SUPPLY CHAIN CHALLENGES FOR SUSTAINABILITY: THE CASE OF WASTE TEXTILES AS RAW MATERIALS

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Relatively little has been written about the fate of textiles after they have reached the end of their useful life within sub-Saharan Africa. Unmanaged discarded textiles can cause environmental and health problems and loss of economic value. Environmentalists argue that uncontrolled burying of synthetic materials may hamper water absorption to the soil, the resulting run-off of rainwater may collect in stagnant pools and contribute to the spread of malaria (Garland 2009). Meanwhile, open burning of mixed household wastes either in backyards or on landfills results in emissions of greenhouse gases to air and inhalation of the resulting gases and aerosols pose a public health risk (Wilson, Velis et al. 2006; Medina 2010). Domina and Koch (1999) identified that post-consumer textile waste is a potentially valuable commodity, but that the value inherent in the materials is often not realised. Our field trip to Tanzania explored the potential for value in the textile fraction of Dar es Salaam's post-consumer and post-industrial apparel waste to be realised.

1. Waste Management in Dar es Salaam

The UN have reported that the fastest rate of urbanisation is in the African countries (UN 2008) and predict that virtually all the world's population growth over the next 30 years will be concentrated in urban areas (UN,2013). With a current population of approximately 3.5 million and a 5% growth rate in population, solid waste management in Dar es Salaam is a pressing issue (Breeze, 2012, Kassenge et al, 2012).

Dar es Salaam, the major commercial centre in Tanzania, has four local councils: Temeke, Ilala, Kinondoni and Dar City Council (DCC) (Faldi, 2011). DCC is headed by the Mayor and the City Director (who is responsible for all activities and reports to the City Mayor). DCC has five departments including the Administration, Human Resources and Finance, Urban Planning, Environment and Transportation, Works and Fire Rescue, Waste Management and Health with associated Heads of Departments who report to the City director (Dar City Council, 2004). DCC coordinates activities, promotes cooperation between the City Council and amongst local government authorities within the City; the Municipalities (Kinondoni, Ilala and Temeke) supervise the activities in sub wards. Although the Local Government Act 1982 empowers the DCC to coordinate activities among the municipalities there is no structure or mechanism outlined for accountability of the municipal councils to the DCC. This has to some extent caused difficulties in the delivery of services and implementation of development projects since in most cases the municipalities work independently without consulting the City Council. An example of this is in the approach to waste management.

The City Council is mainly responsible for solid waste disposal including development and management of the Pugu Kinyamweze dumpsite. Collection and transportation are handled by the respective municipalities as stipulated in the Local Government (Urban Authority) Act 1982 (Section 55). However, planning of various activities concerning waste management is done jointly by the municipalities and the City Council (Dar City Council, 2004). The DCC Head of Department coordinates all departmental activities including supervision of operation and maintenance of the Pugu dump site and coordinating the three municipal councils (Ilala, Kinondoni and Temeke) in management of waste. Waste management services are placed under Waste Management

Department. Other departments such as Works, Health, and Urban Planning are also involved, eg the Environmental Health Officer deals with management of the solid waste dumpsite. Municipal Councils play an important role in the financing, planning and providing waste collection and disposal services from residential, industrial areas and commercial establishments like markets and other informal sectors (Dar City Council, 2004). The Local Government (Urban Authority) Act 1982 (Section 55) has mandated urban authorities "to remove refuse and filth from any public or private place" and to provide and maintain public refuse containers for the temporary deposit and collection of waste (Dar City Council, 2004). Section 9.1 of the Environmental Management Act of 2004 (LEAD 2007) placed the responsibility for providing mechanisms for separation at source with local government authorities. Municipal Council Collection and Disposal of Refuse by-laws further specify that householders should have separated waste collection receptacles for organic and inorganic materials (Oberlin 2012). Theoretically, then, wet and dry wastes are separated. This is particularly important for market wastes, where the bulk of the waste stream consists of putrescent organic matter (Mbuligwe and Kassenga 2004). However, in practice these by-laws are not strongly enforced and source separation is not widely practiced in Dar es Salaam.

The DCC has various programs, projects and strategies which are being implemented by its departments including the Integration of Primary Waste Collection and Secondary Waste Collection Strategy and Establishment of Transfer Stations (Ts) and Material Recovery Facilities (MRF) Strategy. Since 1994, solid waste collection in the ten wards of Dar es Salaam city centre has been privatised. The central and local government bodies franchise the services to a mixture of private companies and community-based organisations (CBOs), who must comply with solid waste management by-laws to retain the franchise and avoid financial penalties (Kironde 1999). The service provision is broadly dependent on the income of the area: commercial organisations who have not made their own arrangements and most high-income residential areas are generally served by private contractors; whilst in lower-income residential areas CBOs are in the main responsible for solid waste collection, although they may share infrastructure with the government and private collectors.

2. Supply chain and reverse logistics

The main ingredients to supply chains are materials supply, transformation and information exchange. Min and Zhou (2002) define a supply chain as an integrated system synchronising interrelated business processes to acquire materials and parts, transforming them into finished or semi-finished products, distributing these products to retailers or final consumers and facilitating information exchange among various business entities. Slack et al. (2007) define the supply chain as an interconnected network of various operations that comprise different parties, including suppliers, manufacturers, distributors, retailers and customers. Bandinelli et al. (2006) indicated that key elements in developing and executing supply chain management are dealing with business strategy development, network configuration, inventory control policies definition, suppliers' integration and partnership formalisation and enabling technologies introduction. Veiga (2013) has argued that every supply chain has forward and reverse logistics. A forward representation of a supply chain system can be depicted in figure 1 below. Materials taken in their raw form from suppliers are being transformed through different manufacturing processes into finished products that are then transported to distributors, retailers and final consumers.

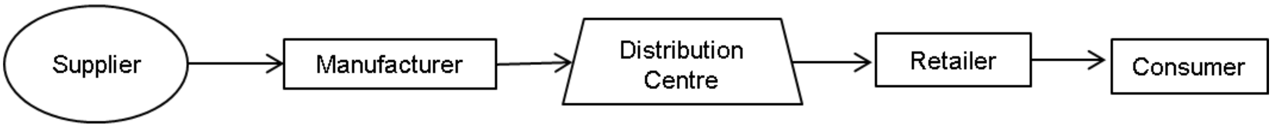

Figure 1. A simplistic representation of a supply chain system

A supply chain will also encounter reverse logistics activities, through returns, repairs, reuse and recycling. Products have the opportunity to return to the same supply chain in their reusable form as depicted in figure 2.

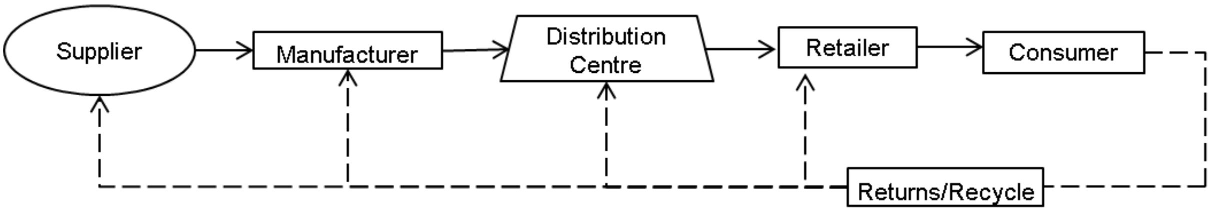

Figure 2. A simplistic representation of a reverse supply chain system

Guide et al (2003) considered the reverse supply chain to be more complex than the forward supply chain, requiring additional consideration in planning, designing and the control of its activities. Tibben-Lembke and Rogers (2002) regarded forward logistics as an active process (firms plan, produce and base supply of product manufacturing based upon forecasts), and reverse logistics a reactive one to more unpredictable factors, and being initiated by the consumer. I has been observed that successful reverse logistics solutions could only occur by efficiently integrating forward and reverse flows (Krikke et al., 2001 and Stock, 2001).

It has been argued that conceptually waste management and reverse logistics differ since waste is assumed to hold no value and the management focus is on legal and environmental consequences while reverse logistics focuses on products with some recoverable value (Brito and Dekker, 2003). Depleting resources and increased energy consumption have generated research interest in reverse logistics, recycling and reusing using end of life products (Michaud and Llerena, 2006, Ellen MacArthur Foundation, 2013). The point at which waste no longer holds any intrinsic value is lower down the waste hierarchy.

End of Life (EoL) Management considers “activities required for retiring a product after the user discards it after its useful life”, resulting in financial gains through saving on landfill taxes, credits for diverting waste from landfill and revenue through selling waste as raw materials for another process and new marketing opportunities through eco-labels indicating green credentials of a product or company (Parlikad and Macfarlane, 2004, Rubik and Frankl, 2006). The five product recovery strategies in EoL management for recapturing value: repair/reuse, refurbish, remanufacture, cannibalisation and recycle (Kumar and Malegeant, 2006); the textiles industry undertakes all.

3. Textile waste

Textile recycling, an ancient practice dating back to Ancient Egypt, has always been market driven, and can recover between 93-98% of the textile waste collected (Brill 1997, Hawley 2004, DEFRA 2006). Oakdene Hollins report (DEFRA 2006) notes that EoL textiles have been sorted and distributed into some 140 different grades and EoL options for textiles depend on the disposal location and material quality:

- Landfill: The least environmentally favourable option and without energy recovery (Michaud, Farrant et al. 2010). In the UK this is sadly still the most prominent end-of-life fate for post-consumer textile, which are usually soiled or unusable (not the right type of fibre mix), or are torn and unsellable (Morley, McGill et al. 2009).
- Waste to energy: Incineration with energy recovery is more favourable than landfill, but relies on the presence of suitable infrastructure. The amount of energy that may be recovered is dependent on apparel composition, but studies undertaken on the UK waste stream project that the energy recovered is not comparable with energy saved through recycling and reuse (Fisher, Collins et al. 2006).

- Recycle: End-markets for recycled and reused textiles are dependent on material composition and recycling of textiles is either through chemical means or mechanical.
    - Mechanical: usually open-loop recycling using material suitable for pulling (knitted items) or shredding into fibres (woven items) for use in new end products. Shoddy may be used in a range of other industries for their fire retardant properties, eg automotive, aircraft or bedding upholstery, yarns for knitting are used for reprocessing as knitted garments. Also non-wovens applications such as insulation, nappies, composites, etc.
    - Chemical: closed-loop chemical recycling of synthetic fibres such as polyester (Morley, McGill et al. 2009) and nylon (Morana and Seuring 2007; Lampikoski 2012) have been introduced with varying degrees of commercial success, with the potential for use in high-value applications, but are sensitive to the presence of other materials commonly found in post-consumer apparel (Morley, McGill et al. 2009; Patagonia 2009; Agrawal and Toktay 2010). The heterogeneous composition of bulk post-consumer apparel poses economic and technical barriers to closed-loop recycling.
- Reuse: The most environmentally favourable routes for textiles, either transported to markets (often to the African continent but also to Europe and Asia), often referred to as the second hand markets, or resold in the UK through retail shops (considered the 'cream' of used textiles), referred to as 'vintage'.

In addition to the composition, the mode of collection may also influence the condition in which textile reaches recyclers affecting suitability for recycling; eg, Ripper and Morrish (2012) found that 100% of textiles collected from a mixed recovery facility in Glasgow, UK initially deemed unsuitable for reuse or recycling but after washing and drying, approximately 50% of the textiles were suitable for reclassification into reuse and recycling grades (Burke, Gardner et al. 2012). Washing and drying is not carried out in most recycling facilities so heavily soiled and damp materials are sent for incineration or to landfill. No studies have assessed the fraction of materials which could be recovered from landfill after washing and drying.

4. Research methods

For two weeks in May 2012, face-to-face interviews were held with Dar es Salaam City Council; Lyoto and Co Ltd., a small private solid waste management company; Ilala Municipal Council; and the informal waste-picking community. Although no interview could be secured with members of the community-based organisations, a representative from WASTEDar, an NGO working directly with waste management CBOs was also consulted. The interviews established the current activities undertaken by the representatives, identified potential points of intervention in an end-of-life apparel collection system and discussed enablers and barriers to the establishment of the system.

To determine the quality and composition of the materials in the landfill, sample collection and characterisation was necessary. About 10kg of textile was collected; as the study was not intended to provide a quantitative value for the contribution of apparel waste to landfill, sampling was conducted based on visual observation of areas on the landfill rich in apparel waste. Three small areas were selected and 1m x 1m square was cordoned off and samples of pre-consumer and post-consumer textiles were extracted from the top 0.1 m of the sample square. The samples were stored in a sterile carrier, transported to the University of Dar es Salaam where they were sterilised by heat treatment and then transported to the UK for testing regarding fibre composition and quality from the perspective of potential to recycle. FT-IR ATR spectroscopy on samples from the landfill as well as reference samples from University of Manchester. Peaks from the reference samples enable identification of fibres within the landfill PCT samples.

5. Results

Storage and collection of waste: The Ilala Municipal Council Collection and Disposal of Refuse by-laws sets that waste receptacles should be of suitable size for the waste stream being collected and fitted with an effective lid. However, the most common primary storage containers for houses were plastic sacks and open buckets (Kassim and Ali 2006), which often contained mixed materials and left uncovered between collections. In the case of market wastes, open skips were filled with plastic sacks. The sacks may be (but not necessarily) separated into wet and dry waste, but with skips left open to the environment, the amount of organic waste attracts vermin, as a result, sacks become ripped between collections. Commercial and market waste was collected by private collectors and the urban councils. The market and commercial wastes were transported directly from their collection site to Pugu Kinyamweze for disposal, there are no transfer stations for materials recovery or sorting.

Sorting of waste: depended on the existence of a strong (formal or informal) market for the separated waste stream. The private contractor explained that his workers separated plastic, glass and metal during the collection process. The sorting process described was ad hoc. When waste receptacles were collected, largely from households, these were passed to a worker who carried out a cursory visual sort for metal, plastic and glass. The trucks had three separate areas at the rear where sorted materials were stored, the rest was stored in the main body. The contractor explained that plastics and metals were very quickly bought by itinerant waste buyers directly from the truck but glass was stored for a regular buyer. Although the market price for glass was substantially lower than for plastic or metal, the regular customer ensured the continuation of this collection. The contractor had, in past years, separated paper, but the relative low market value of paper, coupled with the low volumes in the waste stream, difficulty of identification in mixed waste streams and the potential for contamination had led to cessation of this practice. These same issues arise for textiles, and the company has never practiced source separation of textile materials. The visual sort undertaken on the trucks was considered to be rapid but inefficient. The contractor was in the process of establishing a mobile transfer station in order to minimise the number of trips to Pugu Kinyamweze and there would be greater potential for a more thorough sort when this was complete.

Door to door collection: Interviews with waste pickers at Pugu Kinyamweze revealed that textiles were rarely collected as part of the recycling 'mix' and existing end-markets for the materials were low-value. For metals, itinerant waste buyers purchased materials direct from households; ie, increased demand for recycled materials, coupled with well-defined recycling processes and the quality of post-recycled materials supports the costs of door-to-door collection. To complicate the matter further, householders' (often) negative perceptions of informal waste workers affected the door-to-door collection business - for reasons both founded and unfounded. One householder described the door-to-door collectors of 'chuma chakavu' (scrap metal) as 'really bad' based on the theft of local chain-link fencing by unscrupulous collectors. Where textiles were collected, one waste picker explained that the textiles he collected were transported to Morogoro (a city 190 km west of Dar es Salaam) where they were used in stuffing mattresses and pillows. This finding was supported by a recent small-scale study of recycling opportunities in the Kinondoni municipality where no end-market for textile scraps could be established (Palfreman 2010). In order to support door-to-door collection, the textile material value chain would need to be significantly strengthened.

The Pugu Kinyamweze dumpsite and textile sample characterisation: the empirical work made no attempt to determine the waste composition at the landfill, however, visual observations identified substantial deposits of pre- and post-consumer textiles across the site. The informal collection of other recyclables from collection to dumpsite no doubt influenced the textile concentration at the landfill. Our interests were in characterising the fibres within the samples brought back from the dumpsite were to identify the potential to separate the fibres with a view to potential for it being recycled into fibres for use in the automotive sector as seating or headliner textile. Polyester (PET - due to its light and colour fastness, high abrasion resistance, UV resistance, cleanability and competitive price) and polyacrylonitrile (PAN) (same properties as PET as well as high UV fastness – used for soft tops) are fibres that meet test and cost requirements in automotive textiles. The high cost of wool limits the automotive markets. We were able to characterise and separate the cotton from polyester fibres chemically.

6. Discussion and conclusions

The variety of waste collection services in Dar es Salaam, enabled higher service levels than comparable East African metropolises, particularly collection from the urban poor (Tukahirwa, Mol et al. 2013). The contract based nature of collection services also presents various issues that are recognised by the council, e.g. two years' length of time for a contract for companies limits the return on their investment so there is little incentive for upgrading the technology' with repercussions on the efficiency, levels of delivery of service and area coverage of waste collected. The difficulties that CBOs continue to face in attaining high collection rates from poor informal settlements coupled with financial constraints and poor infrastructure means that dumping, uncontrolled burying and open burning of solid waste, including end-of-life apparel, still occurs (Oberlin 2012). On average, only 37% of Dar es Salaam's solid waste is disposed of to landfill (Enezael 2012). There is as yet, no existing mobile transfer station in Dar es Salaam, which could dual function as a material recovery facility. Whilst this would maximise the collection of non-perishable inorganic materials and facilitate the collection of organic waste for composting or anaerobic digestions, such a strategy is unlikely to add value to the textile chain due to the contamination issues outlined in section 3. It is also likely that the least contaminated and most economically viable recyclable textile waste stream would be the pre-consumer wastes obtained from textile factories and tailors where there may be less contamination, provided they are contained appropriately. However, at Pugu Kinyamweze, pre-consumer waste was clearly evident and held little interest for the waste pickers interviewed. The chemical separation of cotton from polyester from post-consumer textiles found at landfill indicates a potential for supply chain of raw materials to recyclers around the world, however, this would require overcoming not only government policies and standards regarding waste but also local over-supply of landfill destined textiles.

From a reverse logistics perspective, there is a very rudimentary first feedback loop: individuals in the second hand markets gathering up the unwanted/unsold garments of a particular quality to take away to rural markets or mills to be recycled (we believe in Morogoro or Arusha). Although highly problematic, it would appear that developing internal markets is the only viable solution to textile waste for Tanzania. Mechanical recycling of textiles from blankets to developing non-woven products such as insulation materials hold potential. Apart for the high labour costs, the biggest barrier may be public perception of low quality of products made from recycled textiles as a South African study found (Larney and Van Aardt, 2004).

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