A FRAMEWORK FOR MOVING TOWARD SUSTAINABLE SUPPLY CHAIN MANAGEMENT

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ABSTRACT:

Sustainable development was articulated by the Brundtland Commission as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". With respect to growing importance of sustainability, consideration has been given to the convergence of supply chains and sustainability. A focus on supply chains is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery to the customer. In this paper, we explore different changes, needed to be considered, in each level of supply chain of a product, in sustainable development context. These changes can be classified in two groups: process-based and structural changes. Next in this research, a step by step framework will be provided to guide practitioners in moving toward better management of supply chain in the sustainable development environment. This framework will be applied in tire industry as a case study.

KEYWORDS

Sustainable development, Supply chain management, tire industry, life cycle analysis

1 INTRODUCTION

During the last two decades, the focus on optimizing operations has moved from a specific facility or organization to the entire supply chain. By optimizing along the entire sequence of steps that are involved in the production of a product whether it is a good or service, the greatest value can be produced at the lowest possible cost (Handfield and Nichols 1999). Similarly, the focus on environmental management and operations has now moved from local optimization of environmental factors to consideration of the entire supply chain during the production, consumption, customer service and post-disposal disposition of products. This is a critical and timely topic that captures increasing concerns over sustainability, whether driven by current legislation, public interest, or competitive opportunity (Jayaraman, V., et al., 2007).

The interaction between sustainability and supply chains is the critical next step from recent examinations of operations and the environment and operations and sustainability (Linton, J.D., et al, 2007). In this paper, from literature survey, we provide different guidelines and changes needed to be considered in different stages of supply chain from raw material processing to product delivery to customer and take back. Base on these guidelines we present a step by step framework that guides practitioners for moving toward sustainable supply chain management.

2 LITERATURE REVIEW

Traditionally, cost has been the most important factor in supply chain management decisions. Recently, with the growing importance of sustainability, environmental and social impact, are going to play key roles in this area.

Literature about supply chain management in sustainable development context can be categorized in two part:

- Environmental principles applicable to supply chain management
- Scenario analysis of potential applicable changes

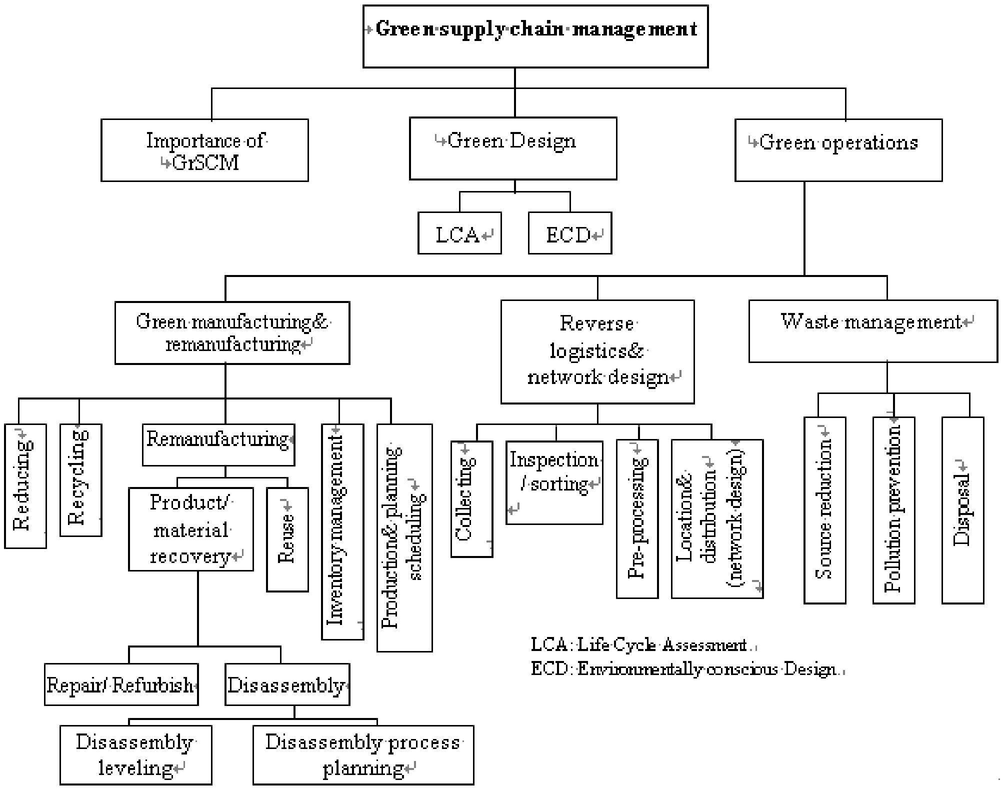


Figure 1 Classification and categorization of existing GrSCM literature. Source: Srivastava S.K. (2007)

2.1 Environmental principles applicable to supply chain management

The majority of supply chain management literature in sustainable context is related to applying environmental principles. Managers have been giving increasing importance to the environmental issues, their impact on operations and potential synergies. since the early 1990s. Earlier literature is generally restricted to the plant or firm level focusing on green purchasing, industrial ecology, industrial ecosystems and corporate environment strategies. Gradually, environmental management aroused increased interest in the field of supply chain management resulting in a growing literature on green supply chains. Sirvastava (2007) classifies literature about green supply chain management (GrSCM) in three sections: importance of GrSCM, green design and green operations. (Fig. 1)

Hanssen, O .J., (1995) introduces four main preventive environmental strategies for improvement of total product system :
1- reformulating user requirements, to find new innovative solutions beyond the scope of today’s product systems;
2. improvements in the performance of the product in relation to user requirements;
3. substitution of the whole product system or substitution/elimination of parts of the system;
4. optimization of the processes and operation of each system unit (raw material excavation, raw material refining, production, use and maintenance, all types of transport and waste management) or in the interaction between system units (transport distance, recovery rates, etc.).

Tsoulfas and pappis (2005) declare that the environmental principles applicable to supply chain design can be classified into 6 groups corresponding to respective company functions:
1. Product design
2. Packaging
3. Collection and transportation
4. Recycling and disposal
5. Greening the internal and external business environment
6. Other management issues

They provide some solutions for better management in sustainable context in each group. Byggeth, S. , et al. (2007) define environmentally adopted processes and provide guidelines that can be considered in product design, transportation and production system to be environmentally adopted.

Allwood, J. M., (2004) define Sustainable manufacturing as "Developing technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste". He offers five options for sustainable manufacturing:

1. Use less material and energy
2. Substitute input materials: non-toxic for toxic, renewable for non-renewable
3. Reduce unwanted outputs: Cleaner production, Industrial symbiosis
4. Convert outputs to inputs: recycling and all its variants
5. Change structures of ownership and production

2.2 Scenario analysis of potential applicable changes

Scenario development as an aid to planning is focused on developing alternative visions of the future. Visioning exercises typically look farther into the future (i.e., 10 years or more) than other futures methods. Scenario planning (or scenario learning) has proven to be a disciplined method for imagining possible futures in which decisions may be played out (Schoemaker, 1995). Scenarios and scenario analysis have become popular approaches in organizational planning and participatory exercises in pursuit of sustainable development.(. Duinker P. N., Greig, L. A., 2007).

Sustainable production group at Cambridge University, have conducted a project to investigate alternative scenarios for UK clothing and textiles. Final report has been published at 2006. (Allwood, J. M., et al, 2006).

Investigated scenarios have been given in Table 1. They analyzed these scenarios from economical, environmental and social point of view. Economic impact is predicted by a simplified set of national accounts. For each base case product a cost model has been developed, showing raw material prices and the build up of production costs and transfer prices to the complete product. Environmental impact is predicted through detailed life cycle analyses (LCA) that is a standard method for evaluating environmental impact of a product system. Social impact is described qualitatively in two areas: the influence of changes on consumers in the UK; the influence of changes on the social conditions of those involved in production. Quantitatively, published figures on working hours and productivity are used to predict the total number of people employed in each country for each scenario.

Table 1 Scenario analysis in UK closing and textiles

Scenario's focal point	Scenarios
Location of clothing and textiles production	• Changing the location of existing operations (from China to UK) • Changed location with new production technology • Changed location, new technology and recycling
Changes in consumer behavior	• Extending the life of clothing • Best practice in clothes cleaning
New products and material selection	• Alternative fibers • Green manufacturing • Smart functions
Influence of government decisions on the sector	• In this section, impact of different government decisions such as free trade has been investigated.

The Swedish Institute for Food and Biotechnology (SIK) also conducted a project to develop and analyze alternative scenarios for pig production.(Stern, S., et al, 2005) Another case for scenario analysis in sustainable context is related to work of Russel and Allwood (Russell S.N, Allwood J. M, 2007). they explore different scenarios for moving toward more localized production of plastic bags in Jamaica. Results shows that more localized production can reduce negative environmental impacts. Review of literature shows that moving toward a more sustainable production needs some changes. These changes can be classified in two categories: process changes and structural changes. Process changes relate to every improvement that can be applied in the single process of supply chain of a product such as transportation or packaging. Structural changes relate to changing configuration of given supply chain network. For example changing location of production from china to UK in the case of UK textile is a structural change. Table 2 summarizes these changes and proposed guidelines in each category based on literature.

Table 2 Guidelines for moving toward sustainability

Changes	subsystems	guidelines
Process changes	**design**	• Design and develop recoverable products, which are technically durable, repeatedly usable, harmlessly recoverable after use and environmentally compatible in disposal. • increase total life span of the product by making it more durable and easier to repair. • Secondary raw materials should be given priority in usage. • Use standardized parts. • Provide for easy disassembly of the product. • Limit packaging to the necessary size. • Design packaging for refilling or recycling and use standardized packaging when applicable. • Increase flexibility in design of products, so parts of the product can be upgraded without changing the whole product. • design for cascade functions (primary, secondary, tertiary functions). • make the product more compact, to reduce weight and material consumption. • substitution/elimination of one main component (e.g. a raw material). • heavy materials are exchanged for lighter materials (especially important for products that are transported). • materials with known negative environmental impact are exchanged for materials with less environmental impact.
	supply	• Impose higher (and greener) standards on suppliers and have a close cooperation with them.
	production	• wastage is avoided in the production processes. • increase efficiency in fulfilling user requirements. • the processes have optimized usage of energy and other resources. • emissions contributing to known environmental effects are limited by different cleaning technologies, e.g., air cleaning systems, water treatment plants and catalysts. • green production.
	Consumption/customer	• change the weighting of requirements by the customers. • Motivate customers and keep records of where they deliver used products or packages.
	Transportation	• use of transport based on renewable resources. • Consider using existing forward supply chain facilities and transportation system as much as possible for the reverse supply chain. • Treat hazardous materials safely. • optimization of transport and logistics.
	Recycling and disposal	• Formulate a policy for the recovery of used products. • Classify used products as early in the recovery chain as possible. • on-site recycling. • off-site recovery.
Structural changes	**Configuration of network**	• construct closed-loop supply chain by recycling effectively and efficiently. • local production. • use of local suppliers in preference to regional/global Suppliers . • Locate recycling facilities close to customer markets. • substitution/elimination of one unit of the product system (e.g. a supplier, a nonrenewable energy resource, etc.).

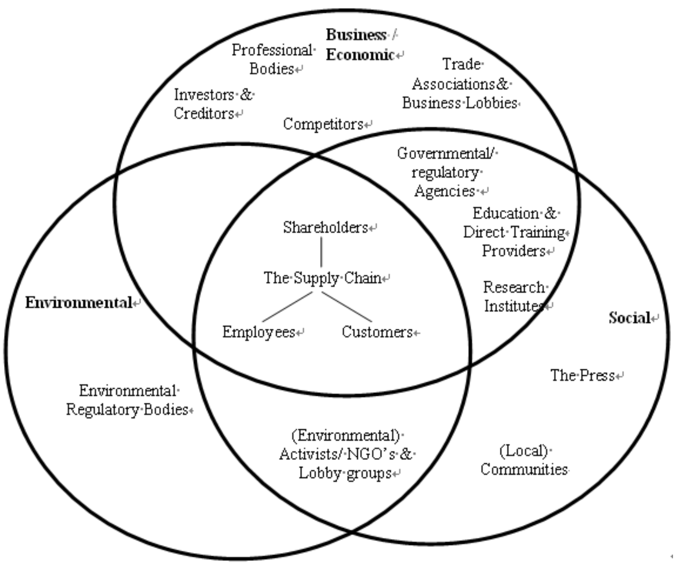


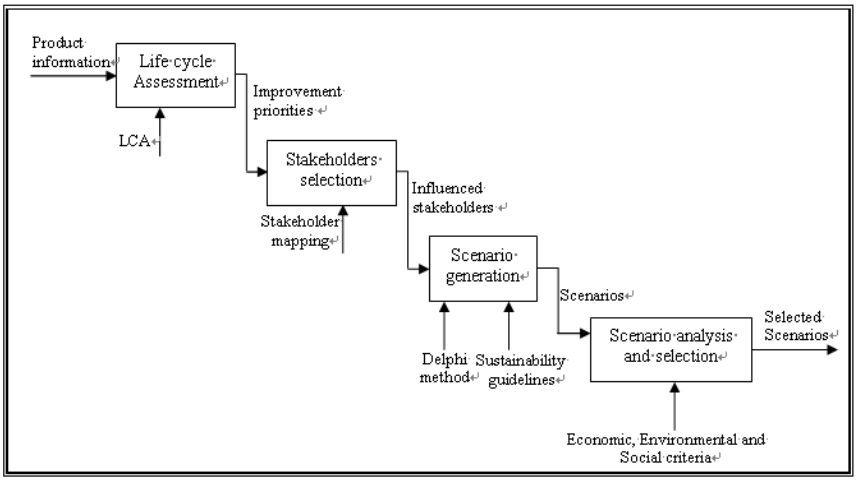
Figure 2 The Supply chain and its stakeholders. Source: De brito (2007)

3 FRAMEWORK FOR MOVING TOWARD SUSTAINABLE SUPPLY CHAIN

In this section we want to provide a step by step framework for practitioners to better managing supply chain in sustainable context. For doing this, at first, there is a need to identify different stages in the supply chain of a given product. Life cycle assessment (LCA) is a useful tool for doing this as well as environmental assessment. LCA starts with (1) definition of the functional unit, then (2) a quantitative inventory of all inputs and outputs is performed, followed by (3) classification and impact assessment and, finally, (4) evaluations. Results of such an analysis enable us to prioritize various stages of a product supply chain. These improvement priorities are the important stages in a supply chain that we should work on it to improve the sustainability of the whole product system. For example in UK textile project, results show that transportation has negligible negative environmental impact with respect to use phase in supply chain of T-Shirt. Then these results are presented to major stakeholders within the supply chain. De Brito, M. P. (2007) depicts supply chain and its stakeholders as Fig. 2.

Selected major stakeholders generate alternative scenarios for managing the supply chain through Delphi study. Applying the Delphi method basically involves several rounds of questions (and feedbacks) being send to a panel of stakeholders. Individual comments/answers remain anonymous to the group. Through the process, each member of the panel has the chance to refine his/her own answers or comments. Linstone and Turoff (2002) further explain the principles beyond the Delphi method providing examples of applications, and a statistical evaluation of the theoretical response distribution and response errors. In this case stakeholders, with respect to changes categories (as shown in Table 2), build alternative scenarios that can be applied in a given supply chain. Generated scenarios should be analyzed regarding economical, environmental and social criteria and the best scenarios will be chosen. The explained framework has been represented using IDEF0 process modeling in Fig. 3.

Figure 3 Framework for mowing toward sustainable supply chain



4 ILLUSTRATIVE CASE STUDY: TIRE INDUSTRY IN IRAN

Due to the increased number of vehicles, the 'mountain' of used tires has grown dramatically during the last decades. Every year, approximately 800 million scrap tires are disposed around the globe. This amount is expected to increase by approximately 2% each year (UNCTAD, 1996). The European Commission's Landfill Directive (European Directive 1999/31, Landfill Directive) will ban the disposal of whole tires to landfill by 2003, and shredded tires by 2006. Furthermore, the European Directive 2000/53 (European Directive 2000/53, End of Life Vehicle), ''End of Life Vehicle'', requires that the 80% in weight of an end life vehicle is reused or recycled, by 2006, and the processes concerned with scrap tires play an important role in achieving this target.

4.1 Life cycle of tire

Based on work of Kromer, et al. (1999), Fig. 4 shows the life cycle of a tire. A review of tire's life cycle is as follows:

The feedstock for tires is manufactured from fossil, mineral and replenishable resources. On the basis of its physical and chemical properties, this feedstock subsequently provides the performance potential for the functioning tire.

The structural parts are manufactured from the feedstock and assembled to form the green tire, which is then vulcanized to yield the functioning tire.

The tire is the link between the vehicle and the road, transmitting to the latter all forces acting on the vehicle and emitted by the vehicle. This function determines its design and chemical makeup. While in operation, the tire is subjected to constant wear due to tread abrasion. Eventually it forfeits its functional value due to lack of sufficient tread depth and is withdrawn from service.

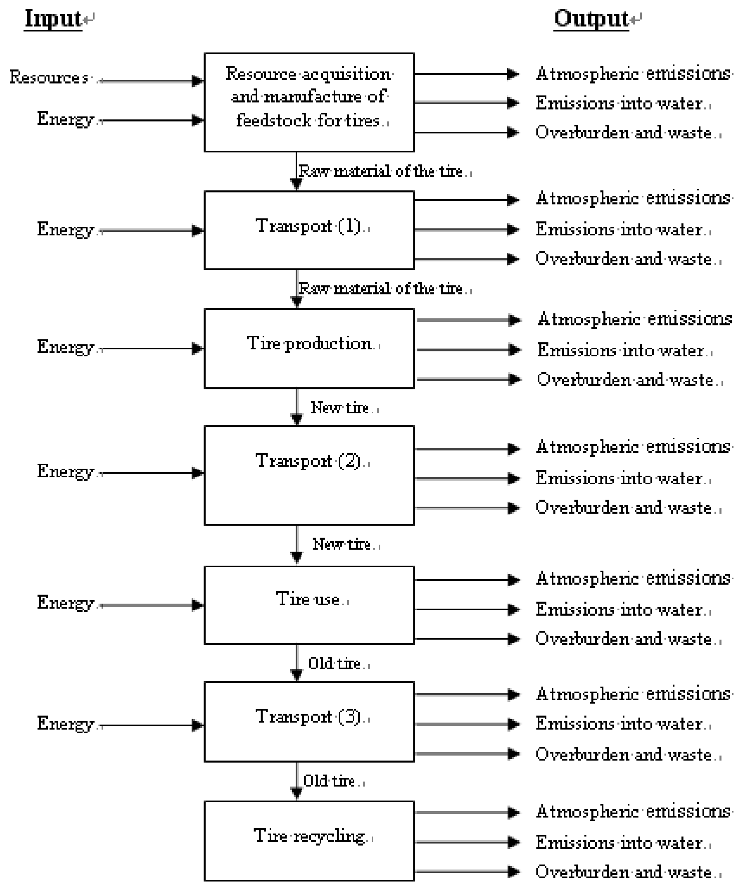


Figure 4 Life cycle of tire. Adopted from :(Kromer, et al., 1999)

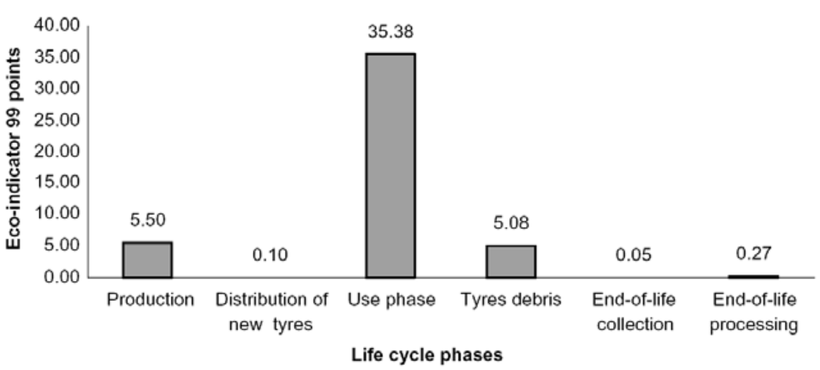


Figure 5 Contribution of the different life cycle phases on the environmental impact source: (PRé Consultants B.V., 2001).

The original tire's material composition and its energy content determines the value of the worn tire – and the recycling possibilities open to it. Worn tires are primarily retreaded or recycled as a rubber powder and rubber granulate. Another option is using as substitute fuel in cement plants. This study will also take a look at the recycling of worn tires in tire power plants.

Between the various life stages – during which the constituent materials undergo changes – the tires must be transported. The transport of the tires is strictly for the purpose of moving the materials under consideration from one location to another (Kromer, et al. 1999).

The resulting life cycle phase contributions to the global environmental impact of the medium-size tire, expressed in Eco-indicator 99 points, are illustrated in Fig. 5. (PRé Consultants B.V., 2001). The results show that the use phase is clearly the most relevant for the environmental burdens associated with the tires' life cycle. Production, tire debris and end-of-life processing are in subsequent orders.

4.2 Alternative scenarios/solutions

Results of LCA give us priorities for improvement. But there is an important point to notice. Results are based on average European car tire and don't correspond exactly to Iran situations. For example Iran situation in scrap tires is very different from European one. In spite of governmental regulations for waste treatment in Iran, about 70 percent of scrap tires disposed in stockpiles. Only 30 percent of discarded tires are processed in retreading (19 companies) and recycling companies. There are four units for tire recycling. Two of them produce pulverized tire and others produce rubber reclaim. The discarded stockpiles have negative environmental impact. The country also losses economical and social benefits, which can be achievable, from treating these scraps.

Regarding guidelines offered in Table 2 and tire industry situation in Iran, Table 3 shows noticeable solutions in each category. These options have been gathered from different stakeholders' point of view (consumers, producers, government). In the case of Iran, upgrading technologies has capital constraints. Legislation and promoting culture are very time consuming policies. End-of-life processing seems to be a better option with respect to economic, environment and social situation in Iran. It is economical because there is no need to great budget to install tire recycling plants with respect to technology upgrading. Environmental benefits are obvious because of existence of big stockpiles of scrap tires. From social point of view installing new plants can provide many job opportunities that is a major problem for developing countries. Designing a sustainable reverse logistics of tires is the subject of another paper of the authors.

Table 3 Possible solutions for better management of passenger tire production in sustainable environment

Category	Possible solutions
Production	• Upgrading production technologies from Bias to Radial
Use phase	• Establishing new legislations for minimum required tread depth. • Promoting recycling culture in public
End-of-life processing	• Tire retreading • Ambient recycling • Cryogenic recycling • Using tire as substitute fuel in cement kiln

5 SUMMARY AND CONCLUSIONS

In this paper we reviewed the literature about supply chain management in sustainable development context. The reviewed literature was classified in two categories: Environmental principles applicable to supply chain management and Scenario analysis of potential applicable changes. We provided from literature guidelines for better managing of supply chain in sustainable environment. We then present a step by step framework for moving towards a sustainable supply chain. This framework starts with LCA analysis of whole production system from raw material to product end-of-life. Result of LCA give stakeholders priorities of sustainability improvement. With the aim of LCA results and sustainability improvement guidelines, major stakeholders can build alternative scenarios/solutions for improving sustainability. Finally these scenarios was analyzed with respect to economical, environmental and social criteria and selected scenarios are offered. Next we applied this framework in tire industry in Iran as a case study. Results showed us that at present, end-of-life processing seems to be a better option for improving sustainability of tire production in Iran.

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