CLOSED LOOP SUPPLY CHAIN FOR END OF LIFE TEXTILES

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1. Introduction

This paper aims to summarise current closed loop supply chain systems available in the literature and identify key characteristics for efficient closed loop supply chains with specific reference to the textile industry. With the aim to reduce the environmental impact of waste textile, this work is looking to identify if this can be achieved by incorporating closed loop elements within the design of a textile supply chain system. This paper also examines supply chain networks and designs required within the context of end of life (EoL) management of textiles.

Closed loop supply chain analyses were carried out by many researchers to aid product development, logistics and supply chain management. Most studies have centred their attention on chemicals, pharmaceuticals or food industries; few have tackled the textiles industry specifically because of its complex supply chain design, logistics, raw materials definitions and fibre mix issues. This work will capture current and specific details from a potential EoL closed loop supply chain system.

Many companies see sustainability not only from the type of products they use within their process, but also from the operations, procedures, materials used and the recycle opportunities offered by their final product.

2. Literature review

Many studies focus on the modelling of the forward flow of the supply chain. This could include moving raw materials from suppliers to be assembled or pre-assembled, followed by the manufacturing process and finishing with distributing products to the final consumers. The need for growth and the need to comply with current sustainability agenda, determined companies to evaluate the design of their supply chain system and incorporate elements to encourage reusing, recycling and reducing waste. Managing reverse supply chains is a complex and laborious activity which involve activities such as cross-border transportation of recyclable products and /or waste and add complexity in the tread-offs of supply chain objectives. Therefore there is a need for companies to pay particular attention to the design of efficient reverse chains (Krikke, et al. 2004).

There are many points in the supply chain where closed loop can be incorporated. They can be directly linked to the same forward supply chain or be linked to a different forward supply chain other than the one which originated the finished products. Fleischrnann et al. (1997) provides a definition for closed loop and open loop supply chain. The difference between closed and open loop is that if the products do not return to the original producer, but they still return in the system they are seen as open loop, however if the products return to the original producer they are seen as closed loop.

According to Krikke et al. (2004) closed loop supply chains consists of both the forward supply chain and the reverse supply chain where loops can be closed by reusing the products as a whole, reusing the components or reusing the materials. They also identified five business processes in the reverse chain such as: Product Acquisition, Reverse Logistics, Sorting and Disposition, Recovery followed by the Re-Distribution and Sales process. The following four types of returns have also been identified here such as end-of-life returns, end-of-use returns, commercial returns and reusable items. Also, Guangfu and Juncheng (2009) considers that closed loop supply chains integrates forward supply chain starting from raw materials to end customers and reverse supply chain starting from customer to plants.

The interaction between supply chain and sustainability has been considered by Linton et al. (2007) by looking at environmental issues such as product design, product life extension and product recovery at end of life.

Closed loop supply chain systems have been modelled by many authors (Fleischmann et al., 2002, Fleischmann et al., 2003, Hammond and Beullens, 2007, Yang et al., 2009) where the aspect of network complexity has been also considered. A study by Pokharel and Mutha (2009) provides a literature review based on content analysis on different advances in research and practice in the area of reverse logistics. Key categories for reverse logistics have been identified here such as: collection, inspection, processing, consolidation and remanufacturing.

The focus of this paper is to present some findings from an exploratory investigation into the product design and supply chain within an automotive textiles design company to identify and evaluate opportunities offered by the forward supply chain to allow for integration of closed loops. We are also looking to assess the value added generated by the incorporation of closed loops into the supply chain of the selected case study and to understand how supply chain design also influences environmental impact from methods of transportation and accumulation of inventory.

3. Methodology and Case study
This investigation is an exploratory single case study automotive interiors company and investigates the design and supply chain system in developing textiles based products.

The company Sage Automotive Interiors (Sage AI) originally a part of Milliken Automotive group and the Viktor Achter Group (Bracewell, 2011) was a result of a management buyout in 2009, when Milliken (involved in textiles and carpeting) decided that the automotive sector was no longer key to their future plans. The Sage AI business is entirely related to the automotive industry (Bracewell, 2011); while they no longer manufacture they work closely with partner groups to bring the design process to fruition (Bracewell, 2011). Sage AI is based in several countries worldwide (e.g. Poland, Japan, India, South America), headquarters in the US. Sage AI fundamental business is design, incorporating engineered and technical qualities to add value to their products; sustainability and innovation is paramount to their vision (Bracewell, 2011).

3.1 The automotive assembly process
The assembly system has been described as tiered: tier one supplies interior compartments, tier two supplies sub-assemblies such as cut and sew, tier three supplies the manufacturing for the upholstery whilst tier four supplies the materials (Shishoo, 2008). Sage AI's Design Director described their position and role within the assembly system as follows: the car company heads the system and buys in major components to assemble the cars (see figure 1). The major components manufacturers supply parts such as seats, engines, floors of the (referred to in the literature as Tier 1). Tier 2 suppliers carry out sub assembly activities such as cut and sew and supply parts such as headliners. Tiers 1 and 2 companies may be integrated and 'cut and sew' operations may be carried out by the same company. Fabric laminators supply to where the cut and sew operations take place (Tier 2). The fabric formation companies may conduct fabric lamination in-house, or out-source. There are many permutations with regards to the types of companies involved in supplying raw materials; companies may supply yarn direct to the fabric formation company and foam and scrim direct to a fabric lamination company or only yarn to the fabric formation company and the fabric formation company supplies the scrim to the fabric lamination company. Moreover, the three companies may be integrated into the same; the permutations depend on how value is created and captured within which the business is operating (Taylor, 2012).

Design, development and logistics, operations may reside within the car company but it is also the position that Sage UK has adopted within the automotive industry. They design and develop textile based automotive interiors for a car company and manage the dialogue between the Car Company and Tier 1 companies; they will also, on commission, manage the rest of the companies within the chain. For example, they will work with a yarn supplier to develop a new product, produce samples and laminate – at Sage, this will involve three separate companies, but usually this is one company.

According to the design director this system is a dynamic and fluid one; the OEM's, frustrated by the increasingly longer lead times and operational constraints, would not work with a fabric supplier unless they also provided cut and sew operations, thus influencing the structure of the industry. The trend, therefore, has been for Tier 1 companies to buy out the fabric companies and become vertically integrated companies to capture maximum value from the operations as possible. For instance a European company called Johnson Controls has 25% of the market and has taken control of upstream as well as downstream activities making the full range of products from seats, instrument panels, headliners etc. This vertical integration enables capture of increasing amount of value along the chain but loses flexibility and speed, which is the advantage that Sage AI has from maintaining their independent state within the system.
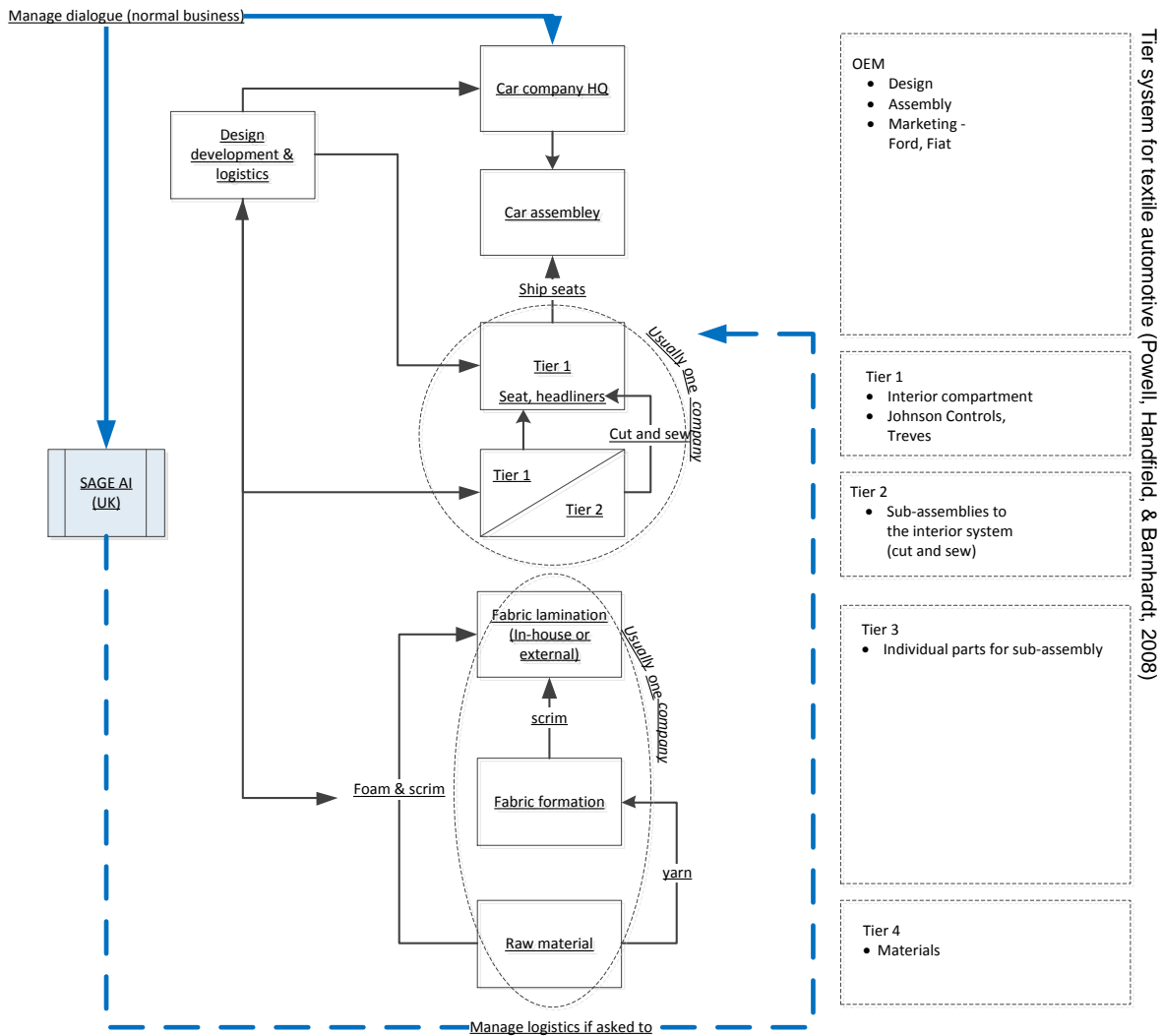
Figure 1: Sage AI position within the automotive manufacture system

3.2 Product development

Within this system Sage AI produces textiles interiors based on two manufacturing routes: woven or knitted (see figure 2). Most developments are related to enhancing these processes, e.g. through embossing, stitch and HF welding (Lofthouse, 2011). The samples are developed in the plants overseas thus knowledge of their capabilities is essential. This ability occurs through experience and a good working relationship with the partner companies, and the UK in-house technician designers (Lofthouse, 2011). The creative or technical designers visit the partner manufactures one a month (Lofthouse, 2011).

Product development or innovation begins with a brief, either from the customer/client (OEM) or in-house (e.g. designer, manager, etc); for example, Sage AI developed for Honda FXC, whereas YES Essentials was developed internally based on consumer research knowledge (Bracewell, 2011). It is not uncommon for the OEM's to tenders briefs to more than one supplier at a time. OEM's distribute requirements via a brief to specify requirements in terms of objectives for the textiles, this process may commence up to three to five years in advance of the final vehicle production dependent on whether incremental or innovative design is involved (Lofthouse, 2011). Dependent on the client's requirements the brief may focus on pattern requirements, technological developments, whilst others may be more responsive to emotive desires of the consumer (Lofthouse, 2011). When developing initial ideas (for either internal or external clients) Sage AI liaise with their suppliers' technicians to establish feasibility with partner companies; where if it is not possible, they will develop new supplier relationships and run feasibility trials (Lofthouse, 2011).

At Sage AI innovation is through yarn formulation and fibre choice is limited to polyester: e.g. highly lustrous, soft matt, textured and novelty yarns to create interest in the woven and knitted fabrics (Lofthouse, 2011). The yarns are supplied by Autofil Worldwide Ltd (Lofthouse, 2011). The company can also piece or yarn dye to the desired requirements and has the facilities to laminate (Bracewell, 2011).
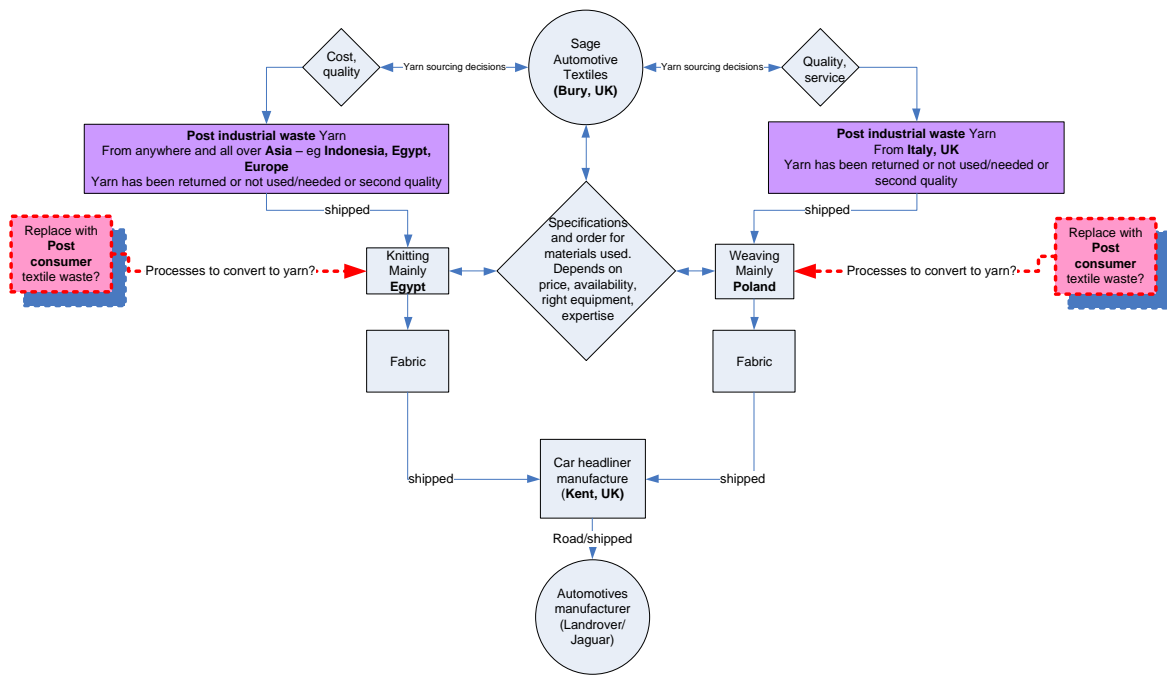

Figure 2: Product development at Sage AI

The initial design process can take between two weeks and two months dependent on the client's needs (Lofthouse, 2011). According to Powell a brief will consist of performance [standards] and cost parameters, colour, pattern, scale of pattern, lustre and handle which is then taken forwards by the designers (Powell, 2008). Timing and major stage-gates will also be confirmed (Lofthouse, 2011). If the initial stage-gate is short the design team will show concepts already in situ to support quick turnaround of sampling; when the stage-gate is long the designers will develop new concepts for a particular brief, this may include two stages prior to sampling (Lofthouse, 2011).

Vehicle interiors are mainly plain, striped, checked or small scale ditsies in neutral colouring with the addition of a small percentage of a brighter accent colour to add interest (Lofthouse, 2011; Powell, 2008). Various OEMs who produce shorter runs have started to offer special editions to add more interest into the colour and design of the automotive (Powell, 2008 citing Powell 2006). As already stated vehicles are developed up to five years in advance, alongside this is the timeframe of seven years that the textiles will be in vehicle production before an updated model is developed and ultimately replaces it (Bracewell,

2011). Thus the fabric has to remain on forecast for a much lengthier amount of time than fashion or home interiors in terms of appearance and colour.

Due to the long lead times a global macro-trends study is projected every four years and micro-trends analysed such as "luxury", "sports", "comfort" to focus the design team (Lofthouse, 2011). Sage AI used to profiles geographically but now reference according to age and lifestyle, e.g. "youth" and "active" (Taylor, 2011). Other elements to be considered are environmental trends, colour, texture and consumer profile (Taylor, 2011). The designers produce a global colour show consisting of four themes to maintain constant fabric design and development and visit trade shows to keep abreast of latest yarn or fabric development techniques and suppliers (Lofthouse, 2011).

The concept, produced on a specific CAD programme is then emailed to the specific processors and dependent on colourways, will take four to six weeks for sampling to materialise. If the colour of the yarn is already available (e.g. black) this would be a four week process however if the yarn needs to be dyed specifically to match other elements of the interior such as vinyls and leathers this can take approximately six weeks (Lofthouse, 2011).

The samples will be reviewed and if approved will commence testing and colour-tuning, if not approved design alterations and further sampling will occur. When samples and testing are approved the design process is finalised, a term described by Sage AI as 'mastering' this is whereby the whole product is fixed (yarns, design, etc), the design is then assigned to production.

Sage AI has maintained sustainability as core to their corporate vales that they had when they were part of Milliken (Bracewell, 2011). Sage AI employ polyester yarns for their textile products that are visible within the automotive. They use a percentage of post-industrial recycled yarns and post-consumer recycled yarns blended with virgin yarns. The post-industrial recycled yarn is easier for Sage AI to use as properties are known and so it can be dealt with appropriately. The post-consumer yarns are made from 100% plastic bottles. The polyester may be coloured and texturised to a very wide variety of looks and feel and this blend, be visually appealing to the customer (the OEM), pass various rigorous tests (such as abrasion and light fastness) so that it will last for up to 10 years, and most importantly it has to be cost effective. Currently the lamination process for the textiles renders the textiles products to be non-recyclable as lamination involves placing adhesives onto the fabric.

4. Discussion and Conclusion

Promotion of recycled textiles used in production is a dilemma: the recycled polyester is blended with virgin polyester and so the resultant fabric does not look different from the non-recycled fabrics thus raising questions from OEM customers and final vehicle consumers alike about the validity of the sustainable claims and extra costs.

Cost of using recycled yarns appears to be in the processing of the yarn: there is a surcharge/premium in terms of the raw materials which is based on the polyester and not the plastics making it difficult for the OEM customer to understand the costing. The cost implications are, for example, 7% mark up on fabric that is 40% recycled and 11% on fabric that is 100% recycled; when this is taken back to the yarn, the cost is double or three times that on the normal price of the yarns. As the use of recycled fabrics will push up the final costs of the car, the consumer has to be interested to buy recycled/sustainable and this is not easy to predict: in the North Americas, there is a large interest while in Europe this is not so appealing. The decision to use recycled content within the product, therefore rests on cost:

- Is it a 'deal-breaker', i.e., would the use of recycled textiles parts secure a sale
- What are the cost implications on the total supply chain
- Does legislation present any advantages in the use of recycled textiles in production

The benefits of using post-consumer recycled yarns is the reduction in greenhouse gas emissions, the reduced energy consumption compared to making virgin yarns from raw materials and associated landfill charges and land use for storing waste plastic bottles (Collora, 2012). Incorporation of post-consumer textiles adds another supply chain loop to consider, as the post-consumer yarns are currently 100% from

plastic bottles which require processing into yarns, there are the collection of plastic bottles, cleaning, transportation and storage of bottles before manufacturing processes to be considered. Most yarn manufacturing takes place in Asia but the suppliers of polyester yarns are based in wider locations, e.g. they have a supplier in the UK in Nottingham. As the tests that automotive yarns and fabrics have to pass are so rigorous, there are few automotive yarn suppliers. Automotive textiles interiors fabrics and yarns are therefore sourced from a small pool of yarn suppliers which may ease the complexity of the addition of a new supply chain route to be considered in the closed loop approach. This paper presents the findings to date for the automotive textile design process; one strand of a larger project that aims to outline mechanisms for closed loop textiles design. Questions raised from this case study that will be a focus of this research are:

- How are the costs of recycled yarns determined?
- How can equality in costs of recycled/virgin yarns be achieved?
- How can/should the sustainability message for recycled textiles be delivered?
- What new technologies may be developed to ensure that end of life considerations can be taken into account when developing laminated textiles for automotive interiors.

References
- Bracewell, T. (2011), Managing Director, Sage AI. Initial meeting with Sage Automotive Interiors. Bury
- Collora, J. (2012) "Recycling Empty PET Bottles" Bottled Water Reporter, December 2011-January 2012, pp8-14, International Bottled Water Association
- Fleischmann, M., Bloemhof-Ruwaard, J. M., Dekker, R., van der Laan, E., van Nunen, J. A. E. E., & Van Wassenhove, L. N. (1997). Quantitative models for reverse logistics: A review. *European Journal of Operational Research, 103*(1), 1-17.
- Fleischmann, M., Kuik, R., & Dekker, R. (2002). Controlling inventories with stochastic item returns: A basic model. European Journal of Operational Research, 138(1), 63-75.
- Fleischmann, M., van Nunen, J. A. E. E., & Gräve, B. (2003). Integrating Closed-Loop Supply Chains and Spare-Parts Management at IBM. Interfaces, 33(6), 44-56.
- Krikke, H., Blanc, I., & Velde, S. v. d. (2004). Product Modularity and the Design of Closed-Loop Supply Chains. California Management Review, 46(2), 23.
- Guangfu, L., & Juncheng, W. (2011, 2011). *Research trends of network design for closed-loop supply chain.* Paper presented at the 2011 IEEE 2nd International Conference on Software Engineering and Service Science.
- Hammond, D., & Beullens, P. (2007). Closed-loop supply chain network equilibrium under legislation. European Journal of Operational Research, 183(2), 895-908.
- Linton, J. D., Klassen, R., & Jayaraman, V. (2007). Sustainable supply chains: An introduction. Journal of Operations Management, 25(6), 1075-1082.
- Lofthouse, S. (2011). Designer, Sage AI. Initial meeting with Sage Automotive Interiors. Bury.
- Pokharel, S., & Mutha, A. (2009). Perspectives in reverse logistics: A review. Resources, Conservation & Recycling, 53(4), 175-182.
- Powell, N. B. (2008). Design of automotive interior textiles. In R. Shishoo (Ed.), Textile advances in the automotive industry (pp. 113-139). Cambridge: Woodhead Publsihing Ltd.
- Powell, N. B., Handfield, R., & Barnhardt, R. (2008). Mapping the automotive textile supply chain. In R. Shishoo (Ed.), Textile advances in the automotive industry (pp. 17-42). Cambridge: Woodhead Publishing Ltd.
- Shishoo, R. (2008). Introduction. In R. Shishoo (Ed.), Textile advances in the automotive industry (pp. xxi-xxix). Cambridge: Woodhead Publishing Ltd.
- Taylor, I. (2011). Design Director, Sage AI, Initial meeting with Sage Automotive Interiors. Bury.
- Yang, G.-f., Wang, Z.-p., & Li, X.-q. (2009). The optimization of the closed-loop supply chain network. Transportation Research Part E, 45(1), 16-28.