SUSTAINABLE OPERATIONS AND SUPPLY CHAINS: A FRAMEWORK FOR TRIPLE BOTTOM LINE

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ABSTRACT

With a heightened international concern about climate change, more manufacturers are adopting green practices and offering green options in their product line. The image built from such initiatives tremendously helps companies to set a foothold in markets where the purchasing behavior of environmentally conscious consumers is guided by the green reputation of a company. This paper evaluates the risks from a non-green profiling and analyses the tacit assumptions under environmental activism to propose that more customers would be willing to pay for green products if environmental activism is approached from a holistic perspective. The paper discusses the main features of green operations, green marketplace, green facilities and green product design. Based on this discussion, the paper proposes a green manufacturing framework consisting of a sequential supply chain model and a balanced score based operational model that organizations can benefit from. Finally, concluding remarks and further extensions are provided.

KEYWORDS

Green Operations; Green Supply Chains, Environment Sustainability, Corporate Social Responsibility

1. INTRODUCTION

The term sustainability refers to the concepts and approaches that aim to achieve the economic development and environment preservation goals to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. Indigenous communities have lived in harmony with the nature for centuries and utilized their knowledge of ecosystem for a sustainable future. The term sustainability came into focus with the Brundtland report published as 'Our Common Future' by World Commission on Environment and Development to study the links between social equity, economic growth and environmental issues [1,2]. The report emphasizes that the sustainable development should not compromise the survival of future generations. Discussions at international events hosted by United Nations, for example, the 1992 Rio de Janeiro Earth Summit gave further impetus to sustainability. One essential objective of this summit was to create an understanding and consensus among various nations as it related to their sustainability practices. The progress made at this summit provided the groundwork for subsequent efforts such as the Kyoto Protocol adopted by United Nations in 1997. Due to these efforts, more than 130 countries reached non-binding agreements, resolutions, pledges and strategic targets for sustainable development. However, disagreements remained among nations regarding who will foot the bill for climate control policy. Although Kyoto protocol was an important step but the commitment to the protocol was not guaranteed by the provisions of the protocol. The Copenhagen Climate Summit in 2009 was another international effort in this direction. One off-shot of these efforts was that in due course of time, the provisions and intents of these agreements reached business levels to generate concepts such as corporate

social responsibility (CSR), sustainable supply chains and green operations. Customers' preference for greener products forced business leaders and strategists to view green sustainable operations as a key element to shape their corporate strategies. Various manufacturing and service organizations in both profit and non-profit sectors started developing codes of conduct, procedures and policies to guide them in conducting their day-to-day business. Firms started designing, manufacturing and promoting green products. Tesla is one such example who opted to work towards developing electric as well as solar powered vehicles rather than focusing on environmentally harmful fossil fuels-based vehicles. Many other players in the auto industry followed suit.

Sustainability has three essential ingredients: environmental sustainability, social sustainability and economic sustainability. Environmental sustainability is ensured by utilizing the environment as a source or sink in a responsible manner. This responsibility requires that rate of extraction from natural resources must stay below the rate of replenishment of those natural resources. Social sustainability refers to the ability to meet the basic needs of a healthy society in an equitable and non-discriminatory manner. Environmental sustainability is the ability of various nations to ensure their economic independence, provide livelihood and prosperity to their respective communities. All three dimensions of sustainability are closely linked to ensure a greener, more prosperous and equitable environment.

Supply chain sustainability refers to the ability of a supply chain to produce and deliver products to the customers to generate shareholders wealth in a manner that is harmless to the environment and the society. Supply chain sustainability can be achieved in various ways. It includes sustainable supply base, for example, procuring from sustainable sources of raw materials and forming strategic alliances with green suppliers. It encompasses the optimal use of production, distribution and warehousing based on minimal inputs, energy and emissions. Further approaches include environment friendly packaging and the management of product's end of life cycle utilizing reuse, refurbish and recycle principles.

The research objective of the paper is to develop a sustainability framework that can provide benefits to the supply chains and to the firms operating within those supply chains. Consistent with the sequential nature of supply chains, and the internal and external process organization structure of a firm, the methodology consists of developing a sequential model for a supply chain and a strategic model for a firm within that supply chain. In the ensuing discussions, we will first discuss the risks associated with taking a non-green profiling in the marketplace to underline that it is no longer a viable option. We will further discuss sustainability from the perspectives of green operations, green marketplace, green facilities and green product design. Finally, we will present a framework to achieve sustainability from a supply chain as well as operational perspective. The main contribution of this paper lies in a manufacturing framework and proposing a balanced score based strategic model at a firm level that organizations can utilize to achieve triple bottom line benefits.

2. RISKS OF NON-GREEN PROFILING

Consumers now-a-days put a high premium on environmentally sustainable products and services. Those companies that do not comply with the environment standards are judged harshly by the consumers. However, still many companies assign a higher level of importance to consumers' price sensitivity vis-à-vis their environmental sensitivity. In the green marketplace discussion below, we will try to address this concern by unearthing the assumptions behind this negative mindset that function as a hindrance to invest in green technology. The investment in green technology needs to be weighed against the risks that come with maintaining the status quo.

2.1. Supply Chain Risks

The global warming and the climate change has resulted in significant increase in natural disasters in recent times and caused disruptions in supply chains. These disruptions cut-off the supply channels making production, distribution and sales facilities vulnerable to risks. Although complying with the environment laws may cost initially, but this cost is minor compared with the costs associated with facing the supply chain risks.

2.2. Litigation Risks

Companies with a poor track record in carbon emissions face the risks of lawsuits like those of the tobacco industries. Several lawsuits have started to appear before the courts with regards to companies that generate pollution. These lawsuits could potentially cost companies millions of dollars and can create personal liabilities for directors and officers who do not address these issues within their companies [3]. Ciba-Geigy Corporation re-examined the waste-water treatment at its dye plant to comply with tighter environmental regulations. This not only improved their environment record but also resulted in an increase in process yield by 40% and annual cost saving of $740,000 [4]. These environmental changes were the result of lawsuits.

2.3. Product and Technology Risks

Companies that fail to innovate and adapt to the changing world are always at risk of falling behind. To reduce the harmful impact on the environment, different governments enforce regulations on the manufacturers to update their technologies. Several appliance manufacturers operating in the construction industry utilize such technology and develop their capabilities to meet those environmental regulations.

2.4. Physical and Financial Risks

One of the underlying causes of disaster events is a disregard for the environment while pursuing economic goals. Natural disasters present a real physical risk to both employees as well as the company assets. For example, a severe hurricane can potentially damage offshore oil platforms and oil production refineries making it highly risky for the workers and assets to operate. Such natural events have a bigger impact on the bottom-line compared with the costs of going green. The costs related to supply chain disruptions, products loss, asset write-offs and the higher insurance premium can be substantial in many industries. According to reports [5], between 1995-2004, approximately 2.5 billion people were affected by natural disasters with 890,000 deaths and costs amounting to US$ 570 billion.

3. SUSTAINABLE OPERATIONS

Green operations attempt to integrate a manufacturing system so that the extraction of raw materials, product design, production, product usage and product disposal stages minimize the harmful impacts on the environment. This type of integration is achieved through maximizing the resource utilization and minimizing the carbon footprint. Green operations refer to the process of executing operations while ensuring that the interactions with the environment are pursued to maintain the environment to its natural state. The main approaches for environmentally sustainable operations include consumption of less materials and energy, material substitutability and eliminating unwanted outputs [6]. The first aspect of this strategy is based on the premise that less material and energy usage results in a reduction in pollution and toxic waste levels while ensuring efficient resource sharing. The second part of the argument emphasizes material

substitutability to replace the raw materials and energy from non-renewable sources with the renewable ones. Such a substitution of materials and energy usage creates an environmentally friendly cycle that preserves natural resources while reducing the inflow of harmful ingredients into the environment. The third aspect underlines the need to reduce unwanted outputs during a manufacturing cycle. These outputs appear in the form of scrap and defective items that consume raw materials and energy from natural resources thereby stressing out the natural resources. A tight quality control mechanism, an early inspection and detection mechanism, and a regular maintenance regime could prove to be effective approaches to address the third concern.

Sustainable operations have the potential to reduce product risks, improve efficiency, provide a competitive advantage and create newer business opportunities. Therefore, green operations are emerging as a sound business strategy option to achieve economic gains, deliver environmentally friendly products and services, and contributes towards corporate social responsibility. Companies endeavor to brand themselves with a green and sustainable image to demonstrate their commitment to the planet. Stricter government regulations and international trade policies further ensure compliance with the environment sustainability. For example, most companies are under pressure from consumers and shareholders to report their sustainability performance. Triple bottom line accounting is one such approach where companies expand their traditional financial reporting framework to include their ecological and social performance.

Green operations being a newer phenomenon, there are no uniformly and internationally accepted codes of conduct and standards. Some firms focus on reducing the carbon footprint of their infrastructural equipment and building facilities while others focus on their process inputs, outputs or the product life cycle. However, there are accreditation bodies such as International Organization for Standardization that provide management tools to enable organizations to improve their environmental performance. For example, ISO 50001 energy management standards created by International Organization for Standardization are applicable across all sectors to promote efficient use of energy [7]. ISO 14001:2015 standards meant for products and services under organizational control stipulate the requirements for an environmental management system.

In the past, efforts in sustainable operations have mainly focused on re-manufacturing and using less toxic materials. Re-manufacturing emphasizes the use of closed loop manufacturing systems that demonstrate their sustainability and cost effectiveness by less reliance on the external sources of materials. Re-furbishing-an important concept of re-manufacturing, repairs and reuses customer returned products that are in a fairly new state. Re-manufacturing also stresses on the disassembly of those products that are near the fag end of their life cycle and reuse the components to support new production [8]. Finally, re-manufacturing suggests processing the end-of-life-cycle products into raw materials and enters them back into the raw material stream, thereby, reducing the reliance on virgin sources of raw materials. For example, the scrap metal obtained from the junk car yards is melted into metallic bars and used in the auto industry. Xerox's bottom line swelled by $700 million from re-manufacturing activities [9]. Most companies endeavor to reduce the use of hazardous chemicals in their production and delivery processes to improve their carbon footprint. For example, the bottle developed by Coke from petroleum and sugar-based materials had a lower carbon footprint than the traditional plastic bottles [10]. Dupont set a corporate Goal of Zero i.e., zero injuries, illnesses, incidents, waste, and emissions, in the priority areas that presented highest risk to safety, health and environment [11].

4. TRIPLE BOTTOM LINE AND CARBON OFFSETS

4.1. People

Besides the social and health benefits of green products for the current and future generations, employees that work in a green manufacturing facilities feel a sense of pride in their works-manship that is often missing in other non-green facilities [12]. Pride in the work environment can potentially translate into a loyal and productive workforce for the company. Furthermore, most companies are realizing the importance of corporate social responsibility and try to maintain a good image in eyes of public and environmental lobbies.

Besides the social and health benefits of green products for the current and future generations, employees that work in a green manufacturing facilities have a sense of pride in their work that is often missing in other non-green facilities [12]. Pride in the work environment can potentially translate into a loyal and productive workforce for the company. Furthermore, most companies are realizing the importance of corporate social responsibility and try to maintain a good image in eyes of public and environmental lobbies.

4.2. Planet

Consumers as well as corporate houses are becoming increasingly more aware of the link between irresponsible economic activity and the environmental degradation. Consumers are paying more attention to reuse, reduce and recycle ideas. Corporate houses have also begun to promote energy efficiency, use of renewal raw materials, controlling carbon emissions, and responsible disposal of waste.

4.3. Profits

With growing number of consumers who prefer greener products and services, a positive environment friendly image wins more orders and sales for a company. The decline in legal issues and litigation costs accruing from harmless processes and products provides additional benefits to the company. Furthermore, companies that integrate environmental sustainability into their manufacturing processes and practices experience further cost reductions through recycling, energy usage and resource conservation. An empirical evaluation of the link between green supply chain management, increased competitiveness and improved economic performance amongst some business organizations in Southeast Asia has been presented in [13].

4.4. Carbon Off-sets

The carbon offset programs sells green tags and carbon credits to businesses, public utilities, government agencies and individuals to offset their carbon emissions. Carbon offsets are the credits for emission reductions achieved by sponsoring projects such as wind energy generation, solar panels installation and energy efficiency retrofits into existing infrastructures. The carbon offset model allows a company producing harmful emissions to purchase carbon credits from environment friendly firms to offset their poor carbon performance and climate impact. Although the model provides a revenue stream for environmentally compliant firms motivating them to further undertake green projects, the carbon offset model has its drawbacks. It allows a company to continue with a below par carbon performance by purchasing credits, carry on with green non-compliance and turn a blind eye to upgradation of technology. Furthermore, it may potentially widen the gap between nations and communities as the wealthy ones can buy their way out of carbon compliance. Despite these drawbacks, the model is advantageous in terms of generating

funding to support green technologies. The carbon offsets model has also been found to be more effective than its carbon tax counterpart to reduce greenhouse gas emissions [14].

5. GREEN MARKET PLACE

Environics International surveyed the consumers' preference for green products vis-à-vis their willingness to pay for green products under the prevalent environmental activism in society [15]. The survey summarizes the results under four quadrants: green consumers, latent green consumers, inactive green consumers and green activists as shown in Figure 1. The results are somewhat outdated and there has been a significant increase in green activism since 2002. However, these results are interesting. Out of the 67% of the consumers who showed high willingness to pay for greener products, a large fraction (i.e., 40%) was willing to pay despite a low degree of activism. Therefore, high degree of activism is not the only dominating factor that influences people's purchasing plans for green products. Factors such as self-awareness, health, safety, and government policies could be other valid factors. Several papers point towards the link between market demand, financial performance and environmental sensitivity. The relationship between market value and the environmental stewardship has been explored. It has been reported that a 10% reduction in emissions of toxic materials resulted in almost $34 million increase in market value [16]. The main predictors of consumer's green purchase behaviors to help policy makers formulate green strategies are analyzed in [17]. An analysis of agri-food supply chain where demand is a function of sustainability and price is presented in [8]. Some past work suggests approaches to rate and select suppliers based on their use of green materials, technologies and environmental performance [18-22). Below, we investigate the tacit assumptions to analyze the nature of green markets [15].

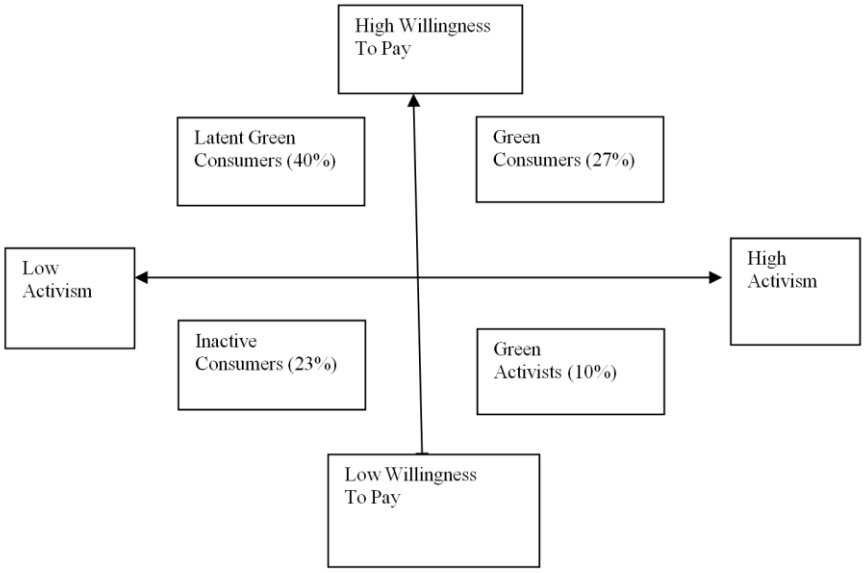

Figure 1. Green consumer behaviour [15]

Hypothesis 1*: Consumer demand for green products is dependent on willingness to pay.*
Tacit Assumption: Consumers pay high prices for green products.

Green and energy efficient products are presumed to be more expensive under this tacit assumption. But in principle, green manufacturing focuses on less material and energy usage and largely depends on recycling and re-furbishing to support the raw material supply rather than the

expensive extraction of materials from virgin sources. As a result, the real cost of a green product must be lower. There could also be examples in favor of higher costs for green products. For example, smaller yields, extra production time, costs of certifications, and biodegradable packaging [8, 23] but such justifications for higher cost also creates a disparagement among environmentally conscious consumers. Many firms attempt to sell sustainability rather sustainable products. The unreasonably high prices of sustainable products often result from high mark-ups for these products compared with conventional products. These mark-ups can be self-sabotaging for green products. Sustainable products selling at 75-85% higher prices than the regular products, creates a price gap that is hard to fill [24]. Production although being a relevant part of a sustainable supply chain, accounts for only 10 to 30 percent of the product cost whereas non-production steps having minimal impact on sustainability also add large mark-ups on the cost of green products. In future, the adoption of environmental accounting practices will pass a lower price to the consumers and will significantly improve the adoption of green products. This will shift more consumers from third and fourth quadrants into the first and second quadrant in Figure 1. The resulting surge in demand for green products will further allow economies of scale and create a positive outcome for consumers.

Hypothesis 2*: Consumer demand depends on activism.*

Tacit Assumption: Activism refers to promoting the ecological and social benefits of green products.

When consumers are quizzed about their purchase plans for green products, the economic argument is not adequately highlighted, a factor that according to hypothesis 1 is the main determinant of demand. Once green activism is promoted in a holistic sense i.e., including economic benefits of lower costs of recycled materials and energy, a significant portion of green consumers are likely to fall under the first quadrant. With the increase in total activism in the marketplace, firms will find it attractive to capture the green market. Under these emerging market conditions, manufacturers will adapt their production processes to gain a competitive edge. Consumers' preference for green products provides an incentive for manufacturers to upgrade their production technology [25]. Therefore, total activism should not only be promoted among consumers, but also among the manufacturers.

6. GREEN FACILITIES

Facilities and buildings account for a major portion of the energy usage and contribute a great deal to total greenhouse gas emissions. Therefore, improvements in building designs can potentially address the problem of reducing greenhouse emissions and energy consumption. The green building concept encompasses all aspects from eco-friendly construction to the eco-friendly operations. Leadership in Energy and Environmental Design (LEED) is a global standard for design, construction, and operation of high performance and environment friendly buildings and LEED is the most widely used green building rating system [26]. Sustainable construction materials provide significant ecological benefits. Use of sustainable raw materials helps in cost savings as well. Green insulation options such as sheep's wool, cellulose, and earth wool provide thermal insulation, absorb harmful elements from the air and are cost effective. The use of recycled wood, recycled metal, precast slabs, and bamboo in building construction are also cost effective and sustainable options. According to the U.S. Green Building Council, buildings' usage of energy at 41% is more compared with transportation sector at 29% usage [27]. Environment sustainability was the main theme during the construction of General Motor's Lansing plant where the use of recycled materials was emphasized. On this project, more than 60% of the building's materials came from local suppliers and approximately 80% of the construction waste was diverted from the landfill [28]. The microprocessors-controlled systems

only lighten up those areas which require worker activity and use dim or no lights during the non-production time. Rainwater harvesting is used for maintaining landscaping, lawns and vegetation and recycled water from a production process is reused for other production processes. In the Kameyama plant of SHARP, the company constructed a closed loop recycling system that re-used all the wastewater discharged from the manufacturing processes [29]. Strathcona paper used 85% re-cycled water, composted all bio-solids and provided this material to local farmers for organic farming [30].

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7. GREEN PRODUCT DESIGN

Green design has several underlying concepts such as Design for Environment; Design for Dis-assembly; Design for Recycling; Life Cycle Analysis and Green Material Selection. These design ideas facilitate recycling, reuse, and easy disassembly in future. For example, Kodak's disposal cameras had 87% of the parts suitable for reuse and recycle so that consumers will not discard them but instead they return them to photo finisher [31]. Often, the costs associated with a disassembly may exceed the value of fresh materials, therefore, a modular product design becomes necessary to reduce the cost of disassembly. Software tools exist to identify the fastest and cheapest disassembly pathways [32]. DFD further emphasizes that innovative designs use fewer parts and raw materials to cut down costs, shorten disassembly time and provide environmental benefits at the same time. Japanese appliance manufacturers carried out major product redesigns for easier disassembly to achieve a 16% cut back in the number of parts in washing machines and a 30% reduction in parts for vacuum cleaners [4]. Hitachi started making lighter products to facilitate the ease of recycling process [33]. Ford Motor Company used

soybean oil to manufacture polyurethane foam for car seats rather petroleum-based foam to reduce energy usage [34]. The lighter components and subassemblies in fuel efficient cars use natural fibers as an input [35].

8. GREEN MANUFACTURING FRAMEWORK

In Table 1, we present a framework that includes a series of sequential steps for green supply chains. This framework is further supported through the green strategic model provided in Table 2 which follows a balanced score card approach and can be applied at a firm level. This model provides links across four dimensions of learning & development, internal processes, market and financials, and carbon performance.

Table 1. Sustainable framework at a supply chain

Product Design	Design products that • are safer • can easily disassemble • use fewer materials • use fewer toxic materials
Sourcing	Source from • green certified suppliers • renewable energy sources • closer geographical locations
Production	Produce using • green facilities and components • fewer parts and raw materials • energy efficient operations and recyclable water • reduced scrap, wastage & defect rate
Distribution	Distribute with • fewer transportation and handling steps • green modes of transportation • green warehouses • minimal packaging
Sales	Sell by promoting • social, environmental, economic activism • product-life-cycle benefits
Performance Measurement	Measure performance through • triple bottom line performance measurements • environment accounting practices
Customer Support & Product Instructions	Instruct consumers on • environment friendly use of product • lesser energy use of product • safe use of product
Re-manufacturing	Re-manufacture product by • closing loop, refurbishing, recycling and reusing • less reliance on virgin sources of materials
Product Disposal	Dispose product through • bio-degrading practices • Compliance with waste disposal guidelines

Table 2. Green strategic model at a firm level

Economic, ecological and social performance across suppliers, products, processes and market			
	Objectives	**Metrics**	**Decision areas**
Performance Dimensions	Profits; revenue; costs; carbon footprint; social contribution	Profit increase; % change in revenue; % reduction in costs; cost reduction from sustainability practices; cost reduction passed to consumers; carbon credit balance	revenue management; cost benefit analysis; budgeting; financial control; environmental accounting, corporate social responsibility
Market 	Market share & retention; social, ecological & economic activism; strategic alliances & partnerships	Market share; level of social, ecological and economic activism; newer environmental products; customer satisfaction surveys on green products; horizontal & vertical integration with green partners; social & environmental initiatives supported	Product promotion & marketing; partnership agreements; mergers & acquisitions; corporate social responsibility; customer relationship management
Internal Processes 	Green product design; green manufacturing; re-manufacturing & disassembly; green distribution; environmental accounting	Green product line; reduction in energy use & energy cost; reduction in disassembly time; reduction in parts & materials; percent of parts recycled; transport & handling steps used; wastewater recycled; product defect & scrap rate reduction, reduction in packaging material	Product design; operations management; warehousing; distribution; packaging; quality management; accounting
Learning & Development 	Sustainable R&D; green supplier development; sustainability training; green customer support	Technology upgrades; number of green certified suppliers; percent of domestic suppliers; sustainability development & training programs for staff and consumers	Maintenance and upgrade; develop supplier base; knowledge management; HRM

The afore-mentioned models in Table 1 and table 2 can provide significant benefits at supply chain as well as firm level. The effectiveness of these frameworks and the expected results will vary depending on various factors such as the management commitment in terms of time and resources, the control over the supply chain and operational functions, and the activism and awareness prevalent in the industry. Secondly, these general models would need further fine-tuning to meet the specific requirements based on the specific industries, product lines, and the markets.

9. CONCLUSIONS AND EXTENSIONS

According to estimates, supply chains account for approximately 60% of all global emissions [36, 37]. The stringent environmental regulations and the concerns about limited energy and natural resources will continue to guide companies to become more environmentally friendly. The trend is quite evident among companies to align with a green culture. Those companies that innovate and put efforts to reduce their carbon footprint not only benefit from the reduced cost in the longer run but they will also earn the goodwill of market and governments. Therefore, sustainable manufacturing provides a sound business strategy that will potentially give a competitive advantage to such companies. The technology and ecological awareness will need to

work in tandem to secure a sustainable economic growth as well as to secure the future of generations to come. This paper examined some of the risks of not following green practices and analyzed the green activism assumptions. The paper further introduced the main building blocks of a sustainable manufacturing system such as green operations, carbon offsets, green marketplace, green suppliers, sustainable facilities and product design. These building blocks were used to suggest a framework consisting of a sequential supply chain model and a balanced score card based operational model that can potentially benefit the companies who endeavor to follow green practices. The suggested framework is likely to be beneficial to achieve triple bottom-line results, but their adoption will be limited unless some universally accepted standards exist for green operations. ISO-14001 is a good step in this direction but there is a need for more standardization in manufacturing specific areas. The suggested models are more geared towards manufacturing organizations but their adoptions by service organizations, non-profit organizations, humanitarian supply chains will need several adjustments. Exploring the frameworks for these organizations are possible future extensions of the work.

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