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TOWARDS AN ECO-EFFICIENCY MODEL FOR EXTENDED SUPPLY CHAIN – BRAZILIAN FOOD INDUSTRY

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Abstract

Designers make decisions that ultimately impact on both the economic and environmental performance of the products and processes, and many of these costs and impacts occur across the supply chain. This paper aims to present an initial discussion towards an eco-efficiency model for product life cycle management within the extended supply chain (ESC) for food industry. Eco-efficiency (EE) has the potential to incorporate both environmental and economic improvement within a company and assist its decision-making processes as well as implement improvements within its ESC. In this context, the proposed model aims to consider economic aspects along the product ESC and to present elements which can help companies to promote improvements within its supply chain by considering a more environmentally friendly perspective.

Key-words: food industry, eco-efficiency, extended supply chain, life cycle management

INTRODUCTION

Environmental tactics have been implemented by companies in response to stricter demands from various sectors of society, namely: NGO's (e.g. Greenpeace), government (environmental legislation), international treaties (e.g. Rio Submit and Kyoto Protocol), and market demands for improving their sustainable performance.

In addition, businesses have been challenged to recognise that the ecological footprint of their products and services is not limited to the production stage of the final product manufacturer (Nawrocka *et al*, 2009). In fact, all stages of the product life cycle influence on the environmental burden of a supply chain, including resource extraction, manufacturing, use, reuse, recycling or final disposal (Zhu *et al*, 2007).

In this context, the extended supply chain (ESC) in product design decisions is a relevant element that needs to be taken into account. ESC is defined as a network of organisations that are involved, through upstream and downstream linkages, in the different process and activities that produce value in the form of products and services to the final consumer, including use and final disposal (Michelsen *et al*, 2006). In other words, the ESC encompasses the full product lifecycle perspective and not only contemplates the cradle to grave vision but also includes the potential for cradle to cradle, as it considers the material returning to its full use using reverse flow which is possible by recycle, reuse and remanufacture.

As a consequence, managing the supply chain based on a lifecycle perspective can be beneficial for organisations. For instance, it might be possible to identify and prioritise the stages with higher pollution burden and environmental risk as well as to avoid pollution transferring from one stage to another. In addition, managing the supply chain based on this perspective helps to promote the competitiveness in the chain, reducing costs and strengthening the image before the society (Haes, Rooijen, 2005; Jabbour, Jabbour, 2009 and Seuring, Muller, 2008).

The product life cycle has historically been driven most intensively by focal companies, which can positively influence the entire production chain, requiring suppliers and service providers to establish environmental practices and procedures which ranges from reactive stance (e.g. attention to legal, operational adjustments, elimination or decreasing the concentration of hazardous substances, etc.) to proactive stance (e.g. implementing certifiable Management Systems, such as Environmental - ISO 14001 and Social - SA 8000, environmental labelling of materials

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and products, sustainability reports, etc.) (Nawrocka *et al*, 2009; Michelsen *et al*, 2006). Further, focal companies often take the original equipment manufacturer (OEM) position in most sectors and offer the chance to influence both suppliers and customers/users.

However, to develop individual actions in the extended supply chain does not mean that the organisation has total control over its product chain. It is necessary to consider the production chain within all organisational and functions levels. Thus, at the strategic level it is expected that OEMs will continue their investment in resources and use of techniques to support continuous improvement of products and services offered as well as to support the decision-making process of supply chain management. For example, the manufacturing sector will be increasingly pressured to adopt environmental tools to optimise the use of its materials and to present environmental criteria for materials purchasing sector. So there must be a strong association of what is defined at the strategic, tactical and operational levels. The changes of decisions on these three levels should happen smoothly and naturally such that environmental issues can permeate the entire company.

Eco-efficiency has been recognised as an important tool to integrate and strengthen various functions of a company as well as to assist its decision-making process and to improve ESC by using environmental, economic performance information (Michelsen *et al*, 2006; Haes, Rooijen, 2005; Burritt, Saka, 2006 and Kicherer *et al*, 2007). For instance, the implementation of EE within food industry chain might be extremely important considering the better control and reduction of environmental impacts in terms of natural resource consumption (water, soil, energy, materials packaging) and output pollution such as: emission, wastewater and waste. Maxime et al (2006) highlight that the food and beverage industry are responsible for processing 80% of primary agricultural production.

In Brazil, the food industry during 2009 had a turnover of 291.6 billion Reais, up 50% over the past nine years, which shows a big picture of continued growth. In relation to Brazilian GDP, it was responsible for almost 10% and employed more than 1.4 million workers in 2009 (ABIA, 2007). In Rio Grande do Norte State, the food industry represents over 70% of exports, mainly through fish and shellfish, fruits, sugar, chocolates and candies and marine salt (In 2004, exports accounted for R$ 413.3 million) (Portal Brasil, 2010). Hence, approaching the productive chain of the food industry with emphasis on EE means to reduce drastically waste, which is generated throughout its extended supply chain, and to minimise environmental impacts.

Therefore, the analysis of the literature revealed that it is difficult to find out how to evaluate the impact of a supply for a product lifecycle in terms of environmental aspects and how to improve some members of ESC and reduce their effect of the product on the environment. In this sense, this paper aims to present an initial discussion towards an eco-efficiency model for product life cycle management within the extended supply chain (ESC) for food industry in order to facilitate the incorporation of environmental and economic improvement by companies of ESC in their business procedure.

PRODUCT LIFE CYCLE MANAGEMENT AND ECO-EFFICIENCY

Product Life Cycle Management

The life cycle management of products (LCM) is an approach, which supports the management and integration of business processes and life cycle information in order to increase productivity and improve the effectiveness of business processes regarding planning, development, manufacturing, maintenance and removal of products (Zancul, 2009). It is a vast theme that involves a variety of areas, such as: marketing (optimise sales curve), the engineering product development (developing products that consider performance requirements, impact on environment and subsequent costs of the life cycle), environmental management (to measure and reduce environmental impacts throughout the life cycle) cost management (providing cost information to direct the engineering decisions) and data management product (to support the creation, management and dissemination, and use of information throughout the product life cycle).

According to UNEP / SECTA (2009), LCM is a business management approach that can be used by all business sizes and types to improve sustainability performance of product. Thus, the LCM can be used to organise, analyse and manage information and activities for continuous improvement of products throughout the life cycle.

The product life cycle is characterised by a succession of stages of production, covering since the extraction of raw materials for their production, until the application of reverse logistic concepts for the gathering of product at the end of their use (Romeiro Filho, 2010).

Members of an extended supply chain, which are located in these different stages of lifecycle, can be mapped and assessed in order to identify improvement opportunities in terms of eco-efficiency. The closer relationship between suppliers and service providers and focal company can

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rise gradually the chances for mutual benefit, as well as to enable improvements in product design, value engineering practices of components, etc. It is also emphasised that many focal companies are finding that by maintaining its suppliers involved in product development process can achieve innovative solutions (Gomes, 2004).

There are several reasons to develop production chain management practices based on a product lifecycle perspective. For example, a study carried out by Zhun et al (2007) within seventy-seven companies across the automobile industry showed that certain laws influenced the adoption of environmental practices, such as eco-design and implementation of investment for improvements from suppliers. The pressure from customers and NGOs resulted in the adoption of green purchasing (materials produced with less environmental impacts).

However, unfortunately, these practices have not been fully implemented yet within Brazilian companies. Jabbour and Jabbour (2009) conducted a study examining the establishment of environmental practices in the selection of suppliers of five major companies in São Paulo State, certified by ISO 14001. They found that only one company influenced their suppliers across the wide range of criteria. It is noteworthy that this particular company had carried out a Life Cycle Analysis (LCA) for its main products which resulted in significant improvements within the company and its production chain. In addition, other two companies had strict criteria with no practical effect on the suppliers while in two ones any systematic relation with their suppliers. Also, the authors stated that the environmental management maturity level of companies was a driving force for the establishment of criteria to select their suppliers.

Strategies and tools have been adopted by focal companies in order to improve environmental stance across their extended supply chain. Haes *et* Rooijen (2005) suggest some approaches to product life cycle that can be incorporated across a chain, namely: Industrial Ecology (multidisciplinary study of industrial systems and economic activities and their relationship to the natural system); Dematerialisation (substantial reduction in the volume of materials and energy usage by products and services), Life Cycle Assessment (designed to assess the consequences of a product or service from cradle to grave), and Eco-efficiency (management philosophy for sustainable development, meaning produce more with less).

Thus, one approach which can be used to manage the ESC focusing on life cycle of product or service is eco-efficiency which will be discussed in the next section.

Eco-efficiency applied within ESC

Historically, the term eco-efficiency was established by the World Business Council for Sustainable Development (WBCSD) in 1991 as the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth's carrying capacity (Lehni, 2000).

According to Verfaillie and Bidwell (2000), EE is a philosophy of management that challenges organisations to get more value for products and services by reducing the quantities of materials, energy and emissions, i.e. producing more with less. Hence, organisations have to be creative and innovative, for example, establishing more efficient practices in the chain of supply and improved products.

Eco-efficiency is a practical approach that has economic and environmental issues integrated into a single path (Maxime, 2006). Accordingly, EE allows an organisation to strengthen its competitiveness, implementing marketing activities, improving the corporate image and to implement actions to recycle waste in supply chains (Cramer, Stevels, 2001).

Saling *et al.* (2002) state that EE identifies weaknesses in global processes and systems throughout the product life cycle, making it possible to prepare and support the development of new processes, accelerate their releases and decrease costs.

Lehni (2000) emphasises that EE has three overall objectives, namely: to reduce the consumption of resource (which includes minimizing the use of energy, materials, water, enhancing recyclability and product durability, and closing material loops), to reduce the impact on nature (which covers the minimisation of air emissions, water discharges, waste disposal and the dispersion of toxic substances, as well as, fostering the sustainable use of renewable resources), and to increase product and service value (this means providing more benefits to customers through product functionality, flexibility and modularity).

The implementation of EE within supply chains is related to the development of strategies to optimise the resource usage and the environmental performance measurement and economic system, covering all the stages of lifecycle, from extraction of raw materials to materials disposal. It might be a win-win strategy, where all member of SC can be involved by focal company in order to achieve environmental and economic benefits.

The use of EE strategies can also be addressed not only to business decisions (e.g. establishment of criteria to promote improvements in production supply, selection of suppliers and service providers), but also market (e.g. shareholders - new acquisitions), government (e.g. development of public policies). Many managers, consumers, and even politicians are interested in environmentally friendly decisions,

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but there is still a lack of clear and precise information (Kuosmanen, 2005).

EE has been worked as the performance evaluation process of economic activities, although, in an isolated manner. Actually, this evaluation process follows the traditional measurement proposed by the WBCSD (Verfaillie, Bidwell, 2000), in which the EE is calculated as the ratio between the value of the product or service (mass or volume, monetary value or function) and the environmental influences of the product or service creation or use (energy consumption, material consumption, consumption of natural resources, generation of waste; characteristics of products / services, generation of packaging waste, energy consumption and emissions during use and disposal).

It must be emphasised that only with the calculation of the EE indicators of a production process it is not possible to obtain conclusive data for decision making and improvement of a product or service. Nevertheless, other stages might also be taken into account in this calculation in order to have a satisfactory degree of comparability between possibility of changing a process, product or service.

Thus, taking into account the life cycle perspective might lead to the identification of trade-offs between production, use and handling of end of life and prevent various types of environmental impacts, especially the transfer of pollution for the next stage of the extended chain (Michelsen, 2006).

Towards a Model of Eco-efficiency across ESC

The calculation of EE indicators are usually focused on OEM productive process and cannot be conclusive for decision-making and improvement of a product or service when other stages are not considered or even a degree of comparability between satisfactory possibility of change of a process, product or service. In addition, each company can use different methods for collecting information which may lead to misunderstandings and a lack of standardisation.

In other words, EE calculation of a single process is not able to understand each environmental performance of a product or operation, neither global impact. Therefore, it is imperative to seek new management models that integrate and focus the following aspects:

- the product lifecycle thinking considered across the extended supply chain;
- the access and handing of environmental and economic information in a clear and standardised way to improve the relationship between service providers versus suppliers versus focal company versus market. This might contribute to the reduction of pollution and optimisation of resource across the production chain as well as promoting quality of life within the limits of the planet.

Basing on these two aspects, the eco-efficiency model proposed, which is addressed to ESC of food sector, will take into account the life cycle view thought EE assessment of members of ESC and identification of environmental improvement. This model encompasses a classification system for the maturity level of eco-efficiency of members of ESC (analysis of EE practices adopted by both focal company and the other member of ESC).

Managing the eco-efficiency across extended supply chain has been encouraged mainly by environmental laws. Example of environmental standards demanded by government can be mentioned, such as the restriction of the use of certain hazardous substances in electrical and electronic equipment established by the RoHS Directive 2002/95, eco-design for energy-using products (Directive 2005/32/EC), the take back obligation for electrical and electronic equipment waste (Directive 2002/96) and registration, evaluation and restriction of chemicals (Directive 1907/2006) (Ongondo *et al.*, 2009; Wang and Gupta, 2011). Consequently, product performance assessment and improvements are being increasingly implemented by focal companies, which have mainly carried out Life Cycle Assessment (LCA) in an attempt to evaluate the environmental impact of a product. However, it cannot point out how each member of ESC contributes to the environmental burden of the product assessed. In addition, the complexity of conducting an LCA in terms of money, time and data collection effort can be considered a limitation for its full implementation (including all steps of life cycle). Thus, it might be more usual for companies to carry out a simplified LCA version. This can provoke controversy as well as be subjective; hence many companies have used LCA to prove that their products are better than those of competitors by making convenient assumptions (Despeisse et al., 2012).

Focal firms can have problems if they do not manage their suppliers in terms of environmental compliance. A specific example is the recall carried out by Mattel in 2007. A total of 20 million children's toys were recalled due to materials found to contain traces of lead used by some suppliers. In addition, according to Roberts (2003), a non-governmental organisation (NGO) can influence the reputation of the focal company, demanding responsibilities in the upstream and downstream production. For example, Nike, Disney, Levi Strauss, Benetton, Adidas and C&A in recent years have been criticised for problems such as environmental contamination that occurred in their suppliers' production stages (Seuring *et* Muller, 2008).

In this context, various tools, methods and methodologies have been developed to help designers and managers to face environmental issues. However, some of these procedures are laborious which makes it difficult to apply in practice. Many authors recommend that these procedures should have a simple format, and be easy to use and understood

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by the designers (Gouvinhas, 1998; Lagerstedt, Gruner, 2000 and Mc Aloone, 2000).

Therefore, the proposed model seeks to lead a reflection from designers and managers when considering the eco-efficiency along the product life cycle management. By considering these variables, the designer and managers can eliminate possible negative environmental effects, without neglecting the product's functionality.

In this context, it is expected that the product life cycle management based on eco-efficiency measurement in extended supply chain to promote environmental improvements in products and services can be carried out by actions such as:

- searching for less harmful materials to the environment during its extraction and processing (deforestation, contamination of water resources, soil and air pollution, depletion of natural resources) including harm to the health of anyone at manufacturing and use stages;
- packaging optimisation through the envisioning of possibilities of how the product will be transported, commercialised and distributed in order to optimise its logistics along its life cycle as well as to consider less waste generation.
- adopting techniques and production technologies with less environmental impact. For example, products with low energy consumption, optimizing the use of materials as well as less polluting materials and consequently lower charges of environmental pollutants.
- optimizing transport. In other words, efficient freight by any mode of transportation used while efficient logistics can also reduce the environmental impact.
- extending product life (period over which the product works well) and its aesthetics (period over which the user perceives the product as attractive).
- facilitating maintenance and repairs: products which are difficult or expensive to maintain can be easily replaced by new products.
- reducing resource extraction in nature as well as reducing the pollution burden and strengthening the remanufacturing process and recycling of materials.

This model could help organisations to operate in a more transparent manner, requiring communication and co-operation between sectors and partners of the extended chain. In addition, assessing the EE maturity level will make it possible to understand how the organizational levels and functions interact with environmental and economic issues. This leads companies to review their production system, improve their products, upgrade the environmental performance of ESC as well as define their level of eco-efficiency.

To sum up, it is believed that the final outcome of this model will be two main elements (Figure 1):

- the development of a validation process of Eco-Efficiency strategies and mapping of environmental aspects and impacts as well as economic aspects along ESC,
- the presentation of elements that can help companies to promote changes within their supply chain, contemplating a more environmentally friendly view, and creating conditions for meeting and exceeding the EE goals along a supply chain.

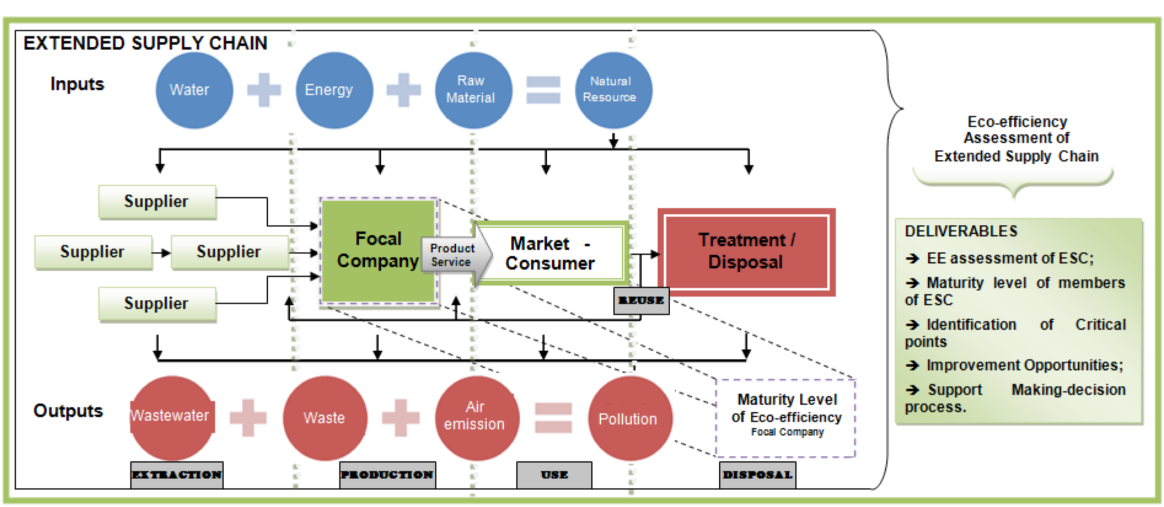

Figure1. Initial Aspects of EE Model to ESC.

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CONCLUDING REMARKS

This article discusses the potential application of Eco-efficiency across the extended supply chain as an alternative form of life cycle management. This model will have as deliverables the development of a validation process for Eco-Efficiency strategies and a mapping of environmental impacts as well as economic aspects along ESC; it includes the presentation of elements that can help companies to promote changes within the chain contemplating a more environmentally friendly view, creating conditions for meeting and exceeding the EE goals along a supply chain.

We believe that this research could be very important for Brazilian reality, it can encourage the organisation to further sustainable actions, strengthen supply chains, support environmental life cycle management of products, and improve the decision-making processes in organisations and in public policy development. It is observed that the proposed model can influence the process of product development across the production chain. Focal companies can lead to environmental improvements throughout the chain, reducing negative environmental effects, without neglecting product functionality.

REFERENCES

Associação Brasileira da Indústria de Alimentação – ABIA. Indicadores econômicos (2010), The Electronic Farmer: <http://www.abia.org.br/>. Accessed on 03 September 2010.

Brasil. Lei 12.305. Institui a Política Nacional de Resíduos Sólidos. The Electronic Farmer: <http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm>. Accessed on 10 Aug. 2010.

Burritt, R., Saka, C. (2006), Environmental management accounting applications and eco-efficiency: case studies from Japan. Journal of Cleaner Production, v. 14, 1262–1275.

Cramer, J., Stevels, Ab. The unpredictable process of implementing eco-efficiency strategies. In: Charter, M., Tischner, U. (Orgs.) (2001), Sustainable solutions: developing products and services for the future. Greenfeaf Publishing, Sheffiel.

Despeisse, M., Ball, P.D., Evans, S. and Levers, A. (2012), Industrial ecology at factory level – a conceptual model. Journal of Cleaner Production, 31, 30-39.

Gomes, C. F. S. (2004), Gestão da cadeia de suprimentos integrada à tecnologia da informação. Pioneira Thopson Learning, São Paulo.

Gouvinhas, R. P. (1998), Design Methods for Production Machinery Companies. PhD Thesis, Cranfield University, UK.

Haes, H. A. U., Rooijen, M. (2005), Life Cycle Approaches: the road from analysis to practice. UNEP/ SETAC Life Cycle Initiative, 2005. The Electronic Farmer: <www.unep.org>. Accessed on 05 jun. 2010.

Jabbour, A. B. L. S., Jabbour, C. J. C. (2009), Are supplier selection criteria going green? Case studies of companies in Brazil. Industrial Management and Data System, v. 4, 477-495.

Kicherer, A., Schaltegger, S., Tschochohei, H., Pozo, B. F. (2007), Combining Life Cycle Assessment and Life Cycle Costs via Normalization. International Journal of Life Cycle Assessment, v. 12, 537–543, 2007.

Kuosmanen, T. (2005). Measurement and analysis of Eco-efficiency: an economist's perspective. Journal of Industrial Ecology, v. 9, n. 4, 15–18.

Lagerstedt, J., Gruner, C. (2000), Company Internal Communications in DFE – Survey in German and Swedish Industry. CIRP 7th International Seminar on Life Cycle Engineering, Tokyo, Japan.

Lehni, M. (2000), Eco-efficiency: creating more value with less impact. World Business Council for Sustainable Development. The Electronic Farmer: <http://*www.wbcsd.org*>. Accessed on 15 jan. 2008.

Maxime, D., Marcotte, M., Arcand, Y. (2006), Development of eco-efficiency indicators for the Canadian food and beverage industry. Journal of Cleaner Production, v. 14, 636–648.

Mc Aloone, T. C. (2000), Industrial Applications of Environmentally Conscious Design. Professional Engineering Publishing Limited, London, UK.

Michelsen, O., Fet, A. M., Dahlsrud, A. (2006), Eco-efficiency in extended supply chains: a case study of furniture production. Journal of Environmental Management, v. 79, 290–297.

Nawrocka, D., Brorson, T., Lindhqvist, T. (2009), ISO 14001 in environmental supply chain practices. Journal of Cleaner Production, v. 17, 1435–1443.

Ongondo, F.O., Williams, I.D., Cherrett, T.J. (2011), How are WEEE doing? A global review of the management of electrical and electronic wastes. Waste management. 31, 714-730.

Portal Brasil. Economia do Rio Grande do Norte. The Electronic Farmer: <http://www.portalbrasil.net/estados_rn.htm>. Accessed on 05 September 2010.

Roberts, S. (2003), Supply chain specific? Understanding the patchy success of ethical sourcing initiatives. Journal of Business Ethics, v. 44, 159–70.

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Volume 12, Número 1, 2015, pp. 48-54
DOI: 10.14488/BJOPM.2015.v12.n1.a5

Romeiro Filho, E. (Org) (2010), Projeto do Produto. Elsevier, Rio de Janeiro.

Saling, P., Kicherer, A., Dittrich-Kriimer, B., Wittlinger, R., Zombik, W., Schmidt, I., Schrott, W., Schmidt, S. (2002), Eco-efficiency analysis by BASF: the method. International Journal of Life Cycle Assessment, v. 4, 203–218.

Seuring, S., Muller, M. (2008), From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production, v. 16, 1699–1710.

UNEP/SECTA (2009), Life cycle management: how business uses it to decrease footprint, create opportunities and make value chins more sustainable. UNEP/SECTA.

Verfaillie, A. H., Bidwell, R. (2000), Measuring eco-efficiency: a guide to reporting company performance. World Business Council for Sustainable Development. 2000. The Electronic Farmer: <http://*www.wbcsd.org*>. Accessed on 15 January 2008.

Wang, H-F and Gupta, S. (2011), "Green supply chain management – product life cycle approach", McGraw-Hill, NY.

Zancul, E. S. (2009), Gestão do ciclo de vida de produtos: seleção de sistemas PLM com base em modelos de referência. Tese (Doutorado em Engenharia de Produção) – Escola de Engenharia de São Carlos da Universidade de São Paulo, São Carlos.

Zhu, Q., Sarkis, J., Lai, K. (2007), Green supply chain management: pressures, practices and performance within the Chinese automobile industry. Journal of Cleaner Production, v. 15, 1041–1052.