Energy Conservation Framework for Green Supply Chain Management

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Abstract

In recent years, designing green supply chains has become more important than ever due to global warming concerns and limitation of natural resources. There are quite a number of studies on preventing and reducing the waste in the supply chains where the range of these studies vary from managing nuclear waste to reducing pollutions created by carbon dioxide (CO2). Furthermore, there has also been an acceptable achievement in reusing and recycling the waste by showcasing its economic and social advantages through Green Supply Chain (GSC). One of the topics that has been received less attention is the use and waste management of energy with the focus of recycling the energy from each stage of supply chain. In this study we present a model that comprise energy as an independent feature in green supply chain and provide suggestions in energy management such as energy usage, reuse, recycle and energy wastage.

Keywords Green Supply Chain, Collect and Reuse Energy, Energy Recycle

1. Introduction

While the supply chain was first introduced in the 1970’s, it took 20 years until the importance of Supply Chain Management (SCM) was emerged (Greatbanks, 2009). Supply chain is a network of facilities (e.g. suppliers, manufacturing, plants, distribution centers, warehouses, and etc.) that performs a set of operations ranging from providing of raw materials, the transformation of these materials to manufactures, producing finished products, and at the end the distribution of the finished goods to the customers (Bramel & Simchi-Levi, 1997). Integrating environmental thinking, as one of the primary factors in sustainability, into the supply chains management become significantly important for many business enterprises and a challenge for logistics management in the 21st century (Vahdat & Vahdatzad, 2017). Implementing Green Supply Chain Management (GSCM) practices is a way that companies will result in better environmental performance and preserving their suppliers or customers (Zhua, Sarkis, & Laic, 2007). Green Supply Chain (GSC) includes both internal and external activities, where internal activities are related to preventing pollution before generating and recycling waste, using products, and extracting resources and raw materials. External activities cope with capturing harmful pollutants followed by proper disposal (Cagno, Guido, Perotti, & Zorzini). The motivation of introducing GSCM is both ethical as reflecting the values of managers and economical as gaining a possible competitive benefit (Testa & Iraldo, 2010). The customers’ social awareness have
increased during recent years and they are more willing to buy products from companies with same concerns about the environment (Sakib et al. 2016).

Environmental impacts happen at all stages of a product’s life cycle, (e.g. resource extraction, manufacturing, use and reuse, final recycling, or disposal) (Zhu & Sarkis, 2006). When companies in the supply chain decide to buy raw materials from suppliers, the company indirectly accepts the generation of waste stream (Handfield, Sroufe, & Walton, 2005). Green purchasing is environmentally preferable purchasing and Green Procurement is also “ecological or eco-responsible procurement”, which involves making decisions rejecting purchase goods, selecting suppliers and utilizing services that can cause harmful damage to the environment (Tripathi & Petro, 2010). In new supply chain approach into a supply “loop”, at a stable state of operation, there will be no specific end for each operation unit (Hsu & Wang, 2008).

Product design is one of the most important features in the loop of supply chain. Eco-design or design for environment can be widely helpful and emerging tool to improve companies’ environmental performance, enable the closed-loop supply chain, and minimize life-cycle environmental impacts (Zhu, Sarkis, & Lai, 2008). Through the 1980s quality revolution and a decade later the supply-chain revolution, the best practices for integration of environmental management with ongoing operations are carried out (Srivastava, 2007). Organizations adopt GSCM on their own environmental concerns, and decide to affect the environmental behavior for their supplier network (Arimura, Darnall, & Katayama, 2011). In next green supply chain generation, waste from large company is used as raw materials in other companies (Zhua & Sarkis, 2004). Recycling used products and converting them to raw materials have not only environmental impacts but also beneficiary for providing raw materials in SCM (Zhu, Sarkis, & Lai, 2007). Prices for energy and especially raw materials have increased in the world as well as demand for raw materials. Historically, Industrial pollution management has been a critical issue for societies. Not only solid and water pollution waste were included in the discussion, but also warnings of global climate change due to greenhouse gas emissions was also prevalent in the argumentation (Zhu, Sarkis, & Lai, 2008).

In this paper we introduce a new model where energy as a key feature of achieving Green Supply Chain has more effects than previous researches. We propose suggestions to save, redistribute, and convert energy in each echelon of a closed-loop supply chain.

The remainder of the paper is as follow: in Section 2 prior research and models in green supply chain management are reviewed. The proposed model with energy waste management is introduced in Section 3 followed by suggestions to reuse and recover the energy in each stage of then chain. In order to conclude the paper, remarks of this study are highlighted and recommendations for future studies are provided.

2. Literature Review

Many papers discuss dimensions and stages of GSC. The U.S. Environmental Protection Agency (2000) provided four basic steps to implement GSC, (a) Identify costs (b) Determine opportunities (c) Calculate benefits, and (d) Decide, implement and monitor (Diabata & Govindan, 2011). Zhu & Sarkis (2006) segregates four activities relating to GSCM including: (a) green purchasing, (b) cooperation with customers including environmental requirements, (c) investment recovery, and (d) eco-design and internal management. Srivastava (2007) classifies GSCM literature into three broad categories: (a) literature highlighting the importance of GSCM, (b) literature on green design, and (c) literature on green operations. The scope of GSCM vary from monitoring general environment management programs to more proactive practices which it can occur in various R’s (Reduce, Re-use, Rework, Refurbish, Reclaim, Recycle, Remanufacture, Reverse logistics, etc.). In green design part, two sections are introduced, including environment conscious design and lifecycle assessment of the product/process. Similarly, green operations involve all operational aspects related to Reverse Logistics (RL) and network design (collection; inspection/sorting; pre-processing; network design), where green manufacturing and remanufacturing also have different attributes such as reduce, recycle, production planning and scheduling, inventory management, remanufacturing, re-using, and material recovery. He also investigates waste management including source reduction, pollution prevention, and disposal.

Zhua, Sarkis, & Laic (2007) discuss five GSCM sections which are (a) internal environmental management (IEM), (b) green purchasing (GP), (c) customer cooperation (CC), (d) investment recovery (IR), and (e) eco-design (ECO). Sheu (2008) has done a comprehensive research on GSCM with nuclear waste. In his research he considered seven primary layers including: (a) nuclear fuel supplier, (b) nuclear reactor, (c) electricity demand market, (d) reprocessing facility (for spent nuclear fuels), (e) interim storage facility, (f) low-level radioactive waste reprocessing facility, and (e) final disposal.

In another research done by Zhua et al. (2008), they focus on three aspects of GSCM practice: (a) external relationships (ER) including green purchasing and customer cooperation over environmental concerns, (b) investment recovery
(IR) from an end-of-life ‘closing-the-loop’ perspective, and (c) broader-based interactions involving eco-design (ECO) practices. In a recent article from Zhu et al. (2010), they completed their research by linking the relationships of awareness of regulations and policies and discussed that different industries with different products may have different levels of awareness, different levels of regulatory pressure being encountered, and GSCM practices being implemented at dissimilar levels presented.

Recent researches focus more on different green activities. For instance, Hang, Lu, & Li (2010) were identified six different aspects to reach GSCM: (a) green manufacturing and packaging, (b) environmental participation, (c) green marketing, (d) green suppliers, (e) green stock, and (d) green eco-design. In a recent research Paksoy, Özcelyan, & Weber (2011) comprise that the GSC design has four elements: (a) Waste of all processes, (b) Using efficient energy resources, (c) Greenhouse gas emissions, (d) Considering legal environmental factors.

Many models created for formulating GSC behavior, some of these models are similar in context but different in shape. Waste stream, recovery, final disposal and consumer exist in most of them. As mentioned before, energy is just considered as an internal factor and prior models have fewer attentions to energy as a critical factor to achieve GSC. The Sarkis model is one of the most famous models at GSC and many studies have used it as the basis of their works. The model was presented in 1995. The model demonstrate practical life cycle of products and include logistics, produce, and distribution. The main purpose was environmental realistic management strategy and waste produced reduction in every stage of a chain. Another objective was preservation of all materials in life cycle products and minimizing each action with external environment. As shown in Fig. 1, considering the fact that waste reduction is the aim of GSC, wastes occurrences at various points are limited by reusing, recycling, and remanufacturing in Sarkis (1997) model (Ho, Shalishali, Tseng, & Ang, Spring 2009).

![Figure 1. Sarkis (1997) proposed model for Green Supply Chain](image)

In Diabata & Govindan (2011) model as shown in Fig. 2, all activities of GSCM such as green design, green sourcing/procurement, green operations or green manufacturing, green distribution, logistics/marketing and reverse logistics are covered. The introduced model discuss all stages of a products life cycle, from raw materials through the design, production, and distribution phases, to the use of the product by consumers and its disposal at the end of the products life cycle.
Kainuma & Tawara (2006) evaluated green supply chain in their model where a systematic reverse logistic chain is introduced. Used products can return to classic supply chain when repaired. If minor repairs to the used products are enough they return to retailer. Any further repair needed, the used products return to specific supply chain facility where at last used products decompose and reuse as raw materials.

Sheu, Chou, & Hu (2005) formulate Integrated Logistics Management (ILM) presented in Fig. 3, their model involves 11 facilities which are classified into two groups: (a) 5 facilities for forward supply chain including supplying of raw material, manufacturing, wholesaling, retailing, and end-customers and (b) 5-layer used-product reverse logistics chain, including collecting points, recycling plants, disassembling plants, secondary material markets, and final disposal locations of wastes. Unlike prior researches, Sheu et al. model is profit base and a flow of revenue in all facilities are considered. The model is more similar to reality since GSC can be very beneficiary for any Supply Chain.

Same to Sheu et al. (2005), a model introduced by Paksoy, Özcelyn, & Weber (2011) classified the chain members into two groups: (a) forward supply chain members, and (b) used-product reverse supply chain members, where dislike Sheu model CO2 emission is considered as an external factor to GSCM especially for logistics. More ever, the flows...
of used materials are dependent to the rate of recyclability of product. Flow of used materials divided to three groups: non-recyclable materials, 50% recyclable materials, and 100% recyclable materials. As mentioned before, in most models, energy is the internal factor but they do not pay attention to the energy as external part of supply chain. Commonly all processes and operations that use energy as internal factor mostly use thermal energy. In fact most of energy dissipation is in the shape of heat loss. Thus by reusing energy in GSC, the claim of completely greening supply chain can become more realistic. As a matter of fact the kind and usage of energy sources can influence success of a supply chain. As an illustration, customers in the Netherlands are becoming more aware of produced energy and they are willing to pay for ‘green’ energy (Baños, Manzano-Agugliaro, Montoya, C. Gil, & Gomez, 2011).

3. Proposed model for Green Supply Chain

As shown in Fig. 4, we propose a new model in Green Supply Chain. The model has Forward/Reverse Logistics in common. Furthermore, we tried to design a model near to reality in shape and facilities. And finally, an energy collector as well as energy source facility is added to the model in order to save and reuse waste stream of energy. What added to model is energy source as an important part of GSC. This source could be a renewable, nuclear, electricity, or fossil heat source. Outgoing energy commonly is heat. In energy collector, it collects and uses as a part of required energy in GSC. This collector would exist in all parts of GSC. Energy is used for changing raw material into virgin material. Even for fabrication it needs energy and in processing assembly, some external energy exists and commonly is heat. An energy collector in all part of chain, collect the energy from process to process. Collecting is the most important part of energy chain. Collectors can change the energy to a usable source for other facilities of SC. Reuse, remanufacture, and recycle energy can happen in energy collector.

![Figure 4. Proposed model to GSC considering impact of Energy](image-url)

To be more specific, our effort was to implement Green operations in each echelon and there exist lots of activities to achieve a Green Supply Chain Managements. In supplier stage, the manufacture has the opportunity to select supplier mode of required raw materials. Commonly, manufactures have long contracts with certain suppliers due to the fact that preventing of raw materials’ shortage. In some circumstances, the manufactures are obliged to buy raw materials from market (e.g. the contract of suppliers is broken due to political or environmental concerns, the bull whip effect happens in supply chain and an unexpected use of raw materials needed). The third way to supply raw materials would be from recycled materials. In process of recycling products, some parts of products would be reusable as raw materials. The first green decision in our model would be supplier selection and green purchasing. The amount of
buying recycled materials as well as supplying from market or certain suppliers would be a place of question. Thus Inventory Management would play a vital role in supplier section.

Used products which need major repair and fabrication would return to manufacturing echelon. In this echelon green design as well as production planning takes into account. New products need to be designed greenly, that can be recyclable. Repaired products will send to distribution echelon to be sold at second hand market or in stocks. In this section, Pricing Management of repaired products is another GCSM decisions. The price should demonstrate the cost of repairing with a margin of benefit. The price should be balanced with new product price in a way that customers have tendency to buy used products. Guarantee of repaired products could be an eligible option to achieve of closed-loop life cycle design.

Used or new products could be returned in any time to collection centers under environmental regulation and could be beneficiary to the GSC. We need a green purchasing management to tend customers returning used products. Even new products could return to cycle of remanufacturing if they don’t achieve a certain quality standards or due to guarantee assurance. Inspection facility should classify returned products. Products with minor repair would be fabricated and return directly to the used products’ distribution centers. Products with major repair will return to manufacturing echelon while some products will send to recycling process to be used as raw materials. An amount of used products will go to disposal as a green operation.

4. Discussion for energy collection and reuse

In energy cases new ways are offered nowadays. Changing power to electricity or storing it is very common, thus there is many ways for preventing energy waste or reusing it. As mentioned, many papers have paid attention to waste of materials in GSC but there are little studies about energy in GSC, while the kind of energy is more important than other part and it can damage environment as much as waste where global warming, for instance, is becoming a crucial environmental issue Thus this paper discussed an all-around GSC and named it spacious green supply chain (SGSC). In a SGSC something are more important like:

4.1 using renewable energy

Renewable energy has multiple characteristics such as reduction dependability to fossil fuel and decline CO2 emission in atmosphere. Benefits of using renewable energy are not only saving energy sources but also multi-dimensional practices like water transfer. Renewable energy are different in shape and type including wind, solar, water, bio-energy, geothermal, and hybrid systems energy (Yu & Chau, 2009). These sources of energy have some limitation which Menegaki (2011) discussed them with SWOT analyze in his work (Liu, Zhao, & Tang, 2010).

4.2 recycling energy

For automobiles, both gasoline vehicles and hybrid electric vehicles, the waste exhaust heat can be recovered or recycled directly to electrical energy for battery charging, and caused increasing the overall vehicle fuel efficiency. An automotive thermoelectric (TE) waste heat energy recovery system has been proposed and implemented for this process by Lemieux et al (2008). Liu et al (2010) propound a Schemat ic configuration of heat pipe heat recovery facility. Cost is one the most important parts and could change decisions in many sections, where recycling or recovering energy can reduce the energy costs. "If the costs of fossil fuels, transportation, energy conversion, electricity transmission and system maintenance are taken into account, the cost of energy produced by combined system with waste heat recovery would be lower than that for conventional refrigeration systems" (Herring, 1999).

4.3 reducing energy

Energy reduction and use it less than usual is the common practice of finding ways to use fewer energy to perform an operation. Herring (1999) points that since 1973 because of OPEC policies about reduction of oil export, there is more attention to reducing in energy consumption and he proposed that energy reduction spread from the pages of obscure energy-economics journals in the early 1990s to the pages of newspapers, such as The New York Times in the mid-1990s.

These are some example for showing energy can change, store and reduce in GSC. In addition, this paper say energy is not waste at all. We can claim that a GSC that do not have attention to energy losses in the producing, distribution and consumption, is not a complete Green Supply chain.

5. Conclusions
In this paper energy in GSC is discussed where there was less attention to energy in green supply chain prior researches. GSC has emphasis on raw materials, recycle, and reuse of it, but energy isn’t in this arrangement even in conceptual models, though energy is the most important section of GSC. As a result, this paper named SGSC as the chain that include all of the critical factors and the chain is going to omit the disposal completely. Thus a model for showing energy in GSC composed and assist energy should reuse in GSC inevitably. Finally utilizing energy (e.g. renewable energy), reduce as a precursor way, reuses, and recycles, as a part of reverse logistic is presented. All of this matter related to energy collector and energy source. We are not ignoring the fact that some part of energy exchange to environment and we are far from claiming zero energy but energy could be save completely. It is clear that in practical model and in different situation energy can be reused in a greener supply chain.

References


### Biographies

**Mohammad Ali Vahdatzad, PhD** is an Assistant Professor of Industrial Engineering at Yazd University, Iran and president of Imam Javad University, Iran. In 1984, He earned his B.S. in Industrial Engineering from Sharif University of Technology, Iran, following M.S. from Cranfield Institute of Technology, England in 1986, and PhD in Industrial Engineering from Birmingham University, England in 1990. Prior to joining Imam Javad University, he was deputy of Iran delegation in The United Nations Educational, Scientific and Cultural Organization (UNESCO) from 2010 to 2012, president of Yazd University from 2004 to 2010 and the university provost from 2002 to 2004. Following his twenty years’ experience in higher education administration, Dr. Vahdatzad has published several journal and conference papers about higher education leadership and organization structures, strategic thinking, and entrepreneurship.

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