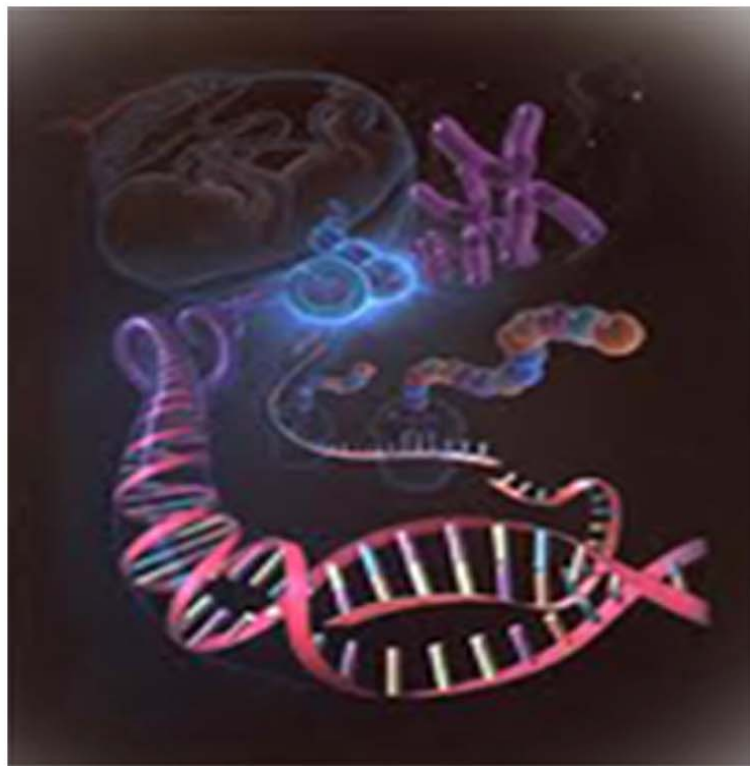




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Review Article

DESIGN OF SUSTAINABLE CHEMICAL PROCESSES AND SUPPLY CHAIN MANAGEMENT SYSTEM

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For the overall growth and development of any multinational company the overall parity from the standpoint of social, environmental and economic considerations is of paramount value and this is because this cultivation helps in rapid growing in awareness in providing sustainable optimal design and neat planning in the process of supply chain. In order to meet up these objectives significant research works has already been done and is still going on so that it can be sustained for a prolonged period of time. Notable approaches that have been taken during this tenure are inventory management, designing of product and planning and proper control in manufacturing capabilities, recovery of the goods, application of reverse logistics technique and more so the application of closed-loop supply chain management has gained. The primary objective of this research is to review the ongoing research activities that are going on with the view of wholesome development and significant improvement in the existing chemical processes and supply chain management process. In this research, the trio areas of focus are respectively (1) Quest for improving supply chain management system so that the energy efficiency of an organization can be augmented. (2) The supply chain management processes that are going to be developed are critically analyzed from the consideration of environmental standpoint. (3) Adequate storage of water resources since for steady running of any chemical industry proficient supply of water is mandatory. This research is an endeavor to summarize the future challenges and scope underlying the betterment of chemical industries from the perspective optimal designing and proper supply chain management technology development and the related opportunities in this regard is also being taken into consideration.

Keywords: Sustainable Chemical Processes, Biotechnology, Green Supply Chain management System, Environmental impact

INTRODUCTION

Environmental impact from the perspective of process designing and supply chain management is an important issue these days and as a result of which major focus has to be given so

that the environmental impact can be lessened in some way or the other. The focus has now been shifted to some extent from a fixed cost based approach to a broader one keeping in mind the long term sustainability factor

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The need is to balance social, environmental and economic objectives in a sustainable manner so that awareness can be grown in this aspect and long term sustainability of the processes being designed can be achieved. So, significant amount of research work is now being put into sustainable business practice development and also talk is on regarding the new rules and regulations that are going to be enforced once the new design is put into the market. The pact between environmental management and Supply chain management has given birth to a new form of supply chain management known as Green supply chain management (GrSCM). The primary importance of GrSCM is derived from the concern over ever deterioration of our environment by various forms of pollution that does not require any more mention this point in time and beside this there is also tremendous amount of pressure from the customer end so as to integrate sound reforming in the management of newer processes and supply chain management system and relevant practices.

Proper designing of supply chain management is determined by factors like the number and also the primary location-chosen for development purposes and the capacity is also needs to be checked at every facilitation centers since these two factors determine the amount of assignment that the processes are going to get from the market. On top of this, the GrSCM has come up with few more plans like 1) incorporation of green design, 2) greener operational practices in the designing and development of supply chain management system. However, the major aspects that must be taken into consideration here are 1) treatment of wastes that is going to generate from the process plants 2) efficient utilization of energy sources 3) restriction on

emission of green house gases 4) efficient work around with available capacities and resources and 5) working being within the laws concerning the environmental aspects.

Already a number of approaches have been proposed in various literatures so as to cut down the energy and resources consumption in the chemical plants. Cano-Ruiz and McRae (1998) has come up with a new design practice in order to mitigate environmental concerns. As per them the main problem with a good number of design processes today is that they primarily focuses on the process manufacturing aspects and thereby the scope gets narrowed. Different approaches like product recovery, reverse logistics and closed loop supply chain processes have gained good amount of praise in the literature reviews. There are primarily twelve principles for better designing of sustainable chemical processes as mentioned underneath:-

- 1. Prevention:** better to take preventive measure earlier so that waste generation is lessened with special emphasis to biotechnological processes and Pharmaceutical manufacturing.
- 2. Atom Economy:** utmost stress need to be put on atom economy to design synthetic processes.
- 3. Less Hazardous Chemical Syntheses:** usage and production of hazardous chemicals need to be brought down considerably.
- 4. Designing Safer Chemicals:** proper stress needs to be put on this aspect.
- 5. Safer Solvents and Auxiliaries:** lesser amount of solvent and related substances should be used in chemical reactions so as to minimize environmental impact.
- 6. Design for Energy Efficiency:** energy requirements of the chemical processes needs

to be optimized so as to minimize environmental and economic impacts and should be minimized.

7. Use of Renewable Feedstock's: focus needs to be shifted from the dependency on fossil fuels towards renewable sources of energy.

8. Reduce Derivatives: derivatives coming out as a by-product out of the chemical process industries needs to be cut down any way by changing the processes by means of proper design consideration and process optimization.

9. Catalysis: it is known that catalytic reagents are superior to normal ones so their use has to be incremented.

10. Design for Degradation: the newer chemical processes needs to be designed in manner so that the products are bio-degradable.

11. Real-time analysis for Pollution Prevention: There has to be provision for real time analysis of pollutants percentages and proper this needs to be put in this regard since this factor is very urgent from the consideration of environment.

12. Inherently Safer Chemistry for Accident Prevention: in chemical processes the safer chemical substances need to be chosen so as to be minimizing the risk of accident.

ASSESSING ENVIRONMENTAL PERFORMANCES OF DESIGN PROCESSES

The need of the supply chain is to process the raw materials to ultimate end product and services packages. These days development of products aims to better the designing of end products from the aspect of cost, functionality and manufacturing but there is also peer pressure from the perspective of sustainable process designing criteria that forces designers to consider

the probable impacts of the design processes on the environment.

Now, it is easy to go on assessing the environmental impacts that comes up from the operational design of a chemical process for any company but then there is also significant amount of difficulties involved in reaching to some agreement with regards to the index that would provide with positive hint towards the growth of successful assessment of the environment.

A good number of different ranking and scoring schemes have already been proposed to gauge the long term effect of chemicals by measuring their toxicity and exposure (Davis *et al.*, 1994). However, these various schemes differ widely in the manner of their criteria for scoring, decision rules and the associated algorithms that are utilized for risk assessment of chemicals. Naturally, it is the deficiency of a general environmental stress assessment system that has augmented the growth with regards to the development of newer metrics so as to measure the performance.

Proper emphasis need to be put on for designing environmentally safer design of chemical processes where methodologies for lessening of (1) energy and resource consumption; (2) check on the abundant emission of pollutants; (3) generation of waste mass is limited; (4) overall indicators for betterment of environment or at least lesser chances of the environment of getting polluted is there. Presence of a suitable metric system so as to gauge the performance of a process or design products has always remained an important aspect from the standpoint of optimum environmentally safe process design and hence has caught the attention of many researchers.

Of late, several systematic methods have been made available to the market and the primary use of this is to scrutinize the quotidian characteristics of the pollutants coming out of the chemical process industries. Some of these examples are noteworthy and hence cited as “the Life Cycle Assessment (LCA)” (Lou, Kulkarni, Singh, & Hopper, 2004), “the minimum environmental impact (MEI) methodology” (Stefanis *et al.*, 2003), the WASTE Reduction (WAR) algorithm (Young and Cabezas, 1999), “the environmental fate and risk assessment tool (EFRAT)” (Achour *et al.*, 2005), “the atmospheric hazard index (AHI)” (Gunasekera and Edwards, 2003) and “the thermodynamic analysis method” (Bakshi, 2002; Hau *et al.*, 2007).

Now days, the life cycle assessment tool is being used widely as a quantitative tool in industrial ecology so as to provide a systematic accountability of the burdens of environment and the probable impacts that may come up from development of the chemical products through its life cycle that is processing of raw materials, manufacturing, distribution and use. The scope of LCA is composed starting from compilation of the inventory of all relevant inputs as well as the outputs of a product or system and proper characterization of all raw materials going into the chemical processes.

Recently the traditional concept of life cycle analysis has been extended towards the optimization of life cycle management that correctly help in identifying the best practices for lessening environmental impacts at various stages of life cycle.

GREEN SUPPLY CHAIN MANAGEMENT

Green Supply Chain Management (GSCM) has

risen to the market as a potential solution to the aspects of environmental innovation and it also binds the associated concerns related to the environment. It is of choice these days from the both ends of academic and practitioners but there is some deficiency in proper examining so as to adopt and enforcement of GSCM best practices in the developing countries yet.

Now, it has become increasing important for industries related to chemical processes to contribute to the burning environmental issues and to the problems of ever depleting energy resources and therefore there is competition in the market and also communal pressure to balance the growth from the standpoint of both economic and environmental aspects. As a obvious outcome of which most of the organizations today are bending towards the voice of going green that concerns the sustainability of the environment. Gradually, they have been able to understand the deeper concern of the society and hence they have adopted considerable alteration in the chemical processes and so also in their business strategy and planning and infact now the Green supply chain Management emerges as a new systematic environmental approach in the arena of supply chain management and is being accepted increasing more and more by the business persons and is becoming a primary subject of research these days from the organizations that believe in forward thinking.

It is of no doubt that economic growth raises the amount of energy and material consumption that primarily contributing to the environmental issues and also the problem of ever depleting energy resources so it is important to integrate the practices being used in managing the concerns related to environment into a

wholesome supply chain management system where there is a bigger opportunity in the growth of the completion and also to raise the profit margin from the perspective of business growth is present.

The definitions of GSCM are many. Accordingly, Zhu and Sarkis defines GSCM as has ranged from green purchasing to integrated supply chains starting from supplier, to manufacturer, to customer and reverse logistics, which is "closing the loop". GSCM can be thought of an integrated thinking that primarily focuses on mitigating the issues with regards to environment by proper design improvement in the chemical processes, source of material selection and proper dispatch of the end product to the consumer end as well as proper management of the end life measure of the end product so as to ultimately gauge the overall environmental burden. The developed countries, as they have high value of human development index, should contribute profusely in dealing with the causes of the environmental issues and the problem with regards to the depletion of our chemical and energy resources and this is reason for which a number of researchers are actually conducting their research work in the developed countries so as to ascertain the integration aspect for the environmental integrity and proper functioning of supply chain management process designing. Sustainability not only require proper integration of business processes that extend beyond the core aspects of supply chain management but also augers to the designing of products, manufacturing of them and characterization of the by-products generated from the chemical processes so as to be at per with the aspect of environmental principles. It is also necessary to make sure that energy conservation and waste

management throughout all the phases of the supply chain management system.

SUSTAINABLE SUPPLY CHAINS WITH RESPECT TO ENERGY EFFICIENCY AND WASTE MANAGEMENT

The current trends have created the necessity for a sustainable system where a supply chain management system can e built up that can help in augmenting the efficiency of the chemical processes related to the process industries and also can potentially contribute to the burning issues of minimizing of pollutants generation in the form of green house gases (like carbon dioxide, Nox, etc).

Environmentally Sustainable Supply Chains

It has always remained the primary focus of study and research that is the development of environmentally sustainable supply chain management system and as is the case a number of studies on the proper designing and functioning of a supply chain management system has been on progress. This has the power to maximize the profit margin of the company if properly designed and implemented keeling in mind all the environmental aspects.

Hugo and Pistikopoulos (Hugo and Pistikopoulos, 2005) develop a multi-objective mixed-integer model for deciding location and capacity expansion of facilities (plants), and transportation issues in a given planning horizon. They have demonstrated how to maximize profit and minimize the environmental impact of the plant operations using the knowledge of LCA criteria but also at the same time satisfaction of the market demand is also achieved. It goes to show

the major challenges and recent improvement in the process industries from the aspect of bettering of supply chain management and augmenting the growth of the chemical process industries keeping a tab on all the potential environmental concerns.

SUSTAINABLE WATER MANAGEMENT IN SCM

The conservation of water and its proper management is a matter of real concern today and it gains the objective of the primary industries in the Nation since they also primarily depend on fresh supply of good amount of water for the running of the chemical process industries and hence the proper water recycling system development and reuse functionalities development should be designers major cause of concern and this is especially vital for those sites where the areas are located in remote and good source of water is also a scarce.

The Water allocation problem has been therefore being researched and studied effectively to mitigate the burning problems that arise from the poor management of our water resources.

Takama, Kuriyama *et al.* (1980) have proposed a mathematical model for the optimal utilization of water allocation in a petroleum refinery. They remained the first to formulate and ascertain the optimum water allocation problem that includes both water using and wastewater treatment processes in petrochemical refinery and from that point of time onwards the proper use of mathematical programming models has gone up shapely and this is also due to the inability of the graphical measurement system that was used earlier for monitoring purposes.

PROCESS CHALLENGES

The ever increasing cost to control the

environmental concerns and recent enforcement of strict regulatory action with regards to the disposal of the chemical wastes tremendously impacted the smooth functioning of chemical process industries and supply chain management system. One approach of solution in this regard is to treat the environmental issues as the constraints that needed to be disposed off but again the main problem with this also is that the solution that are going to be proposed may not properly address the potential environmental problems of these days so rather than tracking it as single forms more focus needs to be given by treating the environmental objectives and concerns as the primary forms of design objectives during the designing phases of the chemical process industries but again this method of looking at the problem may seem to attract attention and seem to be promising but yet the proper designing of such a system by keeping in consideration of all the environmental as well as the design parameters is going to be a daunting task and a real challenge for the designers of the process industries and more than that the final implementation of such a process requires skillful quantification and implementation of environmental aspects in real world by proper design consideration and tracing the cost factor side by side. (for example, small improvements in energy and waste are often very costly).

So, it becomes quite clear that the proper designing and Selection of appropriate performance indicators is a matter of skillful management of the resources that are available at hand and also their proper implementation at work by utmost application of the design considerations.

CONCLUSION

The need of sustainable process development keeping in mind all the process and environmental issues has ultimately accelerated the growth of integrating sound choices for environmentally viable options into supply chain management study and research practices. This is not all even the applicability of mathematical programming is being thoroughly scanned for better designing and optimization of energy resources and being at par with the environmental aspects but till date the actual application of these in solving bigger problems is restricted to some extent due to the restricted arising out of the difficulties in numeric computation while working on large scale issues.

It is quite evident that from the perspective of improvement in SCM system a lot of work has already been done and still researchers are working hard to bring out the best models that would provide even lesser impact on the environment and simultaneously going to fulfill bigger issues in the chemical process industries although there are challenges still present from the standpoint of proper accountability of the uncertainties which always lies there during any kind of process improvement or revocation. One of the most popular approach can be thought of a possible work around to deal with this uncertainty issue is to put stress on stochastic programming since it help in robust optimization and sensitivity analysis and so the development of stochastic methods that are capable of capturing the effects of these variations should be taken into consideration with immediate effect for future research works.

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