Modelling Approaches for a Sustainable Supply Chain

Vivek Sundar Magesh
TVS Logistics Services Limited
Chennai, India
viveksundarm@gmail.com

***Abstract*— Various approaches to model sustainable supply chain management can be cited in literature. This paper begins by explaining the concept of a sustainable supply chain management through its three pillars: environmental sustainability, social sustainability, and economic sustainability. The paper then summarizes four different approaches to modelling a sustainable supply chain found in Literature. These are:**

a) Using the Economic dimension: This involves economic issues and includes aspects of costs and revenues. Researches in this dimension follow a Life cycle Assessment (LCA) approach.

b) Using the Environmental dimension: Here energy demand and CO_2 emissions are chief criteria under observation. Here too one can find LCA based approaches towards modelling the sustainable supply chain.

c) Using the Social dimension: The social dimension includes aspects such as Corporate Social Responsibility and the relationship which business needs to have with society including aspects such as income redistribution, unemployment etc.

d) Integrating all dimensions: This is perhaps the most important approach to model a sustainable supply chain. Most often, this studies aspects of trade-offs between the three dimensions

Keywords— Sustainability, Supply Chain, Environment, Life cycle Assessment, Corporate Social Responsibility

I. INTRODUCTION

Sustainability is the process of addressing the needs of the present without unduly compromising the future. This definition however is vague and raises further questions about the concept of sustainability. Linton et al [1] point out that the following questions need to be addressed about sustainability.

- What resources will future generations require?
- At what levels can pollutants be released without having a negative effect on future generations?
- To what extent will new sources of depletable resources be identified in the future?
- At what level can renewable resources be exploited while ensuring that these resources remain renewable?
- To what extent can technology address sustainable use of resources with continued increases of material wealth?
- To what extent can market forces drive sustainability?
- Do lifestyles need to change and if so how?
- What sort of policies are required to achieve sustainability?

Seuring and Miller [2] offer a compelling definition for a sustainable supply chain. In their words "Sustainable SCM is the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development, i.e., economic, environmental and social, which are derived from customer and stakeholder requirements. In sustainable supply chains, environmental and social criteria need to be fulfilled by the members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria."

Carter et al [3] point out that much of sustainability research has been taking place in a very standalone fashion, where the interrelationships between various aspects of sustainability such as environment, diversity, human rights, philanthropy etc. are not considered. Carter [4] argues that managers have often overlooked opportunities to learn from the successes and failures of one type of initiative and apply this knowledge in future projects in other parts of their organization and in other areas of sustainability. In a nutshell sustainability needs to be handled in a holistic manner with a clear understanding as to how these different aspects fit together.

Carter [4] further argues that managers view sustainability as a social responsibility without accounting for economic performances of the same.

Elkington [5] suggests that sustainability is at the intersection of three indexes: Social Performance, Environmental performance and Economic performances (Refer Fig.1). Engaging in sustainability should be a requirement which focuses on the long run improvement of an organization's economic bottom line. In essence, they ensure the long term wellbeing of the organization. In that sense sustainability ceases to be a 'social responsibility' alone and becomes mandatory for the overall wellbeing of the organization and the supply chain itself.

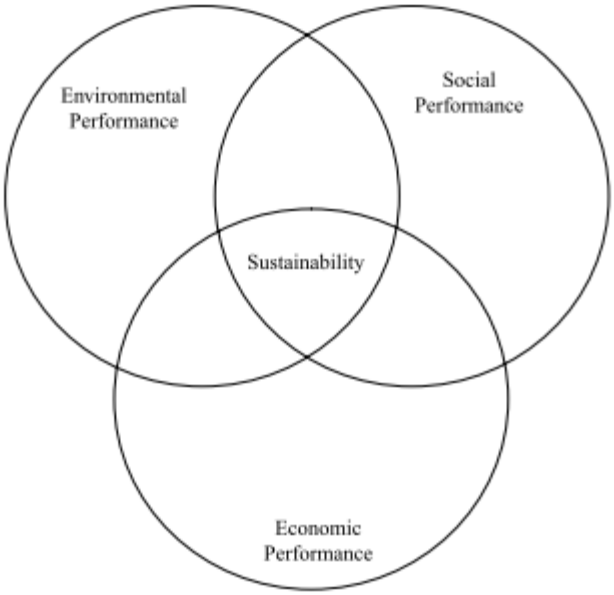

Fig. 1. Sustainablilty at the intersection of three indexes [5]

The next obvious question is about achieving this fit between the three indices. Carter and Rogers [6] suggest that "activities such as cost savings associated with reduced packaging and more effective design for reuse and recycling; lower health and safety costs, as well as reduced turnover and recruitments costs due to safer warehousing and transport and improved working conditions; reduced labour costs in the form of higher levels of motivation and productivity and less absenteeism resulting from improved working conditions; lower costs, shorter lead-times, improved product quality and lower disposal costs resulting from the implementation of ISO 14000 standards and the use of design for disassembly and reuse; and an enhanced organizational reputation, which can make a firm more attractive to both customers and suppliers." They further conceptualize sustainability as "the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter organizational business processes for improving the long term economic performance of the individual company and its supply chains."

Modelling of a sustainable supply chain involves "research where models of causal relationships between control variables and performance variables are developed, analysed and tested" [7]. There are basically four different dimensions to modelling a sustainable supply chain. These are

a) Economic dimension: This involves economic issues and includes aspects of costs and revenues. Researches in this dimension follow a Life cycle Assessment (LCA) approach.

b) Environmental dimension: Here energy demand and CO2 emissions are chief criteria under observation. Here too one can find LCA based approaches towards modelling the sustainable supply chain.

c) Social dimension: The social dimension includes aspects such as Corporate Social Responsibility and the relationship which business needs to have with society including aspects such as income redistribution, unemployment etc.

d) Integration of all dimensions: This is perhaps the most important approach to model a sustainable supply chain. Most often, this studies aspects of trade-offs between the three dimensions [8].

II. MODELLING APPROACHES

There have been many different approaches used to model sustainable supply chain management. We could categorise these into four different types. These are:

A) Life cycle assessment based models

B) Equilibrium models

C) Multi-Criteria decision making

D) Applications of the analytical hierarchy process [8]

In each of these models, usually the focus is on minimizing costs [8]. Let us look at each of these modelling methods in detail.

A. Life-cycle assessment (LCA) based studies

Life cycle assessment studies understand the complex interactions between a product and the environment from the product's beginning to end (Refer Fig.2). Pesonen [9] argues that the focus of product development should not be on product characteristics alone, but rather on improving the entire product life cycle. Holistic management of environmental impacts is essential. "Life-cycle assessment (LCA) is a technique developed to support the product-oriented environmental policies of companies. LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal." [9]

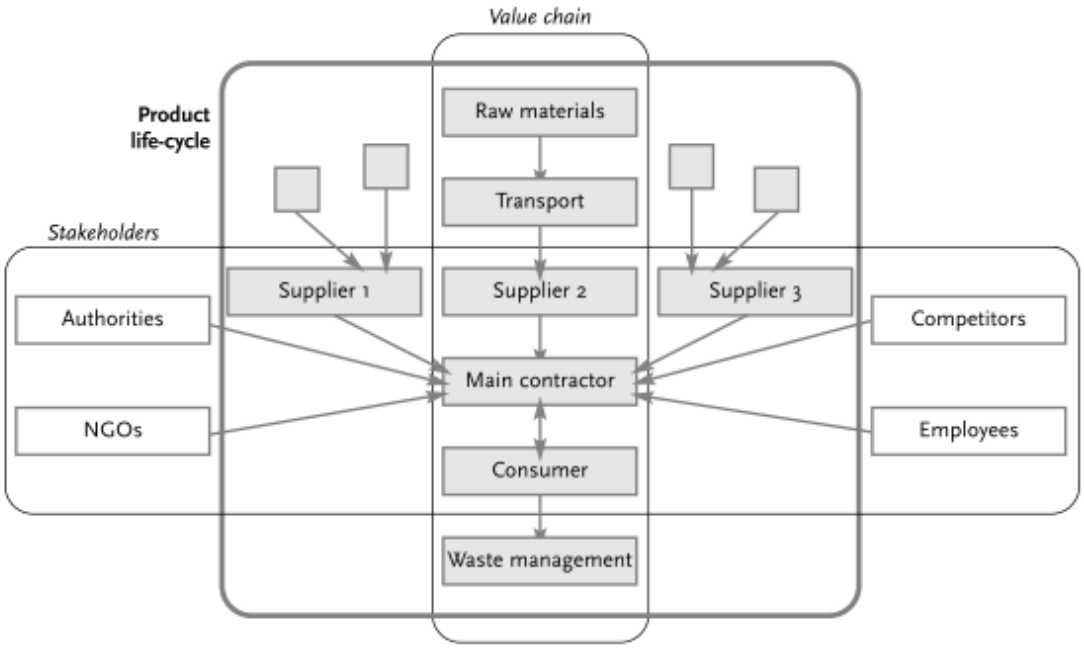

Fig. 2. LCA studies appreciate the environmental impact of a product throughout its life cycle [9]

The LCA framework consists of the following [9]:

- Compiling an inventory of relevant inputs and outputs of a product system (Refer Fig.3)
- Evaluating the potential environmental impacts associated with those inputs and outputs
- Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study

Externally these LCA studies provide information to external audiences, such as shareholders, customers, environmental pressure groups as well as other interested parties.

The chief limitation of LCA is the fact that data may not be reliable and thus the results of the assessment may not be reliable. The methodology itself is static in nature. [9]

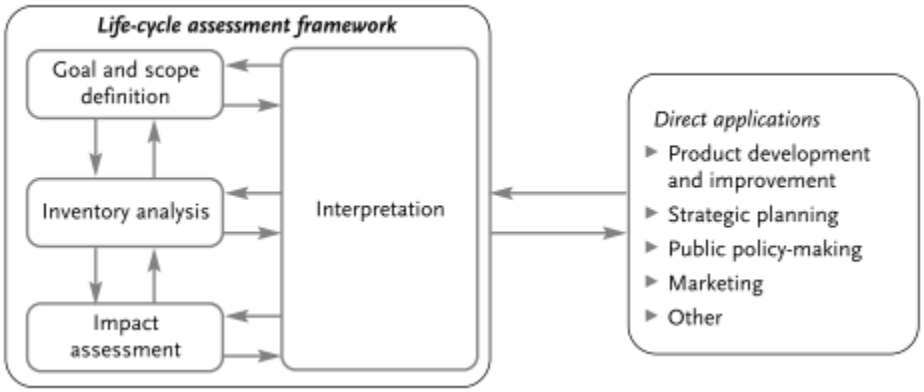

Fig. 3. LCA studies interpret the results of the inventory analysis with respect to the original objectives of the study [9]

However LCA offers a new way of thinking in business development where we take an integrated approach to study the environmental aspects of products and relate their environmental burden related to them during the whole product life cycle. Life cycle thinking fosters increased co-operation and shared responsibility between different actors of society.

B. Equilibrium Models

Equilibrium models focus on the identifying an equilibrium. Such equilibrium would be established by assessing what the optimal level of investment into environmental technologies and respective economic returns would be [8]. Kainuma and Tawara [10] propose a multiple utility function approach built on the following: a) LCA b) Supply chain return on Assets and c) Customer Satisfaction. (Refer Fig.4)

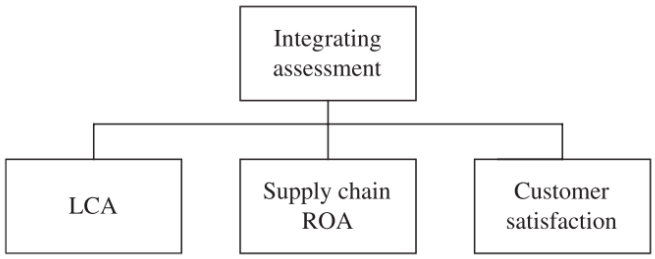

Fig. 4. Assessing sustainablity through a multiple utility function approach [10]

"ROA can be represented by the average stock through a supply chain and Customer Satisfaction can be represented by the out-of-stock ratio. To this we add one more metric, which is evaluated from the environmental viewpoint". Thus in this approach, supply chain performance is evaluated not only from a managerial standpoint but also from environmental aspects, and its efficiency is confirmed through an application study.

One another equilibrium model was proposed by Saint Jean [11] where emission standards were used. Interestingly here a minimum level of environmental and social standards has been specified. Once this is specified, equilibrium is evaluated. However there still exists some vagueness on evaluating social factors which clearly specify the minimum standards of operation. Unlike environmental issues, in the case of social issues providing this clearly is an issue.

C. Multi Criteria Decision Making (MCDM)

In these cases, the focus is on dealing with the different trade-offs among conflicting objectives [8]. Here different objectives need to be met at the same time. Min and Gengui [12] illustrate this modelling approach in their paper for another application.

The first step they adopt is about setting the goal for their supply chain. To set the goals, one further needs to see what the driving forces are. Min and Gengui [12] argue that in their case the driving forces are customer service initiatives, monetary value, information/knowledge transactions and risk elements. One can further delve deeper into each of these parameters and obtain measurable numbers. In case of customer service initiatives, one can have response time and product availability. Similarly in case of monetary value, you can have asset utilization, ROI and cost behavior.

The second step is to look at the supply chain constraints. In their case, capacity, service compliance etc. served as constraints.

Finally one has supply chain decision variables. These are the final outcome variables of the model developed. In [12], Location, allocation, network structuring, service sequence etc. are all the different decision variables.

The above example serves as a multi-criteria model. It could be translated to sustainable supply chain management in a similar manner. We could have relevant goals, driving forces, constraints and decision variables.

.

D. Analytical hierarchy process (AHP)

The analytical hierarchy process is also a multi-objective decision making technique. However it is a semi-quantitative decision making technique which simplifies and structures decisions. Saaty [13] defines the AHP as "A multi-criteria decision making approach in which factors are arranged in a hierarchic structure"

In the AHP, we arrange the factors that are important for a decision in a hierarchic structure descending from an overall goal to a criteria, sub criteria and alternatives in successive levels. It is important to understand that a hierarchy is not a traditional decision tree. Here each level may represent a different cut of a problem. [13]

Once this hierarchy is built, comparisons between elements take place two at a time about the relative importance of the elements when looking at the impact they have on the element above them in the hierarchy. It is here that human judgements are also used about the relative importance of the various elements. These human evaluations are converted to numbers which can be compared and processed over the entire range of the problem. A numerical weight is derived for each element in this case.

AHP has many advantages when applied to sustainable SCM problems. They help in evaluating complex decision situations, where not only are environmental and economic goals assessed at the same time, but also more specialized decisions such as looking at the role of hazardous substance management or green supplier selection and supplier development practices. [8]

Here the aim is not to reach equilibrium or optimal approach but rather pointing toward the complexity of decision making and emphasizing the influence of the decision makers. AHP allows taking different decision criteria into account and evaluating them without necessarily connecting all of them into one quantitative model. [8]

III. CONCLUSIONS

In this paper we have tried to address the various dimensions of sustainability as well as different modelling techniques used in literature.

The equilibrium models as well as the multi-objective decision making build on trade-off situations among environmental and economic goals. It almost seems obvious that these models take their starting point from trade-offs between the economic and environmental dimensions. Such trade-offs are a critical aspect of sustainable supply chain management and often form the starting point for respective action. Further, trade-offs are more straight forward to model in these approaches.

All three goal relations (Environmental, Social and Economic) are observed only for the LCA based papers. LCA data forms a back ground for many of the studies presented here.

The selection of the decision criteria is more flexible within the AHP as they are rather connected in a logical but not in a mathematical matter. This allows choosing criteria that represent either win–win-situations or minimum standards.

REFERENCES

[1] Linton, Jonathan D., Robert Klassen, and Vaidyanathan Jayaraman. "Sustainable supply chains: An introduction." Journal of Operations Management 25, no. 6 (2007): 1075-1082.

[2] Seuring, Stefan, and Martin Müller. "From a literature review to a conceptual framework for sustainable supply chain management." Journal of cleaner production 16, no. 15 (2008): 1699-1710.

[3] Carter, Craig R., and P. Liane Easton. "Sustainable supply chain management: evolution and future directions." International Journal of Physical Distribution & Logistics Management 41, no. 1 (2011): 46-62.

[4] Carter, Craig R. "Purchasing social responsibility and firm performance: The key mediating roles of organizational learning and supplier performance."International Journal of Physical Distribution & Logistics Management 35, no. 3 (2005): 177-194.

[5] Elkington, John. "Enter the triple bottom line." The triple bottom line: Does it all add up (2004): 1-16.

[6] Carter, Craig R., and Dale S. Rogers. "A framework of sustainable supply chain management: moving toward new theory." International journal of physical distribution & logistics management 38, no. 5 (2008): 360-387.

[7] Will M. Bertrand, J., and Jan C. Fransoo. "Operations management research methodologies using quantitative modeling." International Journal of Operations & Production Management 22, no. 2 (2002): 241-264.

[8] Seuring, Stefan. "A review of modeling approaches for sustainable supply chain management." Decision Support Systems 54, no. 4 (2013): 1513-1520.

[9] Pesonen, Hanna-Leena. "Environmental management of value chains." Greener Management International 2001, no. 33 (2001): 45-58.

[10] Kainuma, Yasutaka, and Nobuhiko Tawara. "A multiple attribute utility theory approach to lean and green supply chain management." International Journal of Production Economics 101, no. 1 (2006): 99-108.

[11] Saint Jean, Maïder. "Polluting emissions standards and clean technology trajectories under competitive selection and supply chain pressure." Journal of Cleaner Production 16, no. 1 (2008): S113-S123.

[12] Min, Hokey, and Gengui Zhou. "Supply chain modeling: past, present and future." Computers & industrial engineering 43, no. 1 (2002): 231-249.

[13] Saaty, Thomas L. "How to make a decision: the analytic hierarchy process."European journal of operational research 48, no. 1 (1990): 9-26.

BIOGRAPHY

Vivek Sundar Magesh is an MBA from the Indian Institute of Management at Tiruchirappalli, India. He is presently employed at TVS Logistics Services Limited. His interest areas are in developing better public systems and tackling global problems using techniques from Management Science. He also has an Electrical Engineering degree from the prestigious National Institute of Technology at Tiruchirappalli. As an Engineer he has published papers on optimization using heuristics. He looks forward to researching about improving public systems to tackle global challenges by joining a doctoral program in a reputed global business school.