A Framework for Green Supply Chain Management

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Abstract

As supply chain networks keep on expanding geographically in the globalised environment, the necessity for advanced supply chain operations are ever increasing. However intense supply chain activities have a significant effect on the environment, through for example, the increased amount of emissions generated from transportation and warehouse operations as also waste produced from consolidation and deconsolidation activities.

Under this context the purpose of this paper is to propose a taxonomy of green supply chain practices, while presenting real business case green supply chain operations that promote the significance of the green element for a companies sustainability.

***Keywords**:* green supply chain, sustainability, framework, reverse logistics.

1. Introduction

Liberalization of international trade has designated the key role of developing markets as sources of low cost production processes, due to low wages, cheap land and tax incentives provided by the governments to companies that aim in investing to their markets. This has resulted in the relocation of major industrial plants from the developed to the developing countries, increasing therefore, the transportation distances between demand and supply points. In other words extensive and complex supply chain networks have been developed, that require advanced logistics. Additionally, the continuously increasing globalized cargo volumes have generated the necessity for intense production, transportation, and packaging/unpackaging activities. This in turn has had a significant effect on the society, economy as also the environment, through economic growth opportunities, environmental pollution, noise, accidents, etc. Under this context the concept of sustainable supply chain networks has emerged in order to ensure that supply chain network activities will not comprise the future needs of the society, economy and the environment. To be more specific, sustainable supply chain networks should (i) reassure the society's safety, health, and reduce its disturbance (ii) lead to economic growth, jobs and prosperity and (iii) respect the environment. Moreover, the continual combustion of fossil fuels, from production and

transportation activities has resulted in the production of green house gasses in the atmosphere. This in turn increases the planets average global temperature resulting, through catastrophic climate change events, in a significant economic and social upheaval (Mardsen and Rye, 2009). In this framework the environmental effects of global supply chain networks have gained important attention. As a result the concept of green supply chain management has emerged for addressing the environmental effects of supply chain activities. Green supply chains or ecological supply chains involve the integration of environmental thinking into supply chain management. They also incorporate reverse logistics activities, which close the loop, and therefore the definition of closed loop green supply chains could provide a holistic approach. Typically, improved environmental performance is followed by a reduction in total logistics costs resulting in a win-win scenario for businesses and the environment. Companies can find cost savings by reducing the environmental impact of their business processes. By re-evaluating the company's supply chain, from purchasing, planning, and managing the use of materials to shipping and distributing final products, savings are often identified as a benefit of implementing green policies. On the other hand though, the implementation of numerous green supply chain practices could increase substantially the systems total supply chain costs, resulting in cost/environmental tradeoffs (i.e the utilization of more advanced and expensive Euro trucks).

Moreover, and as the public becomes more aware of environmental issues and global warming, companies must be able to answer questions regarding how green their logistics activities are, how they recycle and what is the carbon footprint of their logistics operations. On this basis numerous corporations are often under considerable pressure from their customers and shareholders (Hall, 2000). Henriques and Sadorsky, (1996;1999) have identified four important environmental stakeholder groups namely: (i) regulatory stakeholders that have the ability to set environmental regulations or pressure governments to set environmental standards (ii) organizational stakeholders, that are directly related to a company and have the ability to set financial pressures (iii) community groups, environmental organizations and other potential lobbies that can mobilize public opinion in favor of/or against a firms environmental strategy and (iv) the media that have the ability to influence the society perception on a firms environmental image. Due to the intense pressures set by these groups, a green image has turned into a top priority business practice adopted by global corporations such as Wallmart, McDonalds, and Xerox (Grove et al., 1996).

Under this context the purpose of this paper is to develop a decision support framework that will assist managers in evaluating green supply chain alternatives. To be more specific this

work will initially classify green supply chain practices into four categories related to: (i) product, (ii) transportation, (iii) warehousing and (iv) reverse logistics and analyze green business supply chain initiatives that correspond to each one of these categories.

The rest of the paper is organized as follows. In chapter 2 the taxonomy of the green supply chain practices will be presented while in chapter 3 the conclusions will be analyzed.

2. Taxonomy of Green Supply Chain Practices

In the following chapter this work will provide significant managerial insight related to (i) Green Product (ii) Green Transportation and Distribution (iii) Green Warehousing and (iv) Reverse Logistics issues.

2.1 Green Product

Green product related issues involve: (i) green product design (iii) green purchasing and (iv) green manufacturing

2.1.1 Green product design

Green product design focuses on production processes that adopt environmentally friendly specifications (Luh, et al., 2007). It involves (i) products made from, recycled or remanufactured materials (O'Brien, 1999, Waage, 2007) (ii) products that can be reused and remanufactured (iii) products with environmentally friendly packaging, (iv) products made from organic components and (iii) the identification of the optimum assembly sequence when designing the product in order to be able to follow the regulated recovery rates in an economic manner at the reverse logistics channel (Chu et al., 2009). On this basis, numerous global companies have redesigned their production lines, by adding green attributes to their products. McDonald's for example, used environmentally friendly materials to make its beverage straws, eliminating 1.000.000 libres of solid waste per year (Grove et al., 1996), while Wallmart managed to save an equivalent of 800,000 gallons of gasoline just by wrapping four kinds of products in a polymer derived by corn instead of oil (Adler 2006). Daimnler-Chrysler designed coconut fibre filled seat-backs and headrests in its Brazilian vehicle production while Southcorp White-goods, an Australian appliance manufacture, developed a new line of dishwaters that use 18litres less water for a full load while its plastic components are coded making recycling and disassembly easier (World business council for sustainable development, 2005). Xerox Europe designed waste free products with a reduced material mix, resulting in easier separation of materials for recycling, and reuse while Sony has made good

progress in reducing the environmental impact of its products by using recycled materials from either exterior packaging or internal components of its products. This way, it has been able to reduce the use of new natural resources and use recycled plastic for its products. It now produces televisions that use recyclable plastic from its own loops. To be more specific it uses polystyrene foams for packaging, and plastic packs from other models in order to produce recycled packing that is used in manufacturing televisions. In 2008, 9 out of 11 models of Sony Bravia's brand LCD television used recyclable items.

2.1.2 Green purchasing

This practice involves the selection of supply chain partners (raw material, components and subassemblies suppliers) based on environmental standards and eco labels. It aims in raising consumer awareness in green products, increase their demand and thus motivate the industry to adopt greener production and distribution processes. Numerous researchers have observed that collaboration regarding environmental issues between the suppliers and the company (or the customer) in a supply chain has a significant effect in the adoption of environmentally friendly practices by all intermediate counterparties (Taylor et al., 2004). Wallmart for example uses an MSC eco label on its fish products, certifying third parties to comply on fishery and processing standards through the supply chain from boat to plate (Plambeck, 2007). Moreover, numerous key supply chain parties have been forced, due to customer demand for environmentally friendly products, to adopt environmental management systems such as ISO 14000 (Murphy and Poist, 2009). Such an example involves a major automotive parts manufacturer that designs and manufactures, for large automotive manufacturers, thermoformed plastic components in India. The company receives intense pressure from his major customers, which are ISO 14001 certified, to attain certification as well (Cote et al., 2008).

2.1.3 Green manufacturing

Green manufacturing incorporates the utilization of environmentally efficient manufacturing hardware and software technologies that minimize energy consumption, and waste. For example, a paperboard manufacturing company that prepares products for customers in North America has purchased a new corrugating machine that reduces the amount of paper needed to corrugate boxes while maintaining their strength (Cote et al., 2008). Moreover Sony uses Product Data Management software (PDM) with green design as an option, eliminating incorrect product variations induced by improper combination of components and/or modules.

This in turn minimizes the number of malfunctioned products and thus generated waste (Luh et al., 2007).

2.2 Green Transportation and Distribution

Green transportation and distribution practices involve (i) green network design (ii) utilization of fuel efficient transport fleets and equipments as also, the application of improved aerodynamics in vehicles (iii) increase of vehicle utilization rates and reduction of empty returns (iv) application of vehicle routing and scheduling softwares and (v) fuel- efficient driving.

2.2.1 Green network design

Green network design examines the effects of location decisions related to distribution centers (Li et al., 2008, Ramudhin et al., 2009) and production facilities (Iakovou et al., 2010) on the systems transportation emissions performance. To be more specific, by operating one distribution center next to each demand point, the supply chain planner minimizes the distances travelled with the environmentally inefficient delivery truck. This in turn minimizes the amount of various emissions generated in the system. By adopting the practice of near-shoring, the practice that involves the allocation of a portion of production processes close to the serving markets, minimizes the amount of transportation emissions generated compared to the practice of off shoring that involves production in distant locations and thus lengthier distances travelled (Iakovou et al., 2010).

2.2.2 Energy efficient transport fleet and equipment

The utilization of advanced Euro norm and hybrid heavy duty and delivery trucks minimize significantly the amount of Particulate Matters (PMs), Hydrocarbon (HC), and Nitric Oxide emissions (NOx) produced (URL: http://www.dieselnet.com/standards/eu/hd.php) through technologically advanced combustion and therefore reduced energy consumption. Wallmart procured hybrid diesel-electric and refrigerated trucks that required less energy for cooling so the engine could be turned off when the truck stopped (Wallmart, 2008). Additionally, reduction in fuel consumption could be also achieved through aerodynamic vehicle design. A report presented by the International Energy Agency in 2007 shows an impressive 10-20% improvement in fuel consumption compared to conventional vehicles.

2.2.3 Increase of vehicle utilization rates and reduction of empty returns

Increase in vehicle utilization rates could be achieved through (i) the application of nominated day delivery systems by suppliers (ii) the cooperation between transport users (iii) the application of efficient packaging techniques, and (iv) the transportation of reverse logistics flows. To be more specific through nominated day delivery systems customers are informed that a vehicle will be visiting an area on a nominated day and in order to receive a delivery that day they must submit their order a certain period in advance. By concentrating deliveries in particular areas on particular days, suppliers can achieve higher vehicle utilization rates. Additionally different retail stores located at a specific area could also cooperate by collecting their demanded cargo in a common area, i.e. a warehouse, and then deliver them with high truck loads to the retail shops. An example of success may be that of Exel LTD, a company that that operates a retail consolidation center for shops located in Heathrow airport. It was estimated that by adopting this practice the company managed to reduce the number of cargo delivery vehicles visiting the Airport by 75% and increase the vehicle loading rate to 90% (Energy Efficiency Best Practice Program, 1998).

Additionally, packaging techniques may also have significant effects in increasing the capacity utilization of a vehicle. For example a large order mail company managed to improve vehicle utilization and cut vehicles – km's by 6% by loading parcels loose than in bags (MacKinnon, 2006). Moreover Wallmart achieved to save $3.5 million in trucking costs per year and by estimate 5000 trees by right sizing the boxes one line of toys (Adler, 2006). Full utilization of a vehicles height could also increase vehicle utilization rates. It was estimated that if pallet loads made full use of the vehicle inner heights, the European grocery distribution system would have required 15% less trucks (Kearney, 1997).

Finally the continuously increasing proportion of products travelling back for reuse, recycling and remanufacturing, along with the growth in the recovery of waste packaging and life expired products may provide an opportunity of increasing return loadings (MacKinnon, 2006, Anderson et al., 1999).

2.2.4 Vehicle routing and scheduling

A large proportion of freight distribution is carried out by road vehicles. The problem of organizing and routing a fleet in a way that reduces transportation costs and improves the level of service provided, is called the vehicle routing and scheduling problem (Golden and Assad, 1998, Golden, Reghavan and Wasil, 2008). There is a variety of software packages for

providing routes and schedules, while managing substantial cost savings (from 5 to 20%) of the global transportation costs (Toth and Vigo, 2001;1997) these cost savings are mainly due to the reduction of unnecessary distances traveled which may lead in the reduction of fuel consumption and thus green house gasses. Additionally difficult journeys (through for example a congested city centre) are scheduled for a time of day where the environmental impact will be minimized.

The reduction of commercial vehicle emissions is a key concern for numerous companies, which try to find ways for reducing their carbon footprint and therefore improve their green credentials. Wallmart for example, is aiming to make its vehicles 25% more efficient within 3 years and 50% within 10 years (Wallmart, 2008), while Tesko and J Sainsbury supermarket chains intend to reduce their transport emissions for a category of goods by 50% in five years and 5% in three years (Tesco, 2008; J Sainsbury, 2008), through the application of vehicle routing softwares.

2.2.5 Fuel –efficient driving (eco-driving)

Driver training programs have shown to improve fuel efficiency by 8-10%. Until today 7000 drivers have received training under the UK governments Safe and Fuel efficient driving (SAFED) program. Fuel efficiency may be also affected by other factors. To be more specific, by leaving the engine idling unnecessarily, failing to check tire pressures and not reporting on engine problems or oil leaks, drivers waste a lot of fuel (Mc Kinnon et al., 2010).

2.3 Green Warehousing

Green warehousing incorporates practices that aim to minimize the environmental impact of warehousing operations. To be more specific, it incorporates practices that (i) maintain the warehouses temperature and improve its lighting efficiency (ii) improve the energy efficiency of mechanical handling operations (iii) handle the remaining pallets.

2.3.1 Energy Savings

Fuel, oil or gas is the primary source for heating a warehouse while electricity for cooling. The extend of which energy is consumed is primarily determined by (i) the temperature required to maintain the stored products in a satisfactory condition. This may require efforts for maintaining maximum or minimum temperature levels as well as to control the humidity, (ii) the background temperature of the internal space of the warehouse for the employees to perform their work in comfort and in relation to the extent of the physical requirements and

the location of the task undertaken. Significant savings in energy can be achieved through (i) the use of close fitting door locks, close fitting barriers or fast-acting doors in areas where fork lifts entry and exit frequently (ii) the segregation of intake and or dispatch areas from other areas of activity and (iii) the use of zoned or time controlled thermostats (Carbon Trust 2002a;2006a). Additionally lighting efficiency in terms of cost, energy use and emissions generated is the most important area in a warehouse to manage. A single 400W high pressure sodium light bolb operated continuously for a year has been estimated to produce an equivalent of 1.69 tones of CO_2 emissions. Therefore lighting has an important environmental effect as it depends on electricity. Cleaning tactically roof lights and could increase significantly the lighting efficiency of warehouses. Additionally a lamp replacement strategy based on average usage and not on failure is also recommended. Finally the utilization of high pressure sodium and triphosphore – coated fluorescent lamps (frequently maintained) could result in total energy savings equal to 23% (Carbon Trust, 2002a;2007, Langwill, 1993).

2.3. Energy Efficiency of handling equipment

In order to achieve rapid and intensive movement of goods all warehouses use a range of various mechanical equipment such as (i) fork lifts, for unloading the container or transportation mode and (ii) reach trucks for storing cargo in the distribution center, at different heights. This increases substantially energy requirements in petrol or LPG gas (for fork lifts) as also in electricity (for recharging the batteries of the reach trucks). The environmental impact of the mechanical handling equipment utilized in the warehouse could be minimized through (i) the utilization of internal combustion power units using bio-diesel or hybrid fuel combinations along with hydrogen fuel cell technologies for the forklifts and (ii) the use of 3-phase AC high-frequency, fast-charging systems and opportunity-charge batteries. Opportunity charging can take a form of rapid charging during coffee brakes and short operational breaks or direct charging by onboard regenerating motors, linked to returning energy produced during breaking or the lowering the forklifts via the hydraulic system directly at the battery. Trials reported by Toyota Material Handling suggest that using recovery energy reduces battery power consumption by between 15% to 25%. On this basis, software technologies such as Enterprise resource planning (ERP), Warehouse Management Systems (WMS) provide interconnectivity and coordination between the warehouse operator and its sources of demand, minimizing therefore unnecessary cargo handling and thus the amount of emissions generated (Mc Kinnon et al., 2010).

2.3.3 Pallet handling practices

The disposal of different sized pallets is a very important problem for many warehouse operators. From an environmental perspective 12% of all lumber processed in the United States was required for manufacturing pallets. In order to deal with this problem a large furniture manufacturer, has participated in an online Materials Exchange Program hosted by the Eco Efficiency Center, offering the pallets to interested parties. The adoption of this practice has been estimated to divert 60,000kg of wood waste away from the landfill annually (World business council for sustainable development, 2005).

2.4 Reverse Logistics

In the following paragraphs, this work will identify the ecological ramifications of product recovery and waste management as also direct reuse of products.

2.4.1 Product recovery

Product recovery management involves the management of all used and discarded products, components and materials in order to recover as much of the products ecological and economical value, and therefore reduce the quantities of generated waste. It incorporates five product recovery options namely (i) repair, (ii) refurbishing, (iii) remanufacturing, (iv) cannibalization and (v) recycling.

2.4.1.1 Repair

The purpose of repair is to return used products in to a working condition by fixing and/or replacing broken parts. Repair usually requires only limited product disassembly and reassembly, while repair operations can be performed at the customer's location or at manufacturer-control repair centers. World class product manufacturers such as IBM, Phillips have invested heavily in order to engage in effective product repair operations (Volkskrant, 1992).

2.4.1.2 Refurbishing

The purpose of refurbishing is to bring used products up to quality standards lower than those of new products. The products are disassembled into modules which are inspected fixed or replaced. Approved modules are reassembled into refurbished products. Military and commercial aircrafts are examples of products refurbished (Mc Kinnon et al., 2010).

2.4.1.3 Remanufacturing

The purpose of remanufacturing is to bring used products up to quality standards as high as new. The modules of the new products are extensively inspected and all depleted parts are repaired with new ones. BMW has been remanufacturing high components such as engines, started motors etc. for many years. These components are tested based on strict quality standards in order to become a BMW exchange part which is then resold with the same quality and warranty 30-50% cheaper while minimizing significantly the amount of waste produced (Thierry et al., 1995).

2.4.1.4 Cannibalization

The purpose of cannibalization is to recover a limited set of reusable parts from used products or components. To be more specific cannibalization involves selective disassembly of used products and inspection of potential reusable parts. The remaining parts and modules are not used. Auora, a U.S. chip manufacturing company is mainly engaged in cannibalizing internal circuits. The company selects the parts they require from the computer and tests, straitens, redips, polishes and sells the chips.

2.4.1.5 Recycling

Finally, in recycling the identity and functionality the products and components are lost. The purpose of recycling is to reuse materials from used products and components. These materials can be reused for the production of new products (if these materials are of high quality) or else in the production of other parts. In recycling the used products and components are segregated into parts. These parts are then separated into different material categories which are then reused in the production of new parts. Sony has developed a revolutionary method for recycling the CD scrap produced during the manufacturing of optical discs. The recovered material is then used in product components. In the recycled process the polycarbonate CD waste gets converted into recyclable polycarbonate CD waste using the proprietary method. The recovered material is then used for the production of casing, top covers, cradles, etc (McKinnon et al., 2010).

2.4.2 Waste management

Waste management involves pre treatment of waste. To be more specific and based on the producer Pre-Treatment Requirement of the Landfill directive implemented in October 2007, Pre-treatment is undertaken when the waste has passed by a three point test in which all three points have been satisfied. To be more specific:

- It must be a physical, thermal or chemical, or biological process, including sorting.
- It must alter the characteristics of waste
- It must reduce its volume, or its hazardous nature, or facilitate its handling or enhance its recovery.

The EC directive on Packaging and Packaging Waste (94/62/EC) aims to reduce the environmental impact by obliging businesses to recover a specific proportion of their packaging waste. This is achieved through electronic Packaging Recovery Notes (PRNs) and Packaging Export Recovery Notes (PERNs) in order to indicate how much packaging has been recovered and recycled. Moreover the EC directives on Waste Electrical or Electronic Equipment (WEEE) (2002/96/EC) and on the Restriction of the Use of Certain Hazardous substances (RoHS) in Electrical and Electronic Equipment (202/95/EC) aim to reduce the environmental impact of packaging from electrical or electronic equipment (EEE) and increase its recovery recycling and re-use. This will in turn reduce significantly the total amount of waste disposed, and producers will be responsible of taking back products and recycling.

Under the EC 2005 Hazardous Waste Directive (91/689/EEC), producers of hazardous waste must be registered to the environmental agency before they can remove material from their premises. The mixing of hazardous and non hazardous waste is strictly prohibited and therefore waste separation and segregation needs to be carefully considered in the reverse logistics process. Additionally, the waste carrier should hold a license along with a specific training is required for carrying hazardous goods. Finally the consignee will be required to keep detailed records of the quantities and origins of waste and provide quarterly reports to its Environmental Agency. This practice enables tracking of hazardous waste movements until it reaches the authorized disposal or recovery facilities.

2.4.3 Re-use

Reuse is a strategy that eliminates waste, reduces waste disposal costs, and conserves energy and materials. It involves taking useful products, such as furniture, books and appliances, discarded by those who no longer want or need them and redistributing them to those who do. In contrast to recycling, which recovers materials for processing, reuse recovers the original product. Reuse, therefore, primarily involves collection and redistribution of goods. Product returns are an increasing concern to industry. Large retailers can have return rates in excess of 10% of sales, and manufacturers such as Hewlett-Packard report product return costs that exceed 2% of total outbound sales. At present, only a small percentage of the value is being recovered (Dimino and Warren, 2004). Through the Consumer Buyback program, all HP retail stores, accept products of any brand manufacturer in the following product categories: Desktop PCs, Workstations, Notebook PCs etc. It has been estimated that the production of 210,000 tones of CO_2 emissions has been avoided in 2009 (URL: http://www.hp.com/united-states/hho/buyback-recycle/index.html?jumpid=ex_R602_go/ConsumerBuyback (sited on the 30/10/2010).

The following graph represents the proposed framework for green supply chain network design.

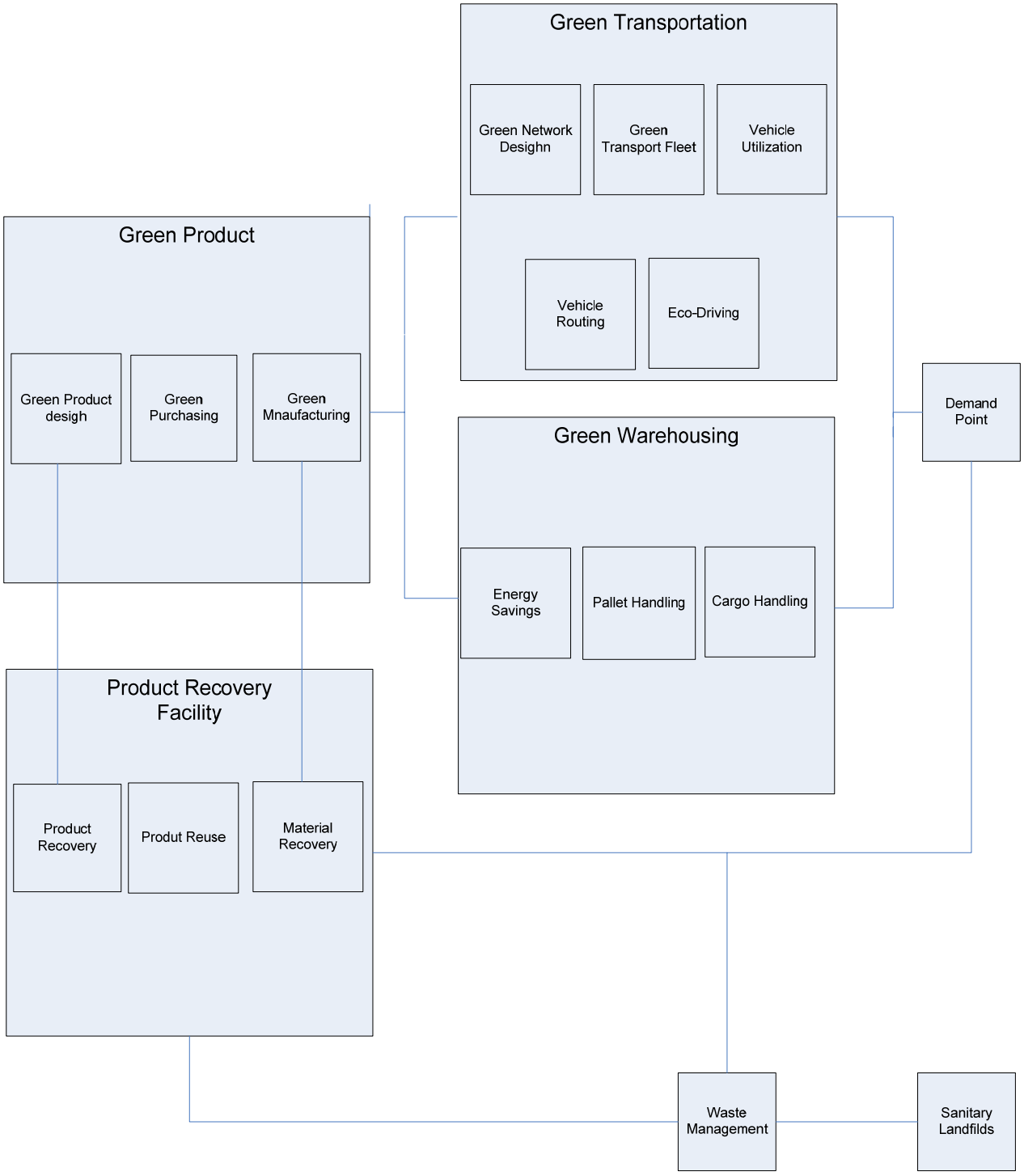

Figure 1. Supply Chain Network Design Framework

3. Conclusions

The integration of environmental concerns in supply chain network design is now a reality for numerous businesses worldwide. The adoption of green practices will not only affect the business that adopts the policy but also the customers and suppliers. The new global trend

towards the holistic tackling of supply chain costs and its environmental performance is becoming a top priority practice of corporations in order to achieve a competitive advantage in an increasingly environmentally sensitive market. In other words green practices that balance profitability with environmental efficiency will constitute cornerstones of sustainability, viability and thus competitiveness. Under this context, this research classifies current green supply chain practices and provides guidelines towards the development of green supply chains.

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Green Supply Chain: from awareness to action. 4th Supply Chain Monitor | White paper | 2010-2011. 4th Supply Chain Monitor BearingPoint.Â The support of companiesâ€™ management committees significantly facilitates and often guarantees the funding and implementation of green projects. The rising interests and motivations are an indication of a higher maturity of companies.Â New directions for green Supply Chain Beyond the various initiatives that the media daily present or that were mentioned by the respondents of the survey, environmental strategies are taking shape. Companiesâ€™ trends linked to green Supply Chain are setting up and demonstrate their maturity. Another key component of supply chain management is logisticsâ€” the activities to obtain incoming materials and distribute finished products to the proper place, at the desired time, and in the optimal quantities. Companies can greatly improve business performance by working with suppliers, shippers, distributors, and customers to better coordinate logistics activities.Â This guidebook provides a four-step framework for identifying and. On a similar note, many companies are using environmental information. also benefitting from chemical service to improve financial performance.