A Review of Optimal Designs in Relation to Supply Chains and Sustainable Chemical Processes

Mohammed Saleh Al.Ansari[1]

[1] Department of Chemical Engineering, College of Engineering, University of Bahrain, Kingdom of Bahrain

Correspondence: Mohammed Saleh Al.Ansari, Department of Chemical Engineering, College of Engineering, University of Bahrain, PO Box 32038, Sukhair Campus, Kingdom of Bahrain. Tel: 973-3944-1110. E-mail: malansari@uob.edu.bh

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Abstract

With the emerging importance of balancing environmental, social, and economic objectives within a company setting, growing awareness of planning of supply chains and sustainable optimal design has been brought into perspective. An immense amount of research has been devoted to this sector, in hopes of capturing these objectives to ensure long term sustainability. Among some of the approaches that have been developed, product design, inventory management, product recovery, production planning with an emphasis on remanufacturing, reverse logistics, and supply chains that are closed-looped have been given additional attention in various pieces of literature.

We will review and analyze some of the research that has surfaced in regards to sustainable chemical processes along with supply chain design. Focus will be given to three main areas, (i) waste management and energy sufficient sustainable supply chains, (ii) sustainable supply chains and their effect on the environment, (iii) sustainable water management principals. The challenges that these three sectors face have been summarized, and all future opportunities have been highlighted.

Environmental sustainability is an issue that receives a lot of attention in the press, journals, and media. Most of the discussions surrounding this debate focus on the environmental impacts that organizational supply chains have on the environment. The goal of this paper is to further investigate the environmental impact concerns, and how these concerns are impacting the operational and strategic management of company supply chains. The research we have complied is intended to give an overview of the practices that companies have adopted and to clarify that further research is still in the midst of being conducted.

Keywords: optimal designs, supply chains, sustainable chemical processes

1. Introduction

Over the past few decades, an immense amount of attention has been given to minimizing the environmental impact that industrial operations impose. As a result of this attention, there has been a rise in the costs of environmental compliance and additional environmental regulations that have been imposed on industrial sectors. Much of the focus on supply chain management, most commonly referred to as SCM, has changed gears from offering a specific cost approach to a broad adoption of developmental sustainability (Piplani, 2008).

The emphasis that has been put on balancing economic, social, and environmental objectives within companies has forced a new awareness to arise in sustaining optimal designs and planning of supply chains. Additional research actions have been employed to extend the current approaches used by businesses in regards to the practices and regulations that they employ. The combination of SCM and environmental management has created new discipline in supply chains that is referred to as Green Supply Chain Management or GrSCM for short (Nikolopoulous, 2012).

The importance of GrSCM is driven by the deplorable state of the environment. Depleting raw material sources, increasing levels of pollution, and overflowing waste sites are the product of poorly practiced supply chain management guidelines. In addition to these issues, the growing consumer pressure has increased the need for businesses to consider the types of choices that they are making in regard to supply chain management practice and research (Nikolopoulous, 2012).

Supply chain design, generally referenced the number and location of producing facilities, the capacity of goods being made at the facility, and the assignment that each market region had. GrSCM has forced this definition to extend beyond what it was previously defined as. With GrSCM additional emphasis is given to (i) green designs (ii) the green operation practices within the supply chain. Vital aspects that are taken into consideration include (i) process of waste disposal (ii) the utilization of energy efficient resources (iii) gas emissions emitted from greenhouses (iv) using resources and capacities efficiently and (v) legally based environmental factors (Srivastava, 2007).

The traditional SCM practices have centered their attention on inventory of location issues, several additional approaches are proposed to help minimize the resource consumption and energy that is used by chemical plants. The downfall to the approaches emphasized by the two is that they focus their attention on the process of manufacturing itself, so the scope of the impact that the process has on the environment is seemingly limited. Along with the other approaches that have been adopted in the recent years, product design, inventory management, product recovery, production planning, supply chains within closed-looped circumstances, and reverse logistics have all been given additional attention in literary works (Andersen et al., 2009; Jayaraman et al., 2007; Schecterle et al., 2008; Ydstie et al., 2002).

We will review over the extensive research that has been conducted on sustainable supply chains in regards to chemicals. The research we will be analyzing extends from the process synthesis phase and ceases at the supply chain management process. First, we will introduce the need for specific environmental impact assessments that should be made in the supply chain. Then, provide a literary review on the planning involved with sustainable supply chains and their optional design will be presented. Additional attention will be given to three primary areas: (i) waste management and energy conservation occurring within the synthesis phase, (ii) the environmental impact that sustainable supply chains have, (iii) water management in regards to sustainable supply chains. Additional challenges regarding these three focus areas will be admonished in context.

There are a lot of literary compositions that address sustainability. In the literature mentioned by Bakshi (2000) that these literary works, sustainability is described as a primary dimension to the social responsibilities that corporations have to the public sector. In a lot of the literary works that have been composed, there is one issue that seems to take center stage. The issue regarding the triple bottom line is continuously addressed. The triple bottom line issue focuses its attention on the increased influence in the ecological, ethical, and economic organizational decision making process.

Back in March of 2008, a white paper was published by the Aberdeen Group, discussing the research that had been done on the practices that best in class companies used when setting up their supply chains. Coincidentally, the best in class companies that were cited for the literary composition all focused their attention towards becoming a leader in the GrSCM sector. They claimed that the biggest pressures they had been experiencing were a result of the added pressure that society has put on large businesses to adopt green sustainability guidelines within their supply chains (Pagell, 2008).

A few of the other concerns that best in class businesses expressed was the rising costs in fuel and energy. Even though the environment does not seem to pose a risk on businesses, further studies have confirmed that with a changing climate, businesses face six risks that can either make or break their supply chain sustainability. The risks include supply chain, regulatory, litigation, product and technology, as well as physical. A lot of the supply chain risks are not prominent for the business owner; they are more or less left on the shoulders of the suppliers.

Businesses need to be wary of the carbon footprints that are being left by the suppliers that they work with. The carbon footprint of business suppliers is what influences the cost of goods and services that these suppliers render. As a supplier carbon related costs increases, businesses must be prepared to match this increase, by paying higher costs for the supplies that they are receiving. Business owners should also be aware of the location of their suppliers, since there are already some locations that are being subjected to carbon regulation policies. In 1996, Florida researched the relationships that exist between environmentally sustainability and manufacturing techniques exercised by businesses. The hypothesis that Florida relied on throughout his controlled study was that firms relied on cost-effective and innovative production practices of their suppliers, in order for them to keep the cost of the goods and services to their consumers low (Andersen et al., 2009; Jayaraman et al., 2007; Schecterle et al., 2008; Ydstie et al., 2002).

2. The Birth of Sustainable Sourcing

Supply Chain Management, most commonly referred to as SCM, by the corporate business owners to rely on these chains is a strategic and systemic assembly of functions that is geared towards improving the performance of organizations over a long-term span. Supply chains involve multiple parties that either directly or indirectly fulfill a consumer's request. Supply chains not only include the supplier and manufacturers of goods and service, but they incorporate other outsourced parties as well. Warehouses, transporters, retailers, and the end customer are all components to how a supply chain functions.

The primary goal of every supply chain is to maximize the value and services of the end generated product. The value of the supply chain is what makes a significant impact on the cost of the final product that is given to a customer. The better a supply chain functions, the more the final end product is worth to the receiving consumer. Commercial supply chains value is directly correlated to the profitability that exists within their supply chain. For example, the difference between the money that is generated from the customer to the overall costs of operating the supply chain have to correlate correctly, in order for a company to obtain revenue from the manufactured goods that they provide.

3. Total Quality Environmental Management

Total Quality Environmental Management, involving the quality improvement of production workers will allow firms, corporations, and businesses to measure the success of their supply chain processes. Worker Involvement in Pollution Prevention uses unique positioning of workers that are employed in manufacturing roles to be able to correctly identify pollution sources. Florida, during his investigations was able to uncover a link that existed between environmental performance and SCM practices. In order for firms to be able to increase the reliance that they have towards their outside suppliers, while also being able to incorporate strategic and systemic approaches to supply chain management, calls for a joint effort to be put forth. The joint effort must be exercised between the suppliers and the end-users, in an attempt to eliminate added waste, which will then allow sustainability to increase. End-users are persuaded to push towards waste reduction methods, and improvements in the costs that are being bestowed upon them, in order to mold relationships that mutually depend on one another (Jorgensen, 2002).

4. What Is the Integrated Chemical Management Approach?

Integrated Chemical Management, commonly used as the acronym term, ICM is a dominant concept that brings together in a comprehensive manner, most of the approaches and principles that have been identified in the study. This approach takes the production, transport, formulation, processing, distribution, utilization, and appropriate chemical disposal methods into consideration. The approach possesses links that allow cleaner production of products and pollutant preventative techniques to be performed in controlled environments. There are four components that exist in ICM (Perea et al., 2001)

The Life Cycle Approach- This approach addresses chemical processes in a holistic form, commonly referred to as the "cradle-to-the-grave" concept. In this approach, stages that exist within the chemical cycle as well as elements that occur within certain stages of this specific cycle are admonished; ensuring that nothing falls through the cracks in retrospect to other schemes that are less coordinated (Perea et al., 2001)

The involvements of Stakeholders- Stakeholders are parties that have a monetary interest in a specific product, or are affected in either a direct or indirect manner by chemical management properties. Adequately consulting the increases in the chemical management policies will ensure that all policies are properly implemented, designed, and enforced.

Participation between and across governments- Evaluations at the national level, with regards to ministries and other constituencies that include local and state authorities, industry interest groups and public groups, to help decrease gaps, eliminate policies that conflict with one another, and deplete overlaps while also contributing towards accomplishing the same common goals. Evaluations at the international level involve coordination amongst international and intergovernmental organization. Discussions are relevant to the effects of chemical management (Chaabane et al., 2012).

Synergies- Making the best use of resources that is readily available while avoiding duplication that is not necessary; allowing joint projects to go underway that can help implement agreements internationally, rather than one solitary agreement (Blau et al., 2000). Also, allowing countries to develop single inventories instead of multiple chemical inventories that are different and overlap current standing agreements.

There are twelve sustainable chemical processes that could best be described as:

1) **Prevention**- Preventing waste from occurring, rather than cleaning up or treating it after its creation.
2) **Atom Economy**- Different synthetic methods should be used to help maximize the amount of natural materials that are utilized to complete an end-product.

3) **Decrease Chemical Syntheses of Hazardous Products**- Whenever it is plausible, different synthetic methodologies will need to be adapted to create substances that do not have a toxic effect on the environment or the health of humans (Blau et al., 2000).
4) **Design Safe Chemicals**- Products that involve the use of chemicals, should be made to perform their end result, while decreasing their toxic effect (Perea et al., 2001)
5) **Safe Auxiliaries and Solvents**- Whenever plausible, the use of auxiliary substances should not be used; innocuous substances should replace their use (Blau et al., 2000).
6) **Energy Efficient Designs**- The energy requirements that are used for chemical processes need to be admonished for the impacts that they have on the economy and environment. The impacts will need to be minimized. If it is possible, different synthetic methods should be used.
7) **Renewable Feedstocks Adopted**- Raw materials or feedstocks should be renewable sources, instead of minimizing natural sources. This can occur only when it is both economically and technically possible.
8) **Reduced Derivatives**- Derivatization that is not necessary, such as utilizing blocking groups, temporary modifiers, or different types of chemical and physical processes will need to be either minimized or depleted altogether, whenever possible. The reason being is because these steps will require the utilization of reagents that can contribute to waste(Perea et al., 2001)
9) **Catalysis**- Selective catalytic agents are superior in comparison to stoichiometric reagents.
10) **Degradation Designs**- All chemical products should exercise a design that enables them after their functions have ended, to break down into degradation items that will not exist in the environment, causing adverse environmental contributions (Cussler et al., 2001; Floudas et al., 2001).
11) **Pollution Prevention Carried out in Real Time**- Analytical methods will need to be developed further, allowing for real-time monitoring prior to hazardous chemical and substances being formulated.
12) **Safer Chemistry Methods Encouraging Accident Prevention**- Any and all substances used to form a different type of substance or encourage a chemical process will need to be chosen carefully; thus minimizing the possibility of chemical accidents that could cause explosions, unpredictable releases, or fires.

5. Other Related Byproduct Info.

All engineering processes and holistically products will use and integrate assessment tools that monitor environmental impacts Subramanian (Pekny et al., 2003). Natural eco-systems will need to be conserved and improved, while also protecting the well-being and health of humans. Life-cycle thinking should be utilized in all engineering acts. All materials energy inputs along with their outputs should be safe and benign, as much as possible (Pekny et al., 2003). Depletion of natural resources needs to be minimized at all costs. Waste prevention needs to be practiced (Cussler et al., 2001; Floudas et al., 2001). Apply and develop instinctive engineering solutions while awarding attention to the geography of the land, cultures, and aspirations. Create new engineering solutions that are beyond the present and dominant technologies that are currently being entertained (Andersen et al., 2009; Jayaraman et al., 2007; Schecterle et al., 2008; Ydstie et al., 2002). Always strive to innovative, invent, and improve solutions to achieve sustainability at all costs. Communities and stakeholders need to be actively engaged in developing engineering solutions. Proper use of a chemical management system will help ensure that chemicals are being safely managed, while still maintaining the benefits that they evoke upon society (Blau et al., 2000; Maranas et al., 2002). This helps not only to ensure the safety of the end-product user (mankind), but also ensures the industry maintains its competitive approach (Pekny et al., 2003).

- Ensure that the public health sector, as well as the environment is protected against risks that are caused by a direct exposure to hazardous chemicals. Using proper risk management measures and applying these measures, ensures safety of the public and the environment as a whole (Blau et al., 2000; Maranas et al., 2002).
- Assuring that any risks that are associated with chemical manufacturing, distributing, utilization, disposal, and recycling are properly managed and characterized.
- Increase the level of public confidence in regards to the safety of chemicals used, distributed, and manufactured.
- Timely responses will need to be provided to any concerns that the public has about the associated risks of chemicals.

5.1 First Principle: All Chemical Management Systems Have Risks

Guillen-Gosálbez (2009) studied the issue and found it that when risk-based approaches are used, they take into consideration the intrinsic hazards that a substance has, along with its potential for the hazards to be expressed. Regulatory approaches are based off of an intrinsic hazard or overexposure that could equate to a loss in the benefit that is derived from the use of specific chemicals. Risk-based approaches allow utilization of highly hazardous chemicals, just as long as the applications of the chemicals are controlled to prevent and restrict any intrinsic hazards (Pekny et al., 2003).

- All decisions should be based off of scientific evaluations outlining risks.
- Chemicals will need to be managed, so they will not impose any significant risks.
- Assessment related decisions will need to be made in a time centered fashion.
- Cost and benefit analysis needs to have a purpose in all risk management decisions.

5.2 Second Principle: Systems Should Screen Chemicals Determining Further Needs

Approaches that focus on screening all chemical substances in a tiered centered approach to identify additional information requirements, allows development of appropriate and necessary risk information, to impact any and all risk related actions, while conserving resources (Blau et al., 2000; Maranas et al., 2002).

- Systems should provide a foundation for screening chemicals. Allowing evaluations to be made if any further exposure or hazard information will be needed to reduce public uncertainty in the risks associated with the chemicals (Pekny et al., 2003).
- Decisions regarding whether chemicals require additional evaluations will be based on criterion that has a firm scientific foundation.
- Clear communications regarding the results, priorities, rankings, and uncertainties that are associated with the screening categorizations will need to be communicated to the public, manufacturers, and additional entities in the supply chain (Pekny et al., 2003).

5.3 Third Principle: The Systems Should Leverage All Available Info.

Approaches that encourage the evaluation and identification of all available information to help decide if additional testing needs to go underway, will appropriately impact the designs and executions of further testing; thus also helping to reduce animal utilization. All information that has been validated will need to be used in all chemical management decisions. If additional information is required and cannot be avoided, all efforts should be made to decrease the amount of animal testing procedures that have to go underway. Other acceptable study methods should be adopted prior to utilizing animals for further testing.

5.4 Fourth Principle: The Systems Need to Recognize the Shared Responsibilities Each Party in the Value Chain Has

Producers and end-users, along with regulatory authorities, have to assist to ensure that the chemicals being used are regulated and managed in a safe and controlled manner. A transparent flow of information needs to be dispersed within the chain, allowing all users and manufacturers the ability to evaluate risks; thus providing relevant and meaningful information to stakeholders. Cooperative efforts should exist amongst producers, users, and distributors of chemicals, ensuring that all information and data that related to chemical risks characterizations are shared, developed, and if appropriate, applied. If a party that is an influence to the value chain is able to identify improper practices that involve a product, that party should work to resolve the issue, along with other participating parties in the chain. If the individual party does not have a sound judgment regarding what needs to be rectified, then the party should take additional measures including and leading up to terminating the sale of the end product (Andersen et al., 2009; Jayaraman et al., 2007; Schecterle et al., 2008; Ydstie et al., 2002).

5.5 Fifth Principle: A Transparency Promoting System

In order to make essential decisions about the management of chemicals, information is vital. Chemical manufacturers and government entities will need to ensure that the processes that they are utilizing for conducting their risk assessments are being done in a transparent fashion, allowing the lament (end-user) to be able to identify cracks in the SCM.

- All information that is utilized to determine risk should be readily available and accessible to the consumer market.

- Proprietary interest details, such as specific information that relates to ingredients used in a product should be upheld and protected as confidential business info.
- If any information used to determine risks has commercial value, additional provisions should be made to this information to help protect commercial interest, but also ensuring that the public can readily access the information if need be.

6. Evaluation of Environmental Performance within the Design Process

Supply chains take many different things into consideration. However, their primary consideration is focused on the processing of raw materials to help create the products and other types of packages that end consumers require. Product development focuses on make improvements in the design process; respect is given to cost, manufacturability, and functionality. Even though manufacturers have to consider multiple things when designing products, an increasing focus on design has forced designers to also consider various environmental influences that take place within the design process (Andersen et al., 2009; Jayaraman et al., 2007; Schecterle et al., 2008; Ydstie et al., 2002).

Even though assessing the environmental impact that the operation that a company engages in is meaningful, other effective tools have to be used in order to assist with sustainability. It is difficult for a lot of companies to reach an agreement regarding the index that it needs to support when it comes to assessing their company in regards to the environmental impacts that it has. There are a lot of different scoring and ranking themes that have been imposed to help measure the toxicity and exposure of different chemicals that are used throughout the manufacturing process. The scoring for these schemes differs, based on specific criteria, and algorithms that are used for assessing chemicals (Andersen et al., 2009; Jayaraman et al., 2007; Schecterle et al., 2008; Ydstie et al., 2002). Because there is no general environmental assessment system that is set into place, there have been many different metrics that have been developed overtime to assist with assessing the environmental impact that different chemicals have.

Most literary pieces emphasize the concept that designs for products need to be environmentally conscious. Different methodologies need to be adopted with a focus on minimizing (i) resource and energy consumption, (ii) release of pollutants into the air, (iii) generated amounts of waste, (iv) contributing environmental issues, (v) the impact of the environment are all taken into consideration. Having to determine a suitable means to assess the environmental impact of a product or process is a vital topic that continues to draw the attention of a large quantity of researchers (Karuppiah, 2008).

Traditional life cycle analysis concepts have been extended to life cycle optimization practices that help identify the environmental burdens that exist within each stage of its life cycle. The life cycle of a product is closely associated with a reduction in the amount of environmental burdens that it causes. This methodology is a great tool that helps to assess the burdens that a supply chain addresses in regards to the environmental aspects of product systems from the point of their raw material stage to their final disposal. However, even though this methodology has helped in pointing out specific life cycle changes that can influence products, their production, and their use, this methodology most commonly relates to the early stages of a product life cycle. A lot of the environmental damages that manufactured products cause occur at the end of their life cycle, when disposal methods and waste management methods need to be taken into consideration (Geisler, 2005).

7. Supply Chain Optimization and Globalization Life Cycle Assessments

Globalization of the chemical process industry has created various social and economic issues. Due to globalization, new markets have opened. With these new markets opening up, the standard of living has increased, but so has competition in the marketplace. With the introduction of e-commerce, market efficiencies have increased, but the profit margins have seen a noticeable decrease.

In addition to these challenges, investor demands have also showed a higher increase in the amount of growth, despite the fact that capital has become intensive. Protection and sustainability in regards to the environment will increase in importance for progressing industries. A lot of the raw materials that manufacturing companies use, such as gas, oil, plants and animals, are beginning to deplete at alarmingly high rates. The depletion rate of these natural resources is adversely affecting manufactured goods. Natural resources are depleting faster than they can be replenished.

Also, one thing that many manufacturers fail to realize is that there are contaminants that exist in the raw materials that are used. These contaminants are easily converted into catalysts, byproducts, and solvents that can produce environmental waste. Another aspect that has caused concern to increase is regarding the effects that increased amounts of carbon dioxide are having on the environment. Estimates proclaim that the level of carbon dioxide that appears in the atmosphere has increased by a third, since the industrial age saw its first boom. This increase has affected global warming potential by 73%.

Another aspect that is cause for concern is the way that water is being managed. Water management is expected to become a primary concern within this present century. All manufacturers that manufacturer chemicals have made a pledge to only provide products that are deemed harmless to the living occupants in the world, as well as to the environment. Something that is closely related to the environmental impact of production is energy challenges.

Presently, 85-90% of the energy that the world has is obtained from burning fossil fuels. However, this strategy is supposed to change in the near future. Alternative energy sources are currently on the rise. Wind and solar energy are the two primary alternative energy sources being utilized, because of their accessibility to convert natural resources into electricity. Further studies are being combated to help come up with an efficient way to manufacturer low cost drugs that will fight some of the world's deadliest diseases, such as AIDS.

Enterprise and exercising supply chain optimization is one area that has gained an immense amount of attention within the manufacturing industry as well as the academia realm. Even though most of the applications in this area are focused on processing commodities, there are also applications and specialties that are focusing their attention on two other influential markets, the food industry and pharmaceuticals. Even though work is progressing forward in these sectors, there is still more work that needs to be accomplished in optimizing these two human influential markets (Linninger, 2001).

What has come to become known as the global life cycle assessment is supporting the idea that reasonable care exercised by the chemical industry is going to require a development of systematic tools and methods in order to coincide with its design of creating products and processes that are environmentally benign. There has been a lot of progress that has been made along the processing level in regards to optimization and synthesis of water networks. Additional progress has been made to help bring some light to implications that take place at the waste levels (Ahmetovicˇı, Martin, & Grossmann, 2010).

Despite all of the work that has been put into establishing all of these processes, there has not been a lot of work that has been put into assessing environmental implications that occur along the product design level and the initial integration of processing (Venkatsubramanian et al., 2003; Westerberg et al., 2000). The designing stage of utilizing environmentally sound solvents that are benign in their design has advanced. However, there will need to be broader approaches adopted when assessing the life cycle of processes and products, allowing accurate long term sustainability predictions to be drawn (Maravelias et al., 2004; Masini et al., 2003; Mendez et al., 2003).

8. PSE Tools and Methods

An important approach that will benefit the product discovery and product design stage along with integrating the aspects of global life assessment and supply chain optimization is going to involve finding solutions to a plethora of challenging issues (Venkatsubramanian et al., 2003; Westerberg et al., 2000). One of the biggest challenging issues includes being able to properly integrate the multiple parts of a chemical supply chain.

According to Badell et al. (2001), the financial trends, increases in technology, and issues that are being faced in job placement, indicate that in order for industries to be able to support value growth and value preservation within the process industry, new advances from PSE in three vital areas needs to occur. These three areas that need to see new advances are enterprise and supply chain optimization, product discovery as well as the product design stage, and proper analysis of the globe life cycle (Venkatsubramanian et al., 2003; Westerberg et al., 2000). To continue to make progress in these areas continued work executing the basic methods and tools in PSE need to be exercised as it was concluded by Grossmann and Guillén-Gosálbez (2010). While this conclusion does not come as a shock to most manufacturers, there are a few observations that can be drawn from the data presented:

1) Shifting to product design is one change that is welcomed to help support PSE emphasized value growth (Venkatsubramanian et al., 2003; Westerberg et al., 2000). However, this shift should not rule out the importance of process design, which is one of the core capabilities of chemical engineers within the PSE model. To support further discoveries, it is vital to correctly connect molecular design levels with properties that exist within the macroscopic design level.

2) Supply chain optimization along with enterprise offers a unique place for PSE, given the fact that it has a significant impact to the value preservation portion of the industry, which has seen an immense amount of

competition. Supply chain optimization provides an opportunity for value growth within influential pharmaceutical industries.

3) Even though high importance has been given to environmental issues and sustainability, research efforts from a PSE perspective have been scarce. A more creative approach is needed to help ensure proactive growth. One opportunity may be to engage in process intensification as a means to help revolutionize chemically based plants. Another opportunity that exists is being able to create a stronger interaction when it comes to the product phases and design phases that are part of the life cycle analysis in regards to chemicals.

4) There are a lot of exciting and potential possibilities within the biological research fields within PSE. But, industrial growth will not become so extensive that it becomes the primary focus of all PSE research that is conducted. Areas such as the electronic area have not received a lot of attention from the PSE community, even though there are a plethora of chemical engineers that have been employed with the industry (Maravelias et al., 2004; Masini et al., 2003; Mendez et al., 2003).

5) Since a lot of PSE tools have shown computational issues, temptation may force people to believe that the only thing that is needed is faster and more advanced computing systems. Even though these two developments will have an impact, breakthroughs will only come when synergy and new theories have occurred within MILP and LP optimization. It is important that new research efforts for the new millennium are emphasizing the correct points to ensure positive growth for the future.

9. The Effects of Green Supply Chain Management

Green supply chain management, which is commonly used in its acronym term GSCM is an environmental innovative tool that combines environmental concerns with supply chain management schemes. GSCM has increased in popularity, both from a practitioner point of view, as well as from an academic standard. Many newly developing countries, such as Malaysia are incorporating this type of supply chain management method into their growing economy.

However, even though economic growth is meant to be a positive thing, it can have negative effects on the environment. With increased economic growth, the levels of energy and materials consumption increases. This helps contribute to resource depletion issues and other environmental issues. Organizations that are facing a lot of competition within the marketplace are being reprimanded that they must be able to successfully balance environmental performance expectations with economic performance expectations (Maravelias et al., 2004; Masini et al., 2003; Mendez et al., 2003).

As a response, there are a lot of businesses that are choosing to go green, showing the world that they have a concern for environmental sustainability. The benefits of green technology are being acknowledged by companies choosing to take this proactive approach. Green supply chain management is emerging as a systematic approach within supply chain management. Its practices are being accepted all over the world, and practiced by companies that want to surpass the typical product life cycle requirements set forth by organizations before them.

We review over some of the literary works that exist in respects to GSCM. Extra focus is given to (i) minimizing waste and recovering energy, (ii) recovery of products with a focus on remanufacturing and recycling. Taking into account the environmental concerns that exist within sustainable supply chains is also admonished.

10. How Sustainable Supply Chains Affect Waste Management and Energy Efficiency

Environmental trends have been created to address the need for decision making while the process synthesis phase is being carried out. The efficiency of how processes are executed is closely related to the process synthesis phase. Solutions to subproblems, such as preventing pollution, minimizing energy, and decreasing freshwater consumption can all be integrated into the process synthesis phase to help counteract the environmental impacts of manufacturing.

Although minimizing the amount of energy that is consumed will not instantly result in minimizing the impact that utility systems have on the environment, it is a start. Implementing minimum targets for the amount of flue gases being used within utility systems and changing fuels can help decrease overall energy consumptive levels.

11. Water Management Principles within SCM

Water management and conservation has risen as an important objective for industrial organizations. Conservation of this natural resource will contribute to conversation of other natural resources, while reducing negative impacts on the environment. With water recycling and reusing strategies being implemented, water consumption has reducing. Reducing water consumption is extremely important in remote areas where this natural resource has to be trucked in as per (Chew, 2009).

Production strategies to produce cleaner water have helped promote the reduction method, and have decreased the amount of waste water. Additional practices such as setting up specialized water networks for the successful transport of water to desolate locations are increasing in efficiency. Theoretic approaches are being developed to help decrease any conflicting interests that participants may have during the construction of these water networks. All of the studies that are being conducted in regards to water management have demonstrated the need for industries to make improvements in regards to the environmental performance through conserving resources and minimizing water, but also in the midst of it all being able to maintain financial viability (Chew, 2009).

12. Current Sustainable Supply Chain Management Practices

The amount of corporate and academic interest in regards to supply chain management has increased significantly within recent years. The requirement to measure the impact that products have on the environment has led to a wide array of methods to measure their effect. These tools range from simple instruments to more advanced instruments that are designed to focus on specific environmental issues. Some complete methods even pose an immense amount of consideration into the life cycle of a product.

Research efforts are more focused towards the product end life, along with the early stages of process development. Other research is geared towards different environmentally conscious approaches to product recovery efforts and remanufacturing. Reverse logistic studies focus on the location to allocation methods. Further research should focus on other issues relating to beginning and end products within the product life cycle, such things as marketing and technology.

Even though there are now clear classification systems that are set up to assist manufacturers will figuring out the most suitable techniques to adopt during the life cycle of product development, selecting the right type of application to use to complete this process is still difficult to do. The academia and industrial industries are adding increased emphasis on the importance of proper waste disposal. However, other sustainability concerns that exist are not being thoroughly researched by either sector.

There are a lot of companies that have already been attempting to actively reduce the impact that their products are having on the environment through introducing new products and sustainable processes throughout the life cycle of their products. Academics that are related to the practices that industrial organizations are beginning to introduce will require further research to be conducted, to help assist in the progression of the industry, as it continues to focus its attention on environmentally conscious designing processes (Maravelias et al., 2004; Masini et al., 2003; Mendez et al., 2003).

13. Challenges

Due to the increasing environmental control costs that are being imposed upon the industrial industry, industries are beginning to embrace the need to minimize the environmental impact that process design and supply management have on the environment as a whole. Aside from the challenges that have been imposed by the economic optimization of processes standard, several other issues that are associated with including environmental impacts in SCM will require further attention (Chew, 2009; Hatzimaikatis, 2000).

One solution is to treat the environmental issues as a constraint. The problem that arises from doing this is the solution may not entirely address the environmental concerns that the public and the remaining portion of the market have. Environmental issues may be treated as an objective for designs to help overcome the multi-objective issues that exist. Adopting strategies that consider environmental concerns as design objectives will help lead to improved economic performance, as well as improved environmental performance (Gunasekera, 2003).

Different sources that are related to the process synthesizing phase have an impact on the environmental analysis outcome. There are several aspects of uncertainty that exist. These aspects of uncertainty include: (i) Inventory of waste generation and emissions, (ii) uncertainties with product life cycles, (iii) the transport and collection of products that are at the end of their product life cycle.

Even though there are many different tools that have recently been developed to help integrate environmental aspects within the design process, the implementation of these tools is scarce, and many case studies regarding the utilization of these tools are not based on any realistic systems or verifiable evidence. A lot of the techniques that exist are not being adopted by a majority of businesses, because of their complexity, the time that goes into implementing them, and the lack of environmental knowledge surrounding them (Morari, 2001).

14. Conclusions

The industries focus on sustainability has directly resulted in a need for properly integrating positive environmental choices into supply chain management practice and research. Although mathematical programming within GrSCM offers industries the ability of performing process operations simultaneously with regards to environmental issues, applications of the techniques is restricted due to the difficulties that can arise when large problems are being dealt with.

Within the supply chain management scheme it is apparent that progress has been made, and will probably continue being made when it comes to incorporating different models in regards to the environmental impacts that exist within multi-objective frameworks. However, there is still a list of challenges that still exist in being able to properly account for uncertainties that are a direct result of these models.

Some of the popular approaches that are being taken into consideration to help deal with the list of uncertainties come in the form of robust optimization, simulations, sensitivity analysis, and stochastic programming. Different developments within the stochastic methods are capable of helping to capture the effects of these varying models. This should be considered when regarding additional and future research on this subject.

Being able to appropriately define performance measures for accuracy and efficiency of network operations is also a primary challenge that will need some addressing when coming up with new modeling systems that will be adopted as a solution technique for supply chain management. As mentioned previously, a lot of sustainable decision making is being made by considering only one of the previously described approaches (i.e. production planning, inventory management, product recovery, and more).

Integrated methodologies that combine two or more of these vital principals will need to be examined further by academics and the industrial community. The only way for the industrial community to move forward, while also adopting the environmental impact creeds that have come to be is to be able to have a more realistic analysis of how all of the systems that they utilize are used. Further investigations will need to continue to be carried out to be able to find the perfect equilibrium that will effectively combine sustainable supply chain management, green supply chain management, and product life cycles together.

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