End-of-Life Management Considerations in the Footwear Industry

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Abstract

Currently, more than 19 billion pairs of shoes are consumed worldwide every year, and this figure continues to rise. This creates an enormous amount of post-consumer (end-of-life) shoe waste that is currently being disposed in landfill sites around the world. The research reported in this working paper is an initial investigation in realisation of a holistic approach to application of product recovery and recycling in the footwear industry. The paper provides a brief review of the trends in the footwear sector regarding the amount of end-of-life waste produced together with existing reuse and recycling activities. It also presents an integrated waste management framework by combining a mix of design and material improvements as well as reuse, recycling and energy recovery activities and concludes by examining the challenges in establishing end-of-life product recovery procedures for post-consumer shoes.

Keywords

End-of-Life Management, Shoes Recycling, Product Recovery, Footwear Industry

1. Introduction

Unsustainable consumption and production patterns in the developed world have led to an increased generation of waste over many decades. Although local and national authorities, governmental agencies, manufacturers and the general public have come to recognise the importance of controlling waste at source, total waste elimination is not possible. There will always be some waste that cannot be prevented at source and so need to be treated at the end of its functional life. Considering the amount of end-of-life (EoL) waste generated every year, understanding and developing methods for EoL management are a major part of the overall waste management concern.

The footwear industry over the last 20 years has placed significant effort in improving material efficiency during the production phase, as well as eliminating the use of hazardous materials in shoe production. However, the environmental gains made in production are being overtaken by the considerable increase in the demand for footwear products. Moreover, the useful life of shoes is relatively short and progressively decreasing as a result of rapid market changes and consumer fashion trends. This creates a large waste stream at the end of the functional life of shoes, which are often being disposed in landfills. Producer-responsibility and other forthcoming environmental legislations, as well as increasingly environmental consumer demands, are expected to challenge the way the footwear industry deals with its end-of-life waste. Thus, an investigation into a holistic approach to shoe recovery and recycling is being undertaken, as reported in this paper.

The initial part of the paper provides a review of footwear types and materials used in shoe manufacturing as well as investigates current trends regarding the amount of end-of-life waste produced by the footwear industry. The latter sections present an integrated waste management framework for shoes and discuss the challenges in establishing end-of-life product recovery procedures for post-consumer shoes.

2. Footwear Types and Materials

The footwear industry is a diverse manufacturing sector which employs a wide variety of materials to make products ranging from different types and styles of footwear to more specialised shoes. Although there are many different styles and categories of shoes, most of them can be described as having a subset of parts and components that are generally common to all type of shoes. In this context, the basic parts of a shoe can be grouped broadly into three categories (Clarks 1976):

- the Upper, which includes all parts of the shoe above the sole, such as vamp and quarters, that are stitched or joined together to become a unit and then attached to the insole and outsole of the shoe,
- the Lower, which refers to the whole bottom of a shoe but not the upper including the insole, the sole and the outsole of the shoe and
- the Grindery, which includes items that incorporated into the shoe and do not belong either to the Upper or the Lower part of the shoe such as toe puff, stiffener materials and eyelets.

Leather, synthetic materials, rubber and textile materials are amongst the basic materials most commonly used in shoe manufacture; each material has its own specific characteristics. Materials significantly influence, not only the life of the footwear but also the end-of-life treatment of the product. Approximately 40 different materials can be used in the manufacturing of a shoe (Weib 1999). However, the common material composition of a typical shoe is presented in Table 1.

Footwear Materials	**Percentage (%wt)**
Leather	25
Polyurethane (PU)	17
Thermoplastic Rubber (TR)	16
Ethylene Vinyl Acetate (EVA)	14
Poly (Vinyl Chloride) (PVC)	8
Rubber	7
Other (adhesives, metals, etc.)	7
Textiles and Fabrics	6

Table 1: Materials composition of a typical shoe (Weib 1999)

In general, footwear products can be divided using a supply or demand point of view. From the supply point of view, shoes can be subdivided by upper material, for example rubber/plastic, leather and textile-based shoes. On the other hand from the demand point of view, shoes can be divided by activity, for example sports, casual, formal and outdoor shoes. Other categorisations can also be made based on age and gender (i.e. men’s, women’s and children’s). For the purpose of this research, footwear products have been categorised into six different types based on their purpose of use:

- Men’s formal shoes
- Men’s casual shoes
- Women’s court shoes
- Women’s fashion shoes
- Children’s shoes
- Adult sports trainer shoes

Table 2 presents the basic shoe types and the most commonly used materials in their manufacture. Upper components, shoe soles and grindery items are presented according to their material of choice.

Types of shoes		Men's Formal	Men's Casual	Women's Court	Women's Fashion	Children's	Adult Sports Trainer
Upper Part							
Leather		✔	✔	✔	✔	✔	
Synthetic Materials	Canvas		✔		✔	✔	
	Polyurethane		✔		✔		✔
	PVC		✔		✔		✔
Lower Part (Soles)							
Leather		✔					
Leather/Polymer		✔	✔	✔	✔		
Vulcanise Rubber			✔		✔		
TPR			✔		✔	✔	
Polyurethane's			✔		✔	✔	✔
TPU			✔		✔	✔	✔
EVA			✔		✔		✔
Grindery Items							
Shanks		✔		✔			
Nails		✔		✔			
Eyelets		✔	✔		✔	✔	
Laces		✔	✔		✔		✔
Threads		✔	✔	✔	✔	✔	✔
Velcro & Catches						✔	
Textile Backers & Linings		✔	✔	✔	✔	✔	✔
Foams- (Padding)		✔	✔	✔		✔	✔
Heal Backing supports.		✔	✔	✔	✔	✔	✔
Toe cap reinforcement.		✔	✔	✔	✔	✔	✔
Heals- (Ladies/Men's)		✔	✔	✔	✔		

Table 2: Component breakdown of different shoe types

3. End-of-Life Shoe Waste

Worldwide footwear production and consumption has been doubled every 20 years, from 2.5 billion pairs in 1950 to more than 19 billion pairs of shoes in 2005 (World Footwear 2007). In the European Union, footwear consumption has been increased by 22% from 2002 to 2005 to reach 2.3 billion pairs of shoes (EC 2005). Additionally, the worldwide per capita consumption of footwear has also been considerably increased, from 1 pair of shoes for every person in the world in 1950 to almost 2.6 pair of shoes in 2005. However, shoe consumption differs significantly per country. Although China has the highest footwear consumption in the world, the United States is the country with the highest per capita shoe consumption, since each inhabitant purchase an average of 6.9 pairs of shoes every year (AAfA 2005). At the other extreme, in less developed countries, the per capita shoe consumption is 0.6 pairs for India and 0.5 pairs of shoes for Vietnam (all types of shoes included) (SATRA 2003). Table 1 presents the per capita shoe consumption in a number of different countries.

Countries	Population (millions)	Footwear Consumption (million pairs)	Footwear Consumption /Capita/Year
EU-25	456.5	2 054 571[1]	4.5
Germany	82.5	320 800[2]	3.9
France	59.6	335 502[2]	5.6
UK	59,3	312 800[2]	5.3
Italy	57.3	395 300[2]	6.8
USA	289	2 007 899[3]	6.9
China	1 287.1	2 900 000[4]	2.2
Brazil	186.0	490 000[4]	2.6
India	1 041.9	N/A	0.6[4]
Vietnam	84,2	N/A	0.5[4]

Table 3: Per Capita Footwear Consumption in Different Countries

[1] (EC 2005)

[2] (CBI 2004)

[3] (AAfA 2005)

4 (SATRA 2003)

3.1 Landfill Restrictions

Most of post-consumer shoes disposed in landfills when their functional life has ended. The standard practice of dumping waste in landfills led to soil, surface and groundwater contamination. Landfill sites can result in serious environmental pollution of groundwater and rivers, due to landfill leachate. Furthermore, landfill space is becoming extremely limited, while the number of landfill sites in the European Union has considerable decreased over the last years. In early 90's, in Germany, there were over 8000 landfill sites in use, while the number of currently operating landfill sites is below 300 (Hempen 2005). The EU Landfill Directive clearly promotes the diversion of waste from landfills towards products and materials recycling using a variety of measures (Council Directive 1999). The landfill restrictions introduced by the Article 5 of this Directive are very important, in particular the reduction in the amount of biodegradable waste going to landfill and the prohibition of landfilling for certain waste types. Since 1st June 2005, German landfills only accept biodegradable municipal waste that has been either incinerated or undergone mechanical and biological treatment while in Austria strict limits on the landfilling of organic wastes has also been introduced (Hempen 2005). Additionally, the UK Landfill Allowances and Trading Scheme Regulations (LATS) introduced in 2004, determines the percentage of certain waste type that regarded as biodegradable municipal waste. These biodegradable percentage range from paper, card and vegetable oils (potentially 100% biodegradable) through to footwear, furniture and textiles (50% biodegradable) to batteries, glass and metal waste (0% biodegradable) (LATS 2004). This means that certain types of biodegradable materials such as leather, natural textiles, natural rubbers etc, which are extensively used by the footwear industry, will be soon required to be reused or recycled instead of directly disposed in landfill sites.

3.2 Producer Responsibility Issues

In most countries, managing end-of-life waste has long been and, in most cases, still is the responsibility of governmental agencies and local authorities. Once products reach the end of their functional lives, producers play no role in collection, recycling or disposal of those EoL products. This approach has started to change with the emergence of a producer responsibility concept. This concept was first introduced in Germany with the 1991 Packaging Ordinance which required manufacturers and distributors to take back packaging from consumers and ensured that a specified percentage is recycled

(Toffel 2003). Producer responsibility legislation was introduced into the EU waste policy with the 1994 Packaging Directive and since then has spread to most industrialised countries (Council Directive 1994). In 2000, the European Commission passed a Directive requiring its Member States to institute a producer responsibility program for end-of-life vehicles (ELV) (Council Directive 2000). Also, an additional Directive for Waste Electronics and Electrical Equipment (WEEE) is expected to be adopted soon by all EU Member States (Council Directive 2003). This concept of broadening manufacturer's responsibility for products beyond their useful life into the post-consumer phase, also concerns closing the loop with respect to materials use and waste management at the end-of-life phase, while providing a source of financing to offset the cost disadvantage of recycling versus disposal and energy recovery. In this context, take-back and producer responsibility legislation is expected to affect the footwear sector similarly to what has happen in other consumer product sectors, e.g. with the implementation of the ELV and WEEE Directives.

4. Current Reuse and Recycling Activities in the Footwear Sector

The footwear industry's response to the increasing problem of post-consumer shoe waste has been negligible. In fact, only one major shoe manufacturer, Nike, has been taken measures to manage its waste. Nike's recycling programme "NikeGO Places" (formerly "Reuse-A-Shoe") is the only product take-back and recycling scheme currently established by a shoe manufacturer. According to Nike (2007), since its inception in 1993, "Reuse-A-Shoe" programme has recycled more than 16 million pairs of worn-out and defective athletic shoes in total.

Another form of reuse activity in the footwear sector is the collection and distribution of worn or unwanted shoes to developing countries. Reuse schemes are mainly supported by charity organisations, local authorities and municipalities such as the Salvation Army Trading Company Ltd. (SATCOL), Oxfam and others. However, there is a strong debate about such reuse activities in terms of their overall environmental impact and their economic consequences for the local communities. According to Wicks et al (1996), re-distribution of second hand products into developing countries may also lead to net economic damage to the local economies due to 'dumping' of cheap used footwear. In the case of Uganda, the import of large volume of second hand shoes in recent years has significantly reduced the size of the local footwear industry. About 7 million pairs of second hand shoes are imported into Uganda annually while only 240,000 pairs are produced by the local footwear industry (Temsch and Marchich 2002). However, as the cost of producing new shoes is coming down and the markets are flooded with lower quality shoes, it is expected that the price difference between new shoes and second-hand shoes will shrink in less-developed countries. The demand for second-hand shoes might then drop in these countries, leading to more post-consumer shoes needing to be recycled and disposed in the developed world.

5. Waste Management Framework for Shoes

Effective management of post-consumer waste is a rather complex issue made up of many components. Although there is no blueprint that can be applied in every industrial sector, the European Commission has set up a waste hierarchy framework which specifies the order in which waste management options should be considered, based on environmental impact (European Commission 2003). Based on this hierarchy, an integrated waste management framework for footwear products has been developed and presented in Figure 1.

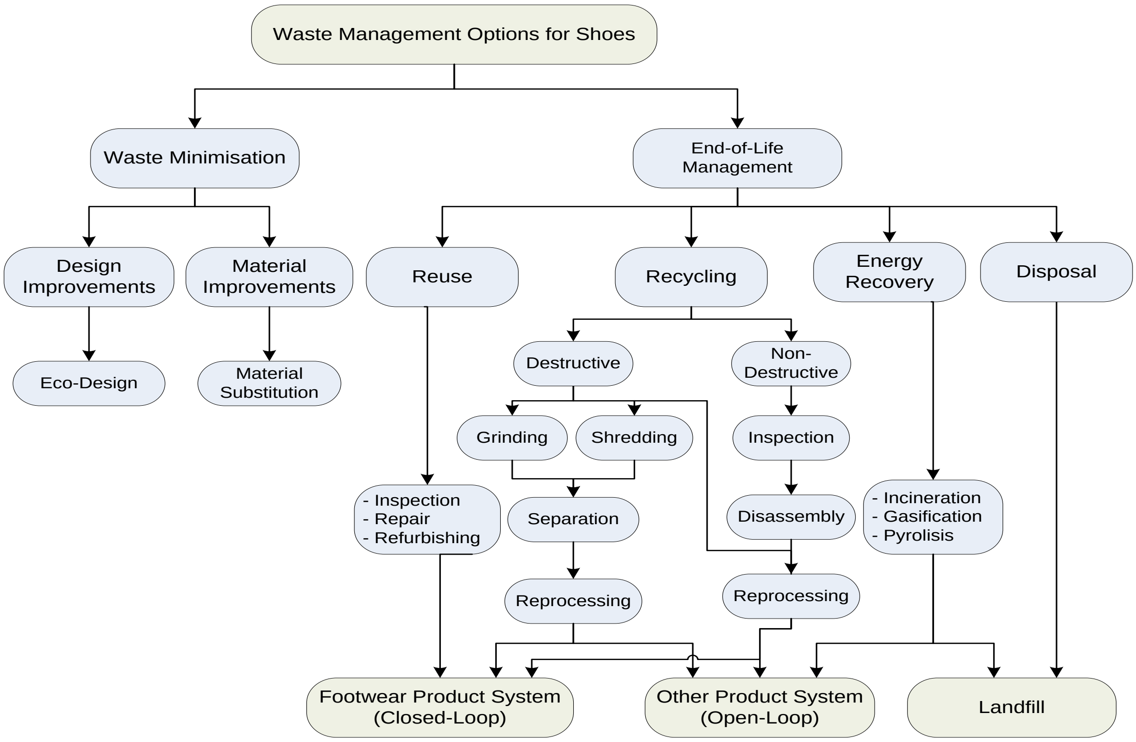

Figure 1: Waste Management Framework for Shoes

This proposed framework divides the waste management options for shoes into two major approaches: proactive and reactive. Proactive approaches include all measures that are taken with the aim to reduce or minimise waste at the source. Reduction of waste, also referred to as waste minimisation, is a proactive approach because simply, waste which is avoided needs no management and has no environmental impact. On the other hand, reactive approaches include all the other waste management options which act in response to the waste problem when the useful life of the product has ended. Reactive waste management approach is also referred as End-of-Life Management.

5.1 *Proactive Approaches*

In general, it makes far more sense to reduce or even minimise waste than to develop extensive treatment schemes and techniques to ensure that the waste poses no threat to the environment. Waste minimisation activities range from product and material changes, to process changes, to changes in methods of operations. Although there is a wide range of proactive waste management activities, there are two major improvement methods that could be applied in the footwear industry in order to reduce or even minimise waste at the source, design and material improvements.

5.1.1 Design Improvements

Waste minimisation strategies should start at the beginning of a product's life cycle, here in the product design phase using eco-design improvements. Eco-design improvements in the footwear sector could have significant impact on environmental quality and could reduce the amount of materials needed, thus reducing the amount of waste that need to be handled at the end of the lifecycle. Also a footwear product which is designed for ease of disassembly will make reuse and recycling of its components and parts easier, thus reducing the amount of materials disposed into landfill.

5.1.2 Material Improvements

The environmental properties of a product can be improved by simply choosing different materials. Material improvements, under certain circumstances, can achieve significant reduction of waste. For example, eco-friendly fabrics can be used in uppers and natural rubber in shoe soles, which can be more easily recycled at the end of the functional life of shoes. Moreover, recycled materials can be used to produce shoes such as Worn Again trainers made from 99% recycled materials such as old tyres, car seat leather and used coffee bags (Worn Again 2007). Finally, biodegradable materials can substitute conventional materials in order to improve the environmental properties of shoes. The two most important features that distinguish biodegradable materials from conventional petrochemical materials are their potential biodegradability or compostability at the EoL phase and the use of renewable resources in their manufacture.

5.2 Reactive Approaches (End of Life Management)

Total waste elimination is not possible. There will always be some waste that cannot be prevented at the source. Where waste material is produced, an optimal end-of-life treatment option must be selected with the lowest possible risks to human health and the environment. Each EoL management option brings different impacts to different parts of the environment.

5.2.1 Reuse

Direct reuse of shoes with minimal processing is a possible option but there are a few variables that need to be considered such as the condition of the shoe at the end of its life, the collection and distribution system as well as the purpose of its reuse.

5.2.2 Recycling

Recycling involves the reprocessing of end-of-life footwear products, parts or materials, either into the same product system (closed loop) or into different ones (open-loop). The end-of-life waste is therefore re-introduced back into the market through a series of recycling processes that can be divided into two major methods: destructive and non-destructive. Destructive methods, mainly through shredding process, could be used to transform shoes into other useful materials. Shredded materials can be directly used in secondary applications such as surfacing of roads, playgrounds and sound insulation. On the contrary, non-destructive recycling methods involve the dismantling of shoes to isolate materials for further recycling in order to obtain high grade of quality of recycled materials which can be used in a wider range of applications. Non-destructive methods generally include sorting, inspection, disassembly, and then shredding of separated materials. However, disassembly of shoes is not an easy task due to the large amount of adhesive typically used to join shoe parts together along with stitching techniques. A number of disassembly experiments related to different types of shoes have been performed, as part of this research work, as depicted in Figure 2. The development of a semi-automated shoe disassembly system is one of the Authors research goals.

Figure 2: Disassembly of shoes

5.2.3 Energy Recovery from Waste

Post-consumer waste can be recovered in order to generate heat and electivity. Energy recovery from waste includes a number of established and emerging technologies such as incineration, gasification and pyrolysis. In the case of leather waste, gasification technology has been applied for heat generation and chromium recovery. For example, a 50kg/h leather waste gasification unit has been installed at Pittards plant in Leeds, UK with good results (ENDS 2003). At the moment, however, such gasification units accept only raw solid waste directly form the tannery production and not finished leather products such as shoes.

5.2.4 Disposal

Not all post-consumer waste can be prevented or recycled and there will always be some waste to finally be disposed off in landfills or even just thrown away. Disposal of post-consumer waste in landfills is often regarded as the last resort waste management option with the highest environment impact. However, landfilling may present difficulties in the future due to recently introduced legislations that ban landfilling of certain waste streams (see Section 3.1).

6. Challenges in Establishing End-of-Life Product Recovery Procedures in the Footwear Industry

Forthcoming environmental legislations and market pressures are expected to force the footwear industry towards measures to deal with its end-of-life waste. Hence, the Authors argue that an end-of-life product recovery system for post-consumer shoes need to be established to minimise the environmental impacts of EoL shoes while taking advantage of the economic value of end-of-life materials, components and products. This highlights a number of challenges for developing such product recovery chain for post-consumer shoes, which are discussed in the following sections.

6.1 Establishing Sustainable Reverse Logistics in Footwear Sector

Reverse logistics and collection of post-consumer shoes is already happening but in a very small scale and mainly for reuse purposes. The standard shoe collection process includes a number of specially designed "shoe banks" based at recycling stations, schools, charity shops and other participating outlets. Other possible shoe collection options include kerbside collection (as part of already existing door-to-door municipal waste collection) and recycling point collection systems (where consumers bringing all kinds of shoes to containers located in recycling stations). However, at present the lack of appropriate infrastructure result in small proportion of post-consumer shoes to be collected for recycling while the majority end up in the normal waste stream for landfill or incineration. Financial incentives could also be considered as an option to facilitate the collection of greater volume of post-consumer shoes i.e. a discount on new shoes when you bring back a pair of used shoes. Clearly, establishing sustainable reverse logistics in footwear industry is one of the key drivers for successful end-of-life product recovery.

6.2 New Generation of Recycling Processes in Footwear Industry

The consideration of shoe composition clearly indicates that a pair of shoes may contain various recycled materials such as leather (chromium-tanned or chromium-free), polymers (PU, PVC etc) as well as natural and synthetic textiles. The challenge is, therefore, to develop a new generation of recycling processes that provides the technical feasibility to recycle the majority of these materials (either as a raw material, a chemical feedstock or as energy) in an environmental friendly manner (low emissions and less use of non-renewable energy and other natural resources). The cost of such an environmentally friendly approach to shoe recycling may be higher than the cost of present waste management method (landfilling) but could become competitive on the longer term as new market opportunities developed for recyclable materials.

The first step in developing a shoe recycling process is to successfully separate post-consumer shoes into well defined mono-fraction material streams, which could be based on either mechanical or chemical processes. The research is also exploring the use of such materials in low grade applications i.e. equestrian surfacing for horse riding arenas, sound insulation etc. and possible use in shoe manufacturing.

6.3 Establishing Value Recovery Chain for Post-Consumer Shoes

Once end-of-life shoe waste is collected, separated and converted into a form that can be used by either the footwear industry or other industrial sectors, then it must compete with virgin materials both on price and performance. A sustainable footwear recycling application heavily depends on establishing a successful value recovery chain. Issues that need to be considered include the size and the value of the end market, the current and predicted buying trends as well as the range and price of competing materials and products. Furthermore, possible legislative requirements can play an important role in developing economically feasible value recovery chains for post-consumer shoes. Such legislation can take the form of business-centred legislation i.e. the recycling fee imposed by the car industry and the white goods sector in certain European countries or consumer-centred legislations i.e. the introduction of a recycling fee for newly sold shoes. The revenues created through such legislations can be used to develop and sustain successful end-of-life product recovery for post-consumer shoes.

7. Conclusions

The large amount of post-consumer shoe waste produced every year, the legislative pressures to divert waste from landfills as well as the hidden value of recyclable materials in post-consumer shoes have led to the investigation of post-consumer waste management issues in the footwear industry. Recycling and product recovery activities for footwear products need to be identified to ensure that landfilling is reduced and hazardous substances do not enter the environment or impact on human health while the economic value of the end-of-life materials, components and products is recovered. Proactive waste management activities such as material substitution will not, in the short term, be able to solve the issues connected to current EoL waste generation. This highlights the need to direct considerable efforts on reactive end of life management initiatives improving the treatment of waste currently generated, especially those focusing on the encouragement of reuse, recycling and energy recovery of footwear products.

In this context, this working paper presented an integrated waste management framework for the footwear industry based on proactive and reactive waste management options, the composition of which is determined by the availability of end-of-life shoes and by access to recycling facilities. However, past experience in other industrial sectors i.e. automotive, electrical/electronic equipment have shown that end-of-life product recovery procedures need to be not only environmentally acceptable but also economically and technologically justified. Many of the technical, economical and environmental issues raised in this paper have highlighted the need to overcome the barriers that exist in establishing end-of-life recovery procedures in the footwear industry. Collection of post-consumer shoes, separation into well-defined material streams and, finally, value recovery of recyclable materials are among the crucial factors in establishing sustainable end-of-life product recovery in the footwear industry.

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