hand textiles from their own sources.

Thus, considering the impact of different measures, it appears that the greatest potential is to be found in the development of new technology and novel business models for the collection and sorting activities. The following table summarizes this.

Re activity	**Local (national) impact**	**Global impact**
Reuse and ReDesign	Reduces new production from virgin fibres. Large national impact.	Small
Recycling to new products	Reduces new production from virgin fibres	Small
New technologies and business models	LARGE	LARGE

Table 3. Estimated future impact of re:activities.

Increasing value by added services is a timely approach to business development. One suggestion is to establish an agency with the aim to support the organizations involved (typically charity) to get maximum revenue observing the three E's. A professional agency has a possibility to work with larger quantities and to find more customers, through circumventing links in the value chain. This agency can be self-financed by commissions. It must work on market conditions and justify itself by offering a better total solution for the customers, i.e. the phase 1 actors.

Another proposed service addition is to establish a testbed for real test-runs in a semi-industrial environment in order to verify R&D and innovation processes or product inventions. Important considerations in this context comprise that the testbed requires both equipment and technical staff, that a specific feasibility study should be carried out, and that the testbed must have access to special fractions of collected textiles according to specifications. Benefits would be that the service provides critical capacity in the process of going from lab-scale to commer- cialization, and – from a national or regional point of view – that Sweden or the Region of West Sweden can be in the forefront of technology development regarding new products, new processes and new business models in the area of Re:Textile.

5. Financial considerations

5.1. Background

A sorting facility for recycled clothing can process, say, 8,000 tonnes of such clothing per year, equivalent to 40 tonnes per day, according to observations at existing sorting plants. The vol- ume corresponds to about 40% of the total consumption (13 kgs/capita) in the region of Västra Götaland (West Sweden). Typical market segments can be assumed as

– High-value clothing, delivered to second-hand stores: 10-20%
– Clothing of lower quality, exported primarily to markets in Africa and Asia: 35-45%
– Cotton clothing lacking wearable quality, torn into wiping rags: 20%
– Recycling into fibre material by mechanical and chemical methods: 20%
– Unusable synthetic clothing, sent for energy recovery (incineration): 5%

The challenge here is to develop value adding features, such as redesign, that will qualify more material for the top of this list, and to optimize the sorting process accordingly. Benefits beyond the strictly commercial activity can be the recruitment of a workforce having limited abilities to establish themselves in regular employment.

5.2. Scenario

One scenario is where the sorting facility receives 80% of the volume from the primary sorter, which may be a charity organization, thus the prime fraction that can be sold at a relatively high price is not available. The sustainability value of textile recovery is recognized by society, including the ability to employ an otherwise disabled workforce, and supported by some legislation provisions.

5.3. Income and cost estimates

Income is to a large extent based on export of second and third fractions, of two different grades destined for Eastern Europe and Africa, respectively. Residual fractions are used for the production of rags, recycled by mechanical or chemical methods, or discarded as waste, where energy recovery is the preferred result.

As stated above, the revenue generation potential by selling the prime, "cherry-picked" items of the collected clothes "as they are" is the highest. Depending upon the retail mark-up the average retail price can be up to 150 SEK/kg. Further details to be highlighted are the following:

1. On an average, the distribution of the collected volume in terms of quality is as follows – Prime/cherry-picked (~20%), East Europe (10-15%), Africa (10-20%), Rags (~20%), Recycling (~20%), and Waste for energy incineration (~10%).
2. The average wholesale price/kg obtained by the sorter are: Prime/cherry-picked (~40 SEK), East Europe (20-25 SEK), Africa (10-15 SEK), Rags (3 SEK), Recycling (3 SEK), and Waste for energy incineration (-0.20 to –0.50 SEK)[29].
3. Weighted wholesale price/kg: Including prime = 16.5 SEK, Excluding prime = 6.5 SEK[30].
4. Actual wholesale price/kg of unsorted items (including prime) = ~8-10 SEK, Actual wholesale price/kg of unsorted items (excluding prime) = ~4-5 SEK.

[29] Most of the time, the sorter pays the energy companies for incineration.
[30] Weighted calculation made on the basis of points 1 and 2.

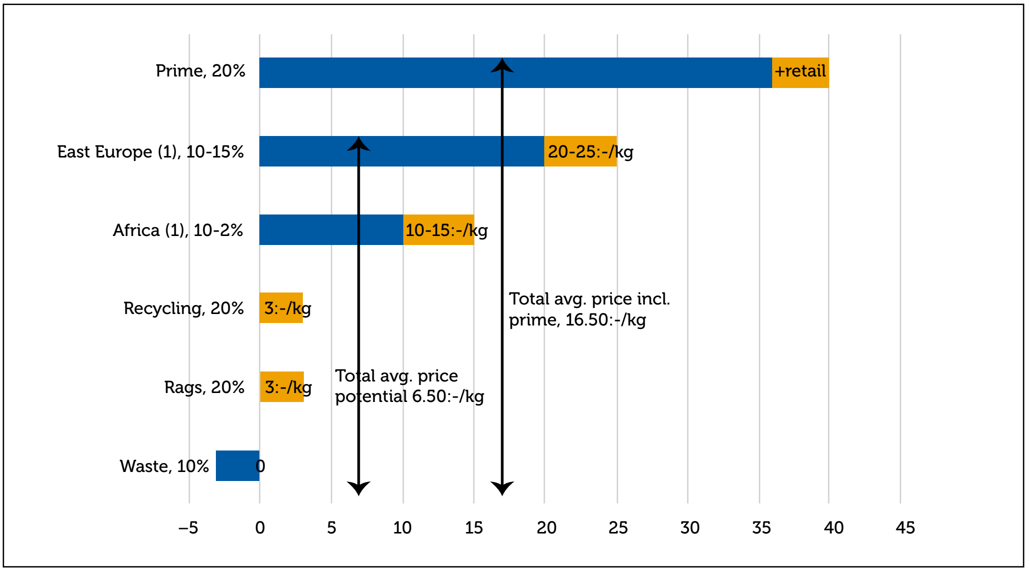


Figure 3. The diagram explains how an average price can be estimated from the expected volumes of the respective fractions and their typical price tag, in SEK/kg.

5.4. Profit and loss estimates

For a second phase sorting taking place in Sweden, the following costs and conditions can be assumed, based on available information in annual reports, websites and on-site observations:

Purchase of pre-sorted goods.............2-4 SEK/kg + transport 0.50 SEK/kg; avg. 3.50 SEK/kg Sorting need and capacity.................................... 40 tonnes/day/facility; 800 kgs/person/day Workforce, incl. administrative staff .... 50 Wages, incl. employer taxes ....216 SEK/hr, 1,728 SEK/person/day; 86,400 SEK/day Assumed other costs (capital, marketing, sales etc.) .... 100 % of wages; 86,400 SEK/day Total processing cost .... 4.30 SEK/kg + 3.50 SEK/kg; 7.80 SEK/kg Potential selling price 1.50-250 SEK/SKU, average estimated income .... 6.50 SEK/kg

The calculated scenario displays a deficit of SEK 1.30 per kg, thus under the assumed conditions the establishing of a national sorting facility is deemed not feasible.

6. Risk considerations

A comprehensive risk assessment is essential for the investment and planning of the textiles sorting facility. In this context, risks can be categorized coarsely as

– Supply and demand risk
– Control risk
– Process risk
– Product risk

Supply and demand risk is associated with inadequate supply, small or fluctuating demand, inability to meet a certain demand by restricted product assortment, inappropriate inventory management or prolonged lead-times, inability to achieve reasonable contribution by low prices or high costs, inability to communicate value to customers, etc.

Control risks comprise political risks, such as legislative barriers, trade union intervention regarding wages and conditions, lacking support from public entities, export and import restrictions, etc., and the lack of supporting structures, such as research and development facili- ties and activities, addressing the sector.

Process risks to some extent overlap the logistics risks related to the management of supply, including collection of used or otherwise discarded garments, and distribution, including delays and principles for risk sharing along the supply chain. It may also include bottlenecks, inappropriate inventory management and inefficient flows in the sorting facility. Process risks also relate to inadequate business models, labour issues and technological insufficiencies.

Product risk relates to the quality of the material before and after sorting, inappropriate sorting categories, the presence of toxic and other hazardous substances, and the sometimes problematic composition of fibres and auxiliary materials. It may also comprise commitments regarding warranties and returns.

It is recommended to perform a risk assessment at an early stage of the development of the sorting facility. Using established methods, risk identification can preferably be carried out by a What If analysis or a PHA, Preliminary Hazard Analysis, maybe amended by a system FMEA (Failure Mode and Effect Analysis) for greater detail and criticality assessment.

Risks categories for second-hand sorting in Sweden[31]	Types	Risk mitigation strategies
Supply risks	**1. Low incoming volume** Large fraction of items may be removed through first sorting and cherry picking by collectors	✓ Develop profitable contracts with initial collectors (mainly charities) to ensure better quality against higher wholesale price. ✓ Develop schemes to increase per capita disposal, higher than sorting and selling capacity of collectors
	2. Low per-capita disposal Large amount of unused clothes accumulates in consumers' wardrobe year after year (~20 garments/capita yearly)	✓ Collaborative efforts by actors to educate and raise awareness of consumers ✓ Provide monetary or value refunds ✓ Create easy access to disposal system
Demand risks	**1. Low future demand for reusable clothes** Growing purchasing power parity (PPP) in developing countries (the present destination markets) could lead to low demand for used clothes in the near future	✓ Develop more upcycled prime and redesigned products ✓ Develop new product-services and business models for these products
	2. Lack of future market development strategies for recycled products	✓ Develop radically new market-oriented and value-added recycled products ✓ Identify the blue ocean strategies to reach beyond existing demand and market
Process risks	**1. Inadequate best available technology (BAT)** Available technology for automatic sorting and removal of toxic contents is still under-developed to meet the challenges	✓ Highly prioritize development of cheap sensor technology for identifying "toxic" content and fibre content
	2. Low sorting capacity	✓ Sorting technology upgradation ✓ Increase workforce or workforce productivity
	3. High labour costs	✓ Workforce training to increase labour productivity ✓ Increase technology intensity in sorting
	4. Incompatibility of traditional business model	✓ Develop an open and flexible structure in order to respond to fast structural and technological changes in the market conditions (as proposed here in an agency-based business model) ✓ Develop leasing agreements with collectors
	5. Increasing PPP in developing countries	✓ Offer more upcycled prime and redesigned products ✓ Offer new product-services through new business models for these products
	6. Lack of vertical integration in the textile and clothing industry	✓ Consolidated effort from TEKO and other relevant industrial and actors and businesses to integrate the production skills, infrastructure and capacity for reusable clothing, rags production and recycling industry
Control risks	**1. Legislative barriers**	✓ Lack of mandatory or similar EPR scheme in Sweden resulting in a very fragmented and highly competitive collection system, resulting in low volume aggregation
	2. Lack of relevant R&D	✓ Establish a testbed for real test runs in a semi-industrial environment in order to verify R&D and product/process innovations

Table 4. Risk types and proposed mitigation

[31] Structured in line with Christopher, M. and Peck, H. (2004), Building the Resilient Supply Chain. International Journal of Logistics Management, 15(2), pp.1-14.

7. Findings and recommendations

It is evident that realistic conditions do not permit a profitable, fully commercial sorting facility. There is a need for further value-adding features, which must be developed in order to ensure the feasibility of such a national facility.

The critical success factors are proposed as follows, based on the analyses reported in chapters 2, 3 and 4 above

1. Today the work relies to a great extent on voluntary work and – to a lesser degree – on *subsidized workforce.* For a national facility there will be a requirement that this condition is institutionalized and supported by legislation, occupational measures or general practice.

2. *Increased prime quality in incoming material* will raise the income level of sold fractions. There are ways to achieve this, of which one is to convince consumers of providing lesser- used material for collection – perhaps at the cost of shorter first-hand use. Another possi- bility is a sharing agreement with the charities, which carry out the first-tier sorting. It involves also measures to enable consumers to make more educated decisions. A certification system may also be helpful to achieve better quality. New actors should be encour- aged to join the market.

3. *Increased productivity* in the sorting centre.

4. *Increased value of output* can otherwise be achieved by innovative sorting, cleaning, rede- sign and remanufacturing methods and development of new products.

5. *Automated sorting* may become increasingly appealing, as new sensors and devices for image-processing, identification, robotics and affordable control units become available. Technology development is needed regarding inexpensive sensors for identifying toxic additives in textiles and for fibre contents.

6. *New business models,* for example streamlined selling/purchasing by agents, who also provide training, packing etc., web services for used textiles brokerage, or financial recalculation of sustainability values, may become established.

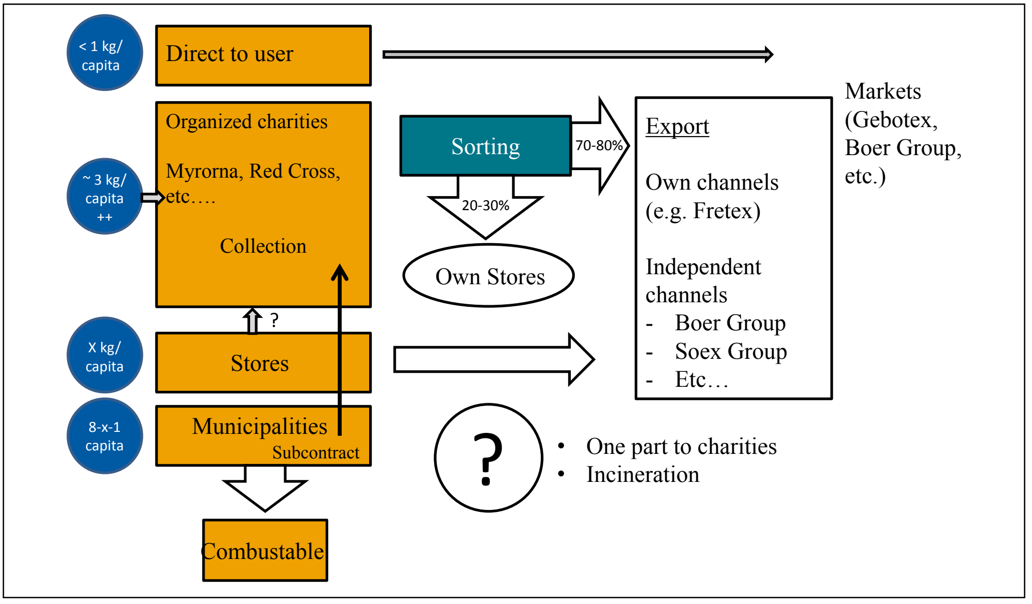
7. *Provision of parallel technical and administrative services,* such as making a test bed available for new development projects, as indicated in 4.3 above, may as well be an opportunity.

Appendices

I. Model for scenario evaluation

A model was developed to assist in judging the feasibility of a sorting centre for used textile in Sweden.

I.i. Flowchart of the process of collection and sorting



I.ii. Calculation model

INPUT COST					
Collection					
TYPE		**Cost**	**Qnty (kg)**	**Total**
Direct handover				
Collection bins				
Home collection				
Postal/Courier				
Cherry Picked				

OPERATION COST			
Sorting			
TYPE	**Cost**	**Qnty (kg)**	**Total**
Manual			
Conveyor belt			
Sensor based			
PROFIT=	**REVENUE**	**(-) COST**	
	RESULT	**FEASIBLE NON-FEASIBLE**	

REVENUE			
Market			
TYPE	**Cost**	**Qnty (kg)**	**Total**
Domestic			
East Europe			
Africa			
Rags/Wipers			
Recycle			
Incineration			

I.iii. Examples of parameters

As explained in Section 6.4 of the report, acquirement cost for used textile is 3.50 SEK/kg and operations (sorting) cost is 4.20 SEK/kg, while revenue can amount to 6.50 SEK/kg. Under these conditions a sorting centre in Sweden is not deemed feasible.

I.iv. Simulation study

A mathematical simulation[32] was conducted to develop a probability-based model of volume flow of post-consumer textile wastes (PCTW) in the present Swedish system and also to cal- culate after how many cycles these would end up at the disposal stage. A three-stage multi- echelon chain was chosen representing: Stage 1: Consumer's Wardrobe, Stage 2: Second-hand: Collection/Sorting/Repair, and Stage 3: Waste/Recycling. From the PCTW flow (in volume), in a Swedish context reported in Tojo et al. (2012)[33], the probability of the material to be at each particular stage was calculated. This is represented by a probability matrix, whose values are denoted by various probabilities (Figure 1); e.g. p12 represents the probability of the PCTW to be in state S2 at stage 2, given that the process was in state S1 at stage 1. This probability does not depend upon which state the chain was in before the current state.

32 Using Markov's chain principle and Matlab tool

33 Tojo, N., Kogg, B., Kiørboe, N., Kjær, B. & Aalto, K. 2012. 'Prevention of Textile Waste Material flows of textiles in three Nordic countries and suggestions on policy instruments.' In I.-. TemaNord (Ed.). Copenhagen: Nordic Council of Ministers

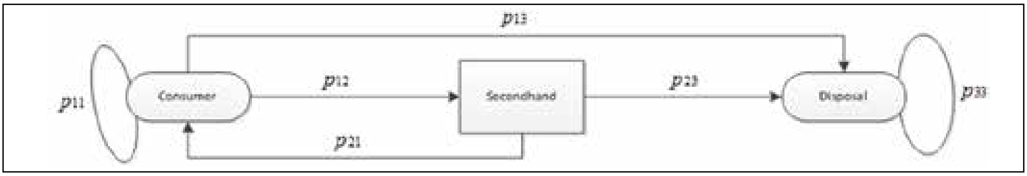


Figure 1: PCTW value chain states, stages and probabilities

On the basis of above disposal volumes in the Swedish PCTW flow, we derived a value of n = 18, meaning all PCTW at state 1 will end up at state 3 (disposal) after 18 cycles. However, after 5 cycles, nearly 95% of the collected material ends up at disposal (Figure 2).

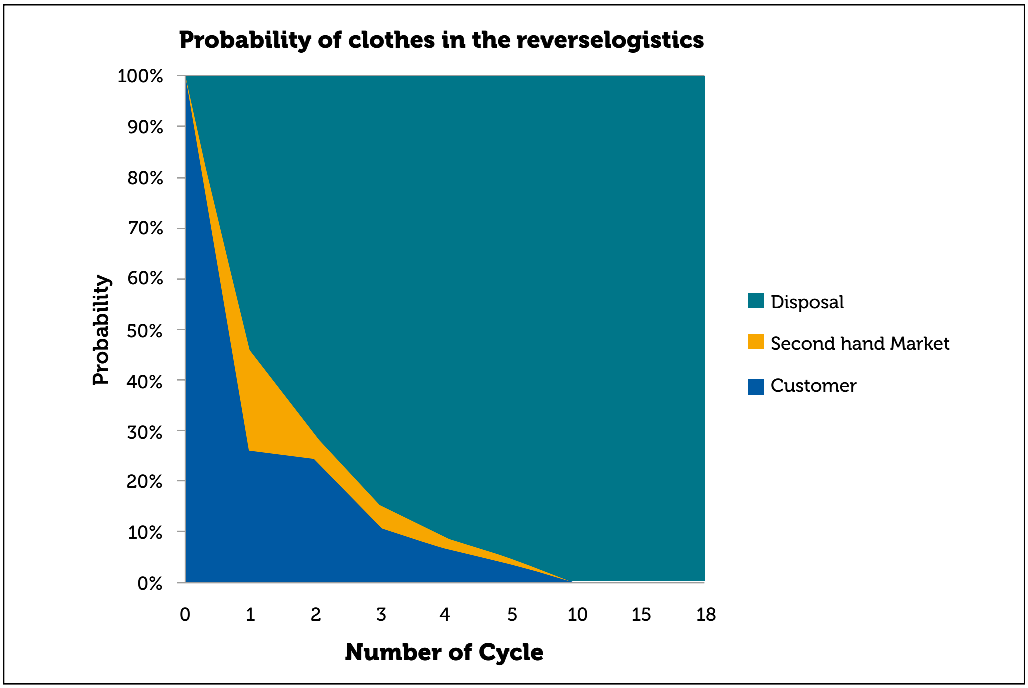
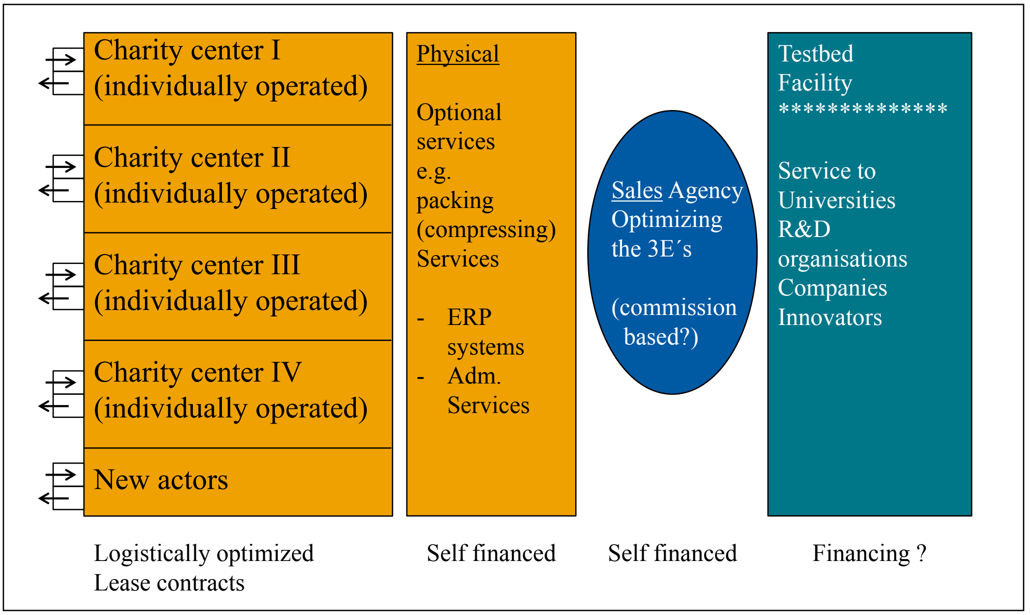


Figure 2. Probability of PCTW in reverse value chain after various cycles

Future work can develop a more realistic version of this simulation (reducing assumptions made), based upon defining the probability of each stage of collection, sorting and processing activities for creating various scenarios.

I.v. Summary of the proposed scenario



II. List of companies visited

S.No	Name	Place	Visit
1	IL Recycling	Stockholm	September 2015
2	Human Bridge	Jönköping	September 2015
3	Emmaus Björkå	Gothenburg	September 2015
4	Fretex Norge AS	Norway	October 2015
5	Lawrence M. Barry & Co	London	November 2015

III. Existing structure of collection and sorting in six countries

Coun-tries	***Total consump-tion of textiles per capita***	***Total collected per capita***	***Structure of collection, who is the main actors, volumes etc.***	***Structure of the collected clothing network***	***Revenue in the value chain***
Denmark	~89,000 tons(2010) or 16 kg/capita	~41,000 tons (2014)	Container collection, I: CO, Door-to-door **Main actors:** Salvation Army, Danish Red Cross, Danchurch Social, Trasborg, UFF (~25 actors)	~90% exported; ~8-10% re-used in Denmark Danish Red Cross, Trasborg – sorting along ~125 criteria in Denmark Danchurch – sells across 240 shops in Denmark only UFF – sends to Humana	Euros 0.45-4/kg for exported used textiles
Germany	1,126,000 tons (2008)	750,000 tons (2008)	I: CO system, Containers, Door-to-door **Main actors:** SOEX, Boer, German Red Cross	43% reused as clothing, Boer, SOEX – Own auto-matic sorting plants; ~400-450 tons/day; over 300 stock keeping units (SKUs)	Euros 0.3-0.6/kg for collected stock in Ger-man market
France	700,000 tons/year (2009) or 11 kg per capita per year	154,000 tons col-lected (2.36 kg/capita/year) – 15% of total;	26,000 collection sites (1850 charities, 22,200 collection banks, 1950 protected booths) **Main actors:** Member of Eco-TLC	40 EcoTLC sorting plants in France; 138,800 tons sorted – 11% of total 60-65% reused (France - 10%, EU – 10%, Africa – 80%)	Revenue for EcoTLC: EPR fees Euros 14 million; Rates - 0.00121-0.0484 Euros Hors taxe (HT)[75]
UK	1.1-1.4 million tons/year (2010)	700,000 tons (2010); 56% re-used/recycled/re-covered	Textile banks (36%), Door-to-door (23%), Charities (19%); ~7000 charity shops member of CRA **Main actors:** Charity Retail Association (CRA), Oxfam	~60 sorted in UK; 40% sorted overseas Various sorted grades (rang-ing 4-30) based on quality	Euros 0.35/kg - mix of textiles in textile banks, Euros 0.61/kg - shop collections, Eu-ros 0.8/kg - charity rags
Switzer-land	Total 10.6 billion CHF (2014); *<Fur-ther data on vol-ume is unavaila-ble>*	50,000 tons col-lected (~6 kg/cap-ita/year); Plus 50,000 tons as-sumed as garbage collection	Containers, street collection, REVANT **Main actors:** TEXAID & CON-TEX, Tell-Tex (SATEX & Soli-tex)	TEXAID, Tell-Tex – Swiss semi-automatic sorting plant; TEXAID sorts ~100 tons/day into 60-80 criteria (65% use-able textiles)	*<Clear data unavaila-ble>*
Canada	Total: 1.13 billion (over $30 billion); 31.67 gar-ments/year *<Further data una-vailable>*	7 kg (of clothing) (~15 lbs.) *<Further data una-vailable>*	Containers & collection bins, Door-to-door **Main actors:** TWD, ECTR, TCTR	Useable clothing (80%); Wiping rags; Textile recy-cling (20%)	~14 cents/exported T-shirt to Africa *<Further data unavail-able>*

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