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Industrial ecology, industrial symbiosis and supply chain environmental sustainability: a case study of a large UK distributor

Michael Leigh*, Xiaohong Li

Sheffield Business School, Sheffield Hallam University, Sheffield S11WB, UK

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ABSTRACT

The supply chain management literature indicates that limited research has explored the roles of Industrial Ecology and Industrial Symbiosis in relation to supply chain environmental sustainability development. Studies have explored supply chain environmental sustainability development and provided different approaches for developing environmentally sustainable supply chains. These include environmental management, design for environment, product stewardship, green purchasing, reverse logistics, recycling, reuse, and remanufacturing. These approaches have often been considered independently. Industrial Ecology and Industrial Symbiosis offer systematic thinking for companies to integrate key elements of these approaches into their supply chain environmental sustainability development. This study aims to develop a conceptual framework to embrace the integration and identify opportunities for companies to work collaboratively. The initial framework was proposed based on the review of the literature associated with environmentally sustainability supply chain management, Industrial Ecology, and Industrial Symbiosis. The initial framework is improved by corroborating the case study company's experience, a large UK distributor. Different hierarchies in waste management have also been considered when developing the framework. The paper emphasises the importance of prevention and reduction methods. The developed framework illustrates the areas and opportunities for supply chain parties to work collaboratively towards environmentally friendly activities. The developed framework contributes to the environmentally sustainable supply chain management literature and encourages companies to apply Industrial Ecology and Industrial Symbiosis to develop their environmentally sustainable supply chains.

1. Introduction

Supply chain management (SCM) has evolved into design, management and optimisation of activities of external and internal parties and their relationships along a supply chain (Spekman et al., 1998). It aims to facilitate better information and material flows through developing integration and collaboration among supply chain parties to form better relationships (Ashby et al., 2012; Handfield and Nichols, 1999). SCM proposes a development opportunity for different parties along a supply chain to work towards a higher level of collaboration through breaking organisational boundaries (Frankel et al., 2008). Sustainable supply chain management (SSCM) considers social, environmental and economic aspects of sustainability along the supply chain (Carter and Rogers, 2008). All three dimensions of sustainability are important to supply chain sustainability development. However, it is not possible to cover all three dimensions whilst undertaking an in-depth exploration in a single research paper. This paper focuses on environmental sustainability. Environmental sustainability is concerned with reduced negative impact of companies' activities on the environment with a long term consideration (Goodland, 1995; Li and Leigh, 2010). Environmental sustainability proposes a challenging area for SSCM and for applying concepts such as Industrial Ecology (IE) and Industrial Symbiosis (IS).

IE considers principles of biological ecosystems when designing and redesigning industrial systems to create more efficient interactions both within industrial systems and between industrial natural systems (Ayres and Ayres, 2002; Lombardi and Laybourn, 2012). IS applies the ecological metaphor of IE to create a collective approach to firms and industries traditionally viewed as separate entities and considers the entire system with regard to the physical exchange of materials, energy, water and by-products (Chertow, 2000; Costa and Ferrão, 2010). IE aims to improve the efficiency of exchanges within and between systems; whilst IS

* Corresponding author.
E-mail addresses: m.leigh@shu.ac.uk, michaelleigh@gmail.com (M. Leigh).

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Table 1
Environmentally SSCM approaches and key references in the literature.

Approaches	Key references
Environmental management/Environment management system	Van Hoek (1999), Lee and Rhee (2005), Vachon and Klassen (2006), Darnall et al. (2008), Nawrocka et al. (2009), Agarwal and Thiel (2012), Wiengarten et al. (2013), Grekova et al. (2014)
Design for environment	Gupta (1995), Tsoulfas and Pappis (2006), Kurk and Eagan (2008), Soylu and Dumville (2011), Bevilacqua et al. (2012)
Product stewardship	Sarkis (1995), Lewis (2005), Ruskino (2007), Snir (2009), Rogers et al. (2010)
Green purchasing	Tsoulfas and Pappis (2006), Gold et al. (2010), Zhu et al. (2007), Eltayeb and Zailani (2010), Green et al. (2012), Yen and Yen (2012)
Reverse logistics	Gupta (1995), Lippman (2001), Blumberg (2005), Kleindorfer et al. (2005), Varma et al. (2006), Andersen and Skjoett-Larsen (2009), Jayant et al. (2012), Huscroft et al. (2013), Mutingi (2014)
Recycle, reuse and remanufacturing	Gupta (1995), Sarkis (1995), Kleindorfer et al. (2005), Kuik et al. (2011), Loomba and Nakashima (2012)

emphasises the collaboration amongst firms in industries to promote actions which are consistent with ecological principles (Chertow, 2000). IS, considering the core of IE, focuses on innovation and networks for knowledge sharing to improve the efficiency of the use of materials and energy, which is beyond waste and by-product exchanges (Lombardi and Laybourn, 2012). Hence, IS and IE are directly related and are increasingly relevant to the environmental sustainability of a supply chain (Mattila et al., 2010; Yuan and Shi, 2009). IE and IS offer valuable thinking to environmental sustainability development of a supply chain by identifying opportunities for businesses along a supply chain through working collaboratively towards reduction of the overall negative impact on the environment. IE has been considered at the firm level (Despeisse et al., 2012; Wells and Orsato, 2005), at the regional level (Boons, 2008; Deutz and Gibbs, 2008; Röser et al., 2011), and the global level (Duchin and Levine, 2013). IS has been applied to a supply chain concept (Bansal and McKnight, 2009; Yuan and Shi, 2009). Only a few studies have considered both IE and IS in the context of supply chain environmental sustainability development with limited consideration of integration (Ashton, 2008; Mattila et al., 2010; Seuring, 2004; Yuan and Shi, 2009). A framework which embraces IE and IS integration within the context of supply chain environmental sustainability development is desirable.

This study aims to develop a conceptual framework for supply chain environmental sustainability development through exploring possible integrations of IE and IS with environmentally SSCM. This is achieved through literature learning and a case study of a large UK distributor. Following the introduction, the literature reviews environmentally SSCM approaches, IE and IS. The research method is presented, followed by an overview of the case study organisation. The company interview results and further implications for the development of the framework are discussed leading to the presentation of the developed framework. Conclusions are drawn at the end and future research areas proposed.

2. Literature review

This literature review contains two parts. The first part presents approaches for achieving environmental sustainability of a supply chain. The second part reviews IE and IS and explores their possible integrations within a supply chain network. The literature review generates the initial framework.

2.1. Environmentally sustainability supply chain approaches

Environmentally SSCM aims to reduce the negative impact on the environment of all activities along a supply chain (Andiç et al., 2012; Sarkis et al., 2011; Wu and Pagell, 2011; Yeh and Chuang, 2011). The development of environmentally sustainable supply chains begins when a focal firm collaborates with its suppliers and/or customers to improve the environmental performance of its products, services, processes, and supply chains (Simpson and Power, 2005). Environmental performance refers to the level of the impact on the environment. Reducing the impact on the environment indicates a better environmental performance. By applying different approaches, the environmental performance of a company and its supply chain could be improved. The environmentally SSCM literature offers different approaches for companies to implement and achieve improvement of their supply chain environmental performance. These approaches along with some representative key references are provided in Table 1.

'Environmental management' contains three different methods within a business strategy at different impact levels: reactive 'end of pipe' pollution control, proactive reusing, remanufacturing, and recycling of products and materials within the supply chain, and an integrated approach into value-seeking supply chain re-design integrated into business strategy (Van Hoek, 1999). A value-seeking pollution preventive approach results in a better environmental performance than an end of pipe approach (Lee and Rhee, 2005). However, environmental management investments tend to be reactive, thus most production processes and products remain unchanged (Vachon and Klassen, 2006).

The use of environmental management system (EMS) such as ISO 14001, are adopted as part of a wider effort by supply chain parties to reduce their negative impacts on the environment along their supply chains (Wiengarten et al., 2013). Organisations implementing an EMS require the cooperation with their suppliers and customers along their supply chains to achieve better results (Agarwal and Thiel, 2012). Organisations that have achieved a high level of in-company environmental management are more likely to have developed an externally-orientated EMS (Darnall et al., 2008; Grekova et al., 2014). However, the implementation of an EMS in a company may not necessarily lead to cooperation amongst the purchasing and environmental functions, and its supply chain parties (Nawrocka et al., 2009).

'Design for the environment' includes both product design and supply chain process design. Design for a more environmentally friendly product considers the creation of recoverable parts of a product that are durable, repeatedly usable, and environmentally recoverable in disposal at its design and development stage (Kurk and Eagan, 2008; Tsoulfas and Pappis, 2006). This approach also takes additional environmental concerns into consideration of a design to enable possible recycling and disassembly at the end of product life cycle (Gupta, 1995). Desirable environmental attributes for designing a product may include free from toxic substances, biodegradable, recyclable, upgradeable, and with low energy consumption (Soylu and Dumville, 2011). This approach focuses on the design stage and emphasises the importance of product, process and supply chain design to their life cycle impact on the environment (Bevilacqua et al., 2012).

'Product stewardship' is an important concept in 'design for product'. It emphasises the importance of the 'cradle to cradle'

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