IOSR Journal of Mechanical & Civil Engineering (IOSR-JMCE)
ISSN: 2278-1684, PP: 57-61
www.iosrjournals.org

Sustainable Supply Chains : An Introduction

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Abstract
Consideration is given to the convergence of supply chains and sustainability. In doing so, the focus on environmental management and operation is moved from local optimization of environmental factors to consideration of the entire supply chain during the production, increasing concerns over sustainability, whether driven by current legislation, public interest, or competitive opportunity. As such, sustainable development is a rich area for academic research that is still in its infancy and has the potential to affect future government policy, current production operation, and identify new business models. This paper provides a background to better understand current trends in this multidisciplinary field that intersect with operations management, and the research opportunities and challenges it present.

1. Introduction

The interation between sustainabilitynd supply chains is the critical next step from recent examinations of operations and the environment (Corbett and Kleindorfer, 2003) and operations and sustainability (Kleindorfer et al., 2005). While important contributionshavebeen made in relation to environmental operations and policy, strategy, finance, product design, supplier relations and post-consumer product management it is critical to move forward to the systemic issues that exist at the intersection of sustainability, environmental management and supply chains.

This paper gives consideration to both sustainability and supply chains. First, the relationship between these two concepts and previous work on environmental management of operations in considered. Second, new questions and research directions prompted by taking a sustainable supply chain perpective are considered. While many of the resulting areas of research relate directly to operations management, a great number of these open issues are fundamentally interdisciplinary in nature. this interdisciplinary nature is evident from the variety of fields in which researchers and practitioners are considering the challenges and implications of sustainability. Finally, the papers in this special issue are positioned within the growing study of sustainable supply chains.

2. Sustainability – on overview

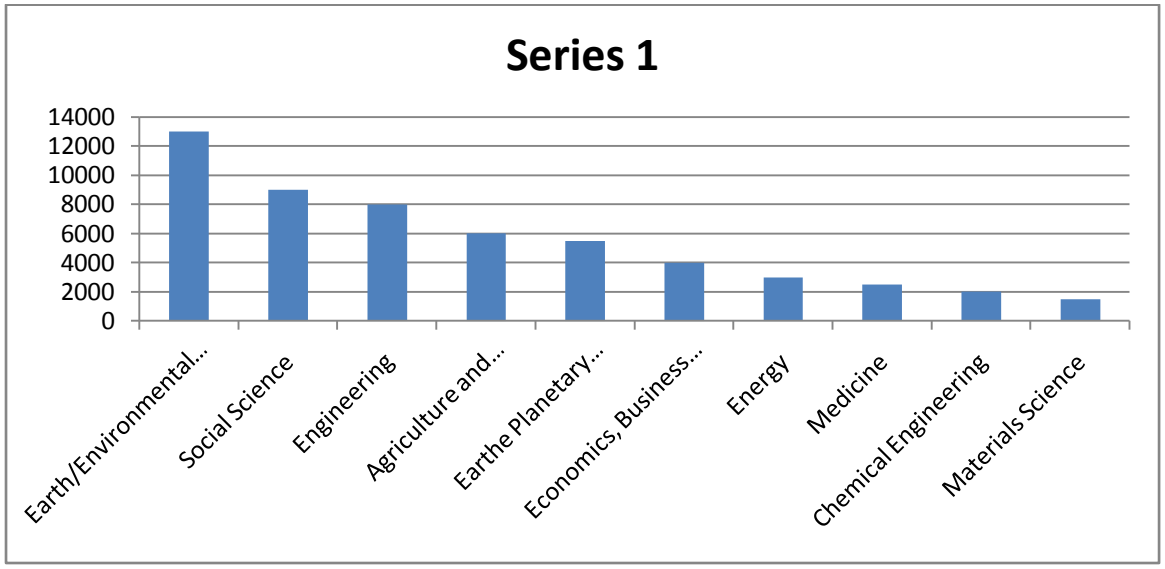
sustainability is increasingly discussed by policy makers (President's Council on sustainable Development, 1996; American chamber of Commerce of Europe, 2004), the popular press (Anon., 2001) and journals in various technical fields. To provide a sense of its recent dramatic growth, Fid. 1 summarizes the number of articles in different fields that consider sustainability and sustainable development, thereby demonstrating sustainability's interdisciplinary nature.

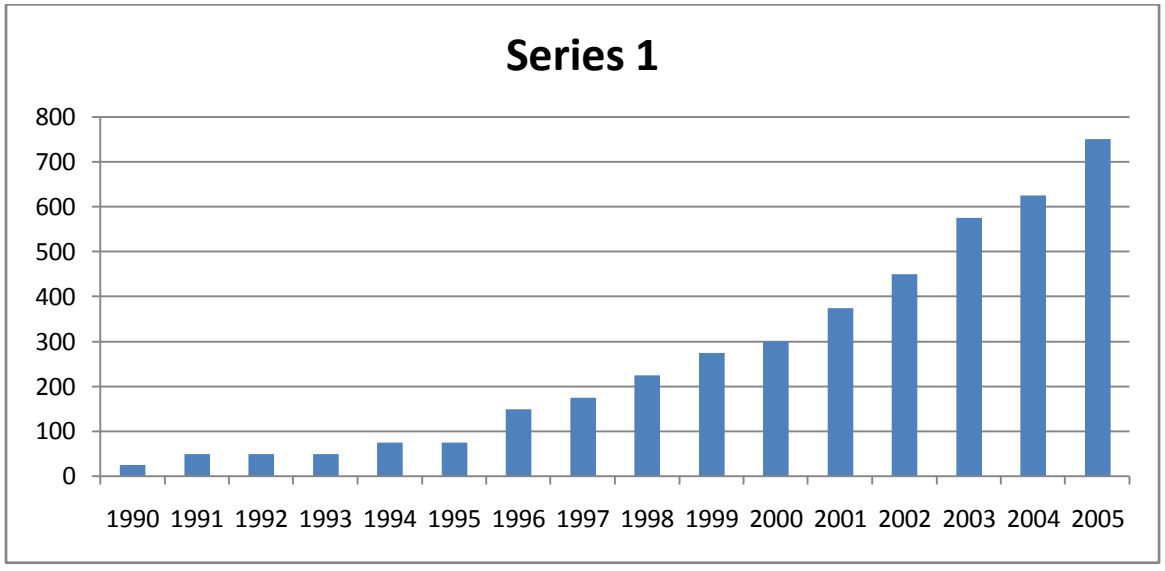
While The first considerationof sustainability can be traced back to practices of many ancient cultures, more recent attention toward sustainability & the environment can be found in the works of economist &philoshopers (e.g. harding 1968, Persons, 1997) Simultaneously , the concept of sustainability entered the polular culture, such as books – teLorax (Geisel, 1971) & films – Soylent Green (Fleischer, 1973) The migrated in the 1990s to the consideration of sustainability in the management literature and has quickly increased since then (fig.2)

The transition from a set of the technical concepts into the political & business mainstream is commonly linked to the book our common future, also known as the Brundland Report (WCD, 1987) sustainability is generally defined as using resources to meet the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987, Daly& Cobb 1994) Not surprisingly , given the vaguarities that surround this definition, hundreds of different interpretations have evolved to operationalize sustainability. As a result, this all encompassing definition of sustainability raised more questions than answers. These questions include.

- 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 depletableresoursesbe identified in the future?
- At what level can renewable resourses be exploited while ensuring that these resourses remain renewable?
- To what extent can technology address sustainable use of resourses 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?





While debate does occur regarding the implications of sustainability & the types of lifestyle or philosophysiesthat maybe required to achieve sustainability (Hart, 1997; Myers, 1997; Vincent &Panayotou1997; Kemp, 1994) the discussion is still in its early stage. One may argue that it is premature and/or just an academic curiosity to consider the operationalization of sustainability. In the past there have been many examples of environmental & public health concerns that were over hypes & eventually either discounted or seen as over hypes & eventually either discounted or seen as a reduced threat by many after additional evidence & insights were obtained (Wildavsky, 1995) However recent reactions to growing environmental concerns of product & process derived pollution have included rapid substantive change. For example legislation was adopted worldwide over a relatively short timeframe to phase out chemicals with Ozone Depleting Potential (Cook, 1996, UNEP, 1994) More recently a steady increase can be seen in both public &private sector recognition of global warming as a societal issue (Ball, 2004, Corey, 2004, 2005, Bodansky et

al 2004) Sustainability as an intergrative concept, is starting to follow a similar trajectory, with new initiatives being proposed or adopted by both the public & private sectors.

Recently the European Union (EU) has become a highly influential proponent of sustainability. The European parliament views this concept as so critical to the future of the EU that current & future legislation must integrate sustainability into implementation orders (American Chamber of Commerce of Europe, 2004) One recent outcome has been the European Directives on Waste & Electronic Equipment (EU, 2003a,b: Perchards, 2005). If the EUs earlier influences in the area of quality management & the global adoption of ISO 9001 certification is an indication, the EUs emphasis on sustainability is likely to be a strong harbinger of actions to be others. Many other countries and juridctions are introducing legislation that addresses similar issues (Maine 2005, State of California, 2003, State of Minnesota, 2003, DEP,2003, Shih, 2001, DEP 1998, Micklitz, 1992)

Clearly there is sufficient activity & ongoing development in the area of sustainability, that it is worthwhile for operations management researchers & practitioners to consider the implications &impact of sustainability on traditional assumptions and practices in the field of operations management. While some of the relevant question have been considered by work in topics such as greener product design (Lennx et al 2000, Dambacn& Allenby 1995, Sarkis, 1995) Cleaner process technology (Clelland et al 2000, Hasek, 1997, porter & Van der Linde, 1995, Huisingh& Martin, 1986) product life extension (Linton &jayaraman, 2005) and environmental management systems (Sroufe, 2004 melnyk et al 2003, Kitazawa &Sarkis, 2000) these subjects are not considered from the unifying perspective of sustainability. Also worth noting ais research in industrial ecology, a field that cosiders industrial processes from the perspective of a biological ecosystem (Allenby 2000, Esty& Porter 1998, Ayres, 1989) Industrial ecology offers useful insights to researchers on the use productive use of by products (wastes) generated along a supply chain. References on industrialecology include Frosch (1994) Frosch&Gallopoulos (1989) Journal of industrial ecology. Having offered an overview of sustainability, sustainability's increasing importance in policy & the limitation of current research to the many questions sustainability poses, the inteaction between sustainability poses, the interaction between sustainability & supply chains are briefly considered next.

3. The interaction between sustainability and supply chains

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& Nichols, 1999) In many cases this approach requires organizations to operate sub-optimally from a cost perspective to creat the greatst possible value along the entire supply chain (Leenders&Blenkhorn, 1998)

A focus on supply chains is a step towards the broader adoption & development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery to the customer. however sustainability also must integrate issues and flows that extend beyond the core of supply chain management, product design manufacturing by products, by products, products end-of-life, & recovery process atend-of-life.

3.1 **Product design**

Techniques such as life cycle assessment (Rebitizer et al 2004, Pennington et al 2004) are used to assist in the determination of how to design a product to minimize its environmental impact over its useable life and afterwards (Karna&Heiskanen, 1998). This field at the interface of engineering, product design & engineering considers resources depletion as well as environmental impacts.

3.2 **Manufacturing by products**

Consideration of the extended supply chain includes the reduction & elimination of by-products through cleaner process technologies (kemp,1994, Johanson, 1992) and quality and lean production techniques (Zink 2005, Ahu&Sarkis, 2004, King &lennox, 2001) From the industrial ecology literature & increasingly considered by manufacturers is th use of by products of manufacturing such as the use of waste heat for conditioning space or the use of food waste for producing new food products (Frosch&Gallopoulos, 1989) This is function of both process design & continuous improvement activities.

3.3 By-products produced during productuse :

The management of product sustainability is not only a function of design, but also product management. The potential for great opportunities and profit have been recognized by many who have called for extended producer invovement and responsibility. This involvement has appeared in calls for the provision of a product as a service (Michaelis and Coates, 1994) or for manufactures to provide a series of services to support and supplement sale of the original product (Wise and Baumgartner, 1999).

3.4 Product life extension.

There are a variety of techniques that are used to extend the life of products (Linton and Jayaraman, 2005). Through the extension of product life, the depletion of resources through the production of new product is avoided. This approach works against the design for obsolescence typical in a consumption oriented society. However, it increase the value created by an individual product. The challenge for the provider of the product is to develop offerings that allow for them to capture more of the product value. Such approaches are discussed by the authors of work relating to by-products produced during product use above. While some manufactures have capitalized on opportunities created by products life extension (examples include : Woellerts, 2006; Guide et al., 2003; Linton and Johnston, 2000), the failure of Original Equipment Manufacturers to capitalize on opportunities has led to vibrant highly profitable business in such areas as remanufacturing (Arndt, 2005; Lund, 1982, 1984)

Changes in policy, such as that for electrical and electronic equipment in Europe (EU, 2003a), force both manufactures and researchers to explore options to improve the sustainability of operations across the supply chain. However, change can also flow in the opposite direction. Research and practice in supply chain management can affect policy, science of social science by presenting alternative scenarios for the development of sustainable supply chains. Sustainability stretches the concept of supply chain management to look at optimizing operations from a boraderprespective – the entire production system and post production stewardship as opposed to just the production of a specific product. Matos and Hall (in press) question the notion of optimization as they explore how the complexity associated with defining, co-coordinating and interacting with integrating sustainability into the supply chain.

In addition sustainability introduces less quantifiable considerations relating to the natural environment and in some cases social issues-what the business ethicists and the accounting fields refers to as the triple bottom line (Elkington, 1998). for example, consideration of the interaction between economic consideration with social and environmental issues – such as noise pollution, congestion, and carbon dioxide emissions – in logistics has been considered by Quak and de Koster (in press) in their work on exploring retailers' sensitivity to sustainability policies.

The previously mentioned trend towards integration of sustainability concepts into legislation changes the environment that firms operate in and the nature of competition as considered by researchers such as Webster and Mitra (in press) in their study of competitive strategy in remanufacturing and the impact of take-back laws. These changes require management to not only address new issues, such as the reverse supply chain, but to tightly change existing practices and create new production and management systems. Kocabasoglu et al. (in press) consider some of these issues in their research on linking forward and reverse supply chain investment; the role of business uncertainty. Having illustrated the broad effects that the integration of sustainability considerations have into the supply chain of policy, competitive environment and strategy, it is also critical to consider that many critical tactical and operational issues must be considered. For example Ackali et al. (in press) consider decentralized collection and processing of end-of-life products and Mazhar et al. (in press) consider how to obtain better use from used products through remaining life estimation of used components in consumer products: life cycle data analysis by Weibull and artificial naural networks. it is also evident upon reflection of this and other research that due to the closed-system nature of sustainability, opportunities to modify operations or changes in tactics can have substantial effects on policy, firm strategy and the competitive environment.

While sustainability provides an overarching frame work for much of the past and ongoing environmental research in operations, sustainability moves beyond current common practice. Supply chains must be explicitly extended to include by-products of the supply chain, to consider the entire lifecycle of the product, and to optimize and product not only from a current cost standpoint but also a total cost standpoint. Total cost must include the effects of resource depletion and the generation of by-products that are neither captured nor used (pollutants and waste). Research into the operational implications of various policies and how business can integrate sustainability is cirtical, since currnt legal trends will force many of these changes whether or not academe and practice is prepared. Such research requires not only that many questions be answered, but a wide variety of approaches including: case studies analysis (Matos and Hall, in press), multiple case modeling (Quak and de Koster), model developmetn (Webster and Mitra, in press: Ackali et al., in press) and machine learning (Mazhar et al., in press).

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