Optimization Approach in Closed Loop Green Supply Chain Management: A Case of Indian Company

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Abstract

The green supply chain management has been emerging as an important new innovation that is being used by organizations to develop strategies in order to achieve objectives worldwide. Green supply chain management is popularly regarded as a management mode that comprehensively addresses environmental influences and utilization of resource efficiently. Organizations are using the issues of GSCM as an opportunity to be seized in demonstrating their good practice in terms of the green agenda. Environment concerns have put organizations under great pressure to take back their manufactured product/products after its usage, so that the product or its parts may be reused, recycled or appropriately disposed of.Closed-loop supply chain management is an efficient, effective and economical strategy aimed at sustaining environmental practices in the manufacturing industries.Logistics network of returned goods from end users back to manufacturers usually involves multiple and conflicting goals.Technological advances, economic activities and prosperity demand for mobility of goods and people from one part of the globe to another. Increased mobility demands for increased transport, which leads to increased issues of fuel-efficient driving, CO2 emissions and challenges of minimizing carbon footprint. As these emissions have strong impacts on climatic change in our world, on humans, on food production, on the sea, on every things so ensuring sustainable growth has therefore become an important and complex challenge for the organization around the globe.

This paper examines the relationship between the operations of forward and reverse logistics and the environmental performance measures like CO_2 emission in the network due to transportation activities in closed loop supply chain network design with the location selection optimization in order to integrate the environmental issues into a traditional logistic system.

So, we present an integrated and a generalized closed-loop network design, consisting of four echelons in forward direction (i.e., suppliers, plants, and distribution centres, first customer zone) and four echelons in backward direction (i.e., collection centres, dismantlers, disposal centres and second customer zone) for the logistics planning by formulating a cyclic logistics network problem. The model presented is bi-objective and captures the trade-offs between various costs inherent in the network and of emission of greenhouse gas CO_2.

Model is validated through a real life case, based on electric home appliance manufacturer based in Delhi and NCR and the result shows that the proposed model is able to support the logistics decisions in a closed loop supply chain efficiently and accurately.

Keywords: Green Supply Chain Management, Carbon emission, Closed loop supply chain management.

1. Introduction

Our planet is metamorphosing from a land of abundant and affordable source of energy to a world of polluted, scarce and immoderate or uneconomical energy. It is imperative for its inhabitant to become aware about the challenges and the repercussions they have to face in case of impending energy shortage scenario. The scarcity of resources, global warming and pollution are attention needing issues these days. Stakeholders are becoming interested in what companies do to greenify their supply chain to have sustainable business. This requires definite and conscious interventions to be taken in order to keep our system and its processes under control. Supply chains becoming complex and business environment is changing with enormous speed. Though India is still a developing nation, it is keen on maintaining a balance with environmental protection; hence it has increased its emphasis on economic development. This balancing act, very importantly includes India's manufacturing industry and supply chains. Every organization in the system may be big or small is engaged in activities which demand the consumption of energy and resources. There is constant demand of energy and resources and that too at an affordable price and for which the supply seems deficient. This requires the attention of logistics and supply chain managers to protect and preserve lead resources; to balance efforts to reduce costs for the maintenance of good environmental (ecological) performance.Most of the modern organizations are contemplating the integration of environmental practices compulsory regulations, voluntary environmental programs into their strategic plans and daily operations(Pagell , Yang , Krumwiede, and Sheu 2004).

1.1Green Supply Chain Management:

Although an objective of every business is to maximize profit, in order to survive in today's economic climate, organizations have to take serious considerations of sustainability issues for the continuous supply of resources required to produce products and fulfill demands. Imminent threat of global warming has drawn the attention of researchers towards green supply chain management (GSCM). Green Chain management is the inclusion of environmental concerns into our supply chain management right from product design, supplier selection and material sourcing, manufacturing processes product packaging, delivery of the product to the consumers, and end-of-life management of the product after its use (Srivastava 2007 ; Beamen 1999; Zhang *et al.*1997;Lintona*et al*. 2007). Detailed planning and execution of our entire supply chain right from the beginning of a green product design to a closed loop product return processing, is essential for the success of Green supply chain. The study of GSCM has helped the firms in creating value in supply chain relationships by increasing the benefits of the product for the customers, reducing the costs of the product, improving delivery service, or reducing the time of delivery (Christopher, 2005;Ulaga, and Eggert, 2006).

1.2SustainableManagement:

Sustainable businesses have become the prime topics of discussion among the government, customers and organization due to awareness about green and sustainable environment. The contribution of sustainability in supply chain management is enormous, especially when it minimizes the carbon emission renewable energy, and management of waste to avoid landfills and incinerations. Looking at the current situations of resource scarcity , exhausted land for landfills , and the pressures to reduce the carbon footprints globally , sustainability efforts are no longer optional or un important (Srivastava 2007). By injecting sustainability into the core business, a firm can achieve full efficiency and educed environmental impact. In fact, green supply chain management (GSCM) has become a great concern for business organizations, particularly in logistics in the 21st century (Diabat and Govindan 2011). This is largely due to the stringent laws and regulations governing the product take back such as the introduction of Waste Electrical and Electronic Equipment (WEEE) directive (Prahinski , C. and C. Kocabasoglu 2006). In addition, countries across Asia are a little bit slow in responding to the sustainability concerns (Johannesburg Summit, 2002).

1.3 Reverse Logistics:

Social and environmental activists, government legislations and awareness campaigns are forcing organizations to supply environmentally harmonious products and at the same time also to be more responsible for the returned products.We need to adopt the concept of 'reuse and remanufacture the used product' or in other words Gr. SCM, in order to economize the consumption of resources. Kannan , Sasikumar, and Devika(2010) reducing their carbon emissions with the help of green supply chain has gained importance among other issues for the firms and their customers (52). In 1987, the Brundtland Commission defined the term 'sustainable development' as the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

Looking at the definition, given by Zhu and Sarkis, (2006) environmental impacts takes place at all stages of a product's life cycle from the raw material extraction to manufacturing, use and reuse, final recycling, or disposal, namely from cradle to grave appears that the ultimate objective of environment protection can be achieved through CLSCs (Andiç , Yurt, and Baltacıoğlu2012).

Hence, the sustainability endeavours are pushing the organizations to seriously consider the application of the CLSC concept (Beamon 1999 and Seuring 2004).The emerging of sustainable supply chain demands required an identification of the closed-loop supply chain model (Solvang, Deng, and Solvang 2007). The sustainability approach seeks to combine the present industrial development with the requirements of future generations (Wilkinson *et al.*, 2001).

A GrSC aims at confining the waste within the industrial system in order to conserve energy and to prevent the dissipation of dangerous materials into the environment (Johnny *et al*. 2009). Its clear that there is a focus for GrSCM which range from reactive monitoring of general environmental management programs to more proactive practices such as Re's (e.g recycling, reclamation , remanufacturing , reverse logistics) of environmental management and incorporating "innovations". A GrSC aims at confining the waste within the industrial system in order to conserve energy and to prevent the dissipation of dangerous materials into the environment (Johnny *et al*. 2009).

1.4 Closed Loop Supply Chain Management

The concept of GSCM requires the organizations to extend the 'forward supply chain' one step further up to the collection, dismantling, reworking, material extraction and proper disposal of products ,which is achieved through processes such as repair, remanufacturing and recycling, which, combined with all the associated transportation and distribution operations, are collectively termed asReverse Chain activities. In reverse logistics there is a link between the market that releases used products and the market for ''new" products. When these two markets coincide, it is called Closed Loop Network(Krikke*et al.* 2004). Thus the supply chain in which forward and reverse supply chain activities are integrated is said to be closed-loop, and research on such chains have given rise to the field of closed-loop supply chains ,CLSCs, and this process alternatively is known as closed loop supply chain management ,CLSCM.Closed-Loop Supply Chain Management includes processes and operations that can not be found in conventional supply chain management. Guide and Van Wassenhove (2003) further add that the additional activities the reverse supply chain includes comprise product acquisition, reverse logistics, test, sort, disposition, refurbish as well as distribution and marketing. CLSC is therefore seen as a strategy towards achieving a green supply chain (Olugu and Wong 2012).

CLSCs can be defined as the integration of forward and reverse logistics whereby the returned products are recovered and reinserted back into traditional forward flow , establishing a continuous supply loop (Wells and Seitz 2005) that aims for economic , environmental, and social accomplishments(Giovanni 2011) . By looking at the definition, it appears that the ultimate objective of environmental protection can be achieved through CLSCs (Andiç ,Yurt, and Baltacıoğlu 2012).

Aclosed-loop logistics management ensures the least waste of the materials by following the cradle to cradle principle and conservation law along the life cycles of the materials. In reverse logistics used products, either under warranty or at the end of use or at the end of lease are taken back, so that the products or their parts are appropriately disposed, recycled, reused or remanufactured. In closed-loop supply chain, the original equipment manufacturer (OEM) collects used products from customers and further processes them to the dismantlers to do the sorting or the disassembling for recovery, reuse or disposal (Rogers andLembke1999) to make a profit or reduce their environmental impacts. Closed-loop logistics comprises of two parts: forward logistics and reverse logistics, the product recovery is reverse logistics .Roger and Timber- Lembke (1999) define reverse logistics as , “The process of planning, implementing, and controlling the efficient ,cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin, for the purpose of recapturing value or proper disposal’. Reverse logistics options consist of reuse, resale, repair, refurbishing, remanufacturing, cannibalization, and recycling (Krikke ,Bloemhof-Ruwaard , Wassenhove2003). With well-managed reverse logistics, 3*R* of *r*educe, *r*ecovery and *r*euse for environmental protection can be achieved with cost savings in procurement, disposal and transportation (Fleischmann ,Beullens , Bloemhof-ruwaard,and Wassenhove2001).The design of reverse logistics network has been subject to recent research. Due to the differences in the characteristics of flow between the forward and reverse channels, the design of reverse logisticsnetwork attracted some of the research effort. Multiple case studies in different fields: automotive industry (Schleiffer, Wollenweber, and Sebastian2004;Schultmann, Zumkeller, and Rentz, 2006), electric appliances industry (De Brito, Flapper, and Dekker 2003;Ciupek, Franke, andSeliger, 2003), paper recycling (Fleischmann, Beullens,Bloemhof-Ruwaard, and Van Wassenhove2001);Chan, Chan and Zhang 2006), carpet recycling (Helm and Harvani2006) have been conducted to the end of designing an efficient reverse network capable of dealing efficiently with the reverse flow to the end of achieving sustainability.Beside it they are explicitly focus on significant sources of greenhouse gas emission, and one of those sources is transportation. CO_2 is very prominent in its hazardous consequences on human health. Transport is the second-largest sector of global CO_2 emission. CO_2 constraints in logistics markets will need to be realized in the near future as it was enforced by protocols, and a shift in freight transportation could be expected to reduce the CO_2 emissions within the reasonable cost and time constraints (Piecyk , Alan and McKinnon 2010).

1.5 Current Focus:

This paper attempts to design a CLSC based Green Supply Chain Management model that would minimize the issues involved with economical and environmental impacts simultaneously, and integrate forward and reverse logistics with the aim of reducing waste.

In this study, we model and analyse a CLSC for its operational and environmental performances, i.e., a multi echelon forward–reverse logistics network model is described for the purpose of design with the reflection of the effects on environment of greenhouse gas emission. Objectives of the model is to maximize the total expected profit earned and minimizing CO_2 emission due to transporting material in forward and reverse logistics networks with the use of different type of vehicles for transport, each of which has its own emission rates and transportation costs. Using the proposed model and a case illustration result of computational experiments shed light on the interactions of various performance indicators, primarily measured by cost and then captures the environmental aspects.

1.6 Green Scenario in Developing Countries:

1.6. 1 Green Production/SCM and Developing Countries:

The concept of green production carries the promise of a new economic growth paradigm that is friendly to the earth's ecosystems and can also contribute to poverty alleviation. Green initiatives adopted by most of the organizations around the globe are playing pivotal role in reversing the climatic changes, in reducing the Greenhouse gas emissions, in preserving the limited natural resources. Organizations around the globe are opting for cradle to cradle products that are more energy efficient and environmental friendly. By implementing practices like recycling, kitchen-waste diversion, waste-disposal, retro-fitting energy efficient lighting, rain-water harvesting, community outreach programs and buying green power, they are trying to reduce the detrimental effects caused by non-sustainable practices.

A large proportion of the population in developing countries lives on under $1 or $2 per day. The poor spend a large proportion of their incomes on food, may lack access to basic infrastructure, and own few productive assets. A third of children under five in developing countries show evidence of long-term malnutrition and are increasingly susceptible to many other diseases. In India, majority of organizations have put in place various initiatives for creating a sustainable environment. This includes not only making employees, suppliers, business partners and customers environmentally-conscious but also encouraging all stakeholders to choose approaches that support sustainable environment. Various regulatory bodies have brought forth innovative practices to have mandatory provisions for protection of the environment. Number of acts and rules for Water (Prevention and Control of Pollution), Air (Prevention and Control of Pollution), Wildlife (Protection), Forest (Conservation), and Environment (Protection), Hazardous Waste (Management & Handling) formulated since 1970 to present day are being implemented.

1.6.2 Green Production/SCM and Competitive advantage:

The overall aim of green production is to minimize the environmental impact of a product's manufacture. Sustainable consumption means satisfying a maximum of consumer needs and wants while minimizing the environmental impacts of products and services. By taking the idea of 'doing more with less', organizations are carefully devising preventive environmental management approaches to renovate their production processes from design and manufacture through use and disposal. Careful analysis is done during the production process to help reduce the environmental impact of individual products over their entire life cycle of design, production, usage, maintenance and developing standard screening processes for final disposal of the product. The focus is on building a sustainable value chain through responsible use of resources by maintaining cordial relationships with suppliers- downstream, upstream and cross-stream for which we may need some expert opinions and advice. In 2003, IFC committed a loan of $75 million to Power links Transmission Limited, a joint-venture company, to construct power transmission lines to carry hydropower from Bhutan to northern and eastern states in India leading to the creation of about 9,700 direct and indirect jobs over the 25-year life of the project. In addition, the second-order growth effects of the increased supply of power and its improved reliability have generated 75,000 jobs from 2006 to 2012, of which 4600 jobs were created in West Bengal.

Due to lack of experts, particularly in developing countries, training programs have not yet caught on and also there is feeble willingness to finance cleaner production due to financial institutions' misconceptions. There is a dire need to encourage shared understanding of problems –not only production issues but also social, environmental and economic challenges.

The scenario is particularly true in the case of agriculture, where green technologies tend to improve the agricultural productivity of rural smallholders. One of the most serious potential effects of global warming is the lower productivity of agriculture in developing countries. For the same reason, however, poor rural communities are also among the main beneficiaries of the green economy. Sustainable agricultural production methods have great mitigation and adaptation potential, particularly with regard to topsoil organic matter fixation, soil fertility and water-holding capacity, and increasing yields in areas with medium to low-input agriculture and in agroforestry.

1.6.3 Green Production/SCM and development advantage to Developing Countries:

Green SCM helps in using alternative renewable resources for becoming self-sufficient, in gaining a competitive edge over the market, in saving money and finally aids us in saving earth from gravest and greatest crisis that has resulted from insensible use of science and technology and has endangered species for our future generations. Many organizations have expanding environmental portfolio which offer relevant answers to the nation's energy and sustainability challenges. Apart from allowing customers to enjoy the benefit of lower energy costs, higher productivity and profitable businesses, the society benefits through improved environmental care and living standards. Many organizations have been continuously working towards improving business process by innovation and feedback for making them more safe and eco-efficient in the usage of resources and management of facilitiesan important measure to promote sustainable development. It includes regulation, pricing policies, taxes and subsidies to limit pollution and emissions and to control over-exploitation of natural resources and making prices better reflect environmental values, as well as mainstreaming environmental criteria in government procurement policies.

'Attero' has developed a recycling technology to extract metals and plastics from e-waste, such as computers and mobile phones. In the process it has created jobs, reduced pollution and conserved metal resources. The organization also focusses on educating low-skilled workers who collect and informally recycle most of India's e-waste. The same scenario can also be seen taking shape in the case of agriculture, where green technologies tend to improve the agricultural productivity of rural smallholders. One of the most serious potential effects of global warming is the lower productivity of agriculture in developing countries. For the same reason, however, poor rural communities are also among the main beneficiaries of the green economy. Sustainable agricultural production methods have great mitigation and adaptation potential, particularly with regard to topsoil organic matter fixation, soil fertility and water-holding capacity, and increasing yields in areas with medium to low-input agriculture and in agroforestry. Many organizations have been continuously working towards improving business process by innovation and feedback for making them more safe and eco-efficient in the usage of resources and management of facilities an important measure to promote sustainable development. It includes regulation, pricing policies, taxes and subsidies to limit pollution and emissions and to control over-exploitation of natural resources and making prices better reflect environmental values, as well as mainstreaming environmental criteria in government procurement policies. The innovative practices adopted by 'Jain Irrigation' have achieved water savings equal to the annual water consumption of more than 10 million households. Through this initiative, 16,300 small farmers have raised annual incomes by up to $1000. Tata Group has also taken initiatives to develop strategy to improve water efficiency in their operations, across 11 Tata group companies. This will set the paradigm of water conservation in industries for India.

1.6.4 Green Production/SCM: Clean and healthy production leads a clean and healthy life

The term "cleaner production" was formally adopted at the Canterbury seminar. It was defined as "the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment"[1.] Cleaner production plays a critical role with respect to influencing changes in consumption and production patterns. Experience with cleaner production programs reveals that a 20% reduction in waste and emissions is achievable with no new investment. A further 10-20% reduction is possible if minor investments are made, with a payback period of less than six months[1.]

Meeting consumer needs and desires, while promoting cleaner production and sustainable consumption, is one of the greatest challenges facing humankind. Addressing poverty and environmental degradation requires changing how goods are produced, distributed and consumed. It also requires conservation and more efficient use of resources such as energy, together with action-oriented thinking. Developing countries around the world need to implement some effective national programs which would include labeling environmental friendly products, programs encouraging cleaner production and schemes involving 'eco management' and 'audit of environment'. Governments of these nations need to introduce principles for concluding voluntary agreements and should prepare a methodology for implementing life-cycle assessment (LCA) for enterprises.

Table 2.2 Differences between developed and less developed countries.

	Developed Countries	Less Developed Countries
Road transport	Higher ownership Cars dominant Higher vehicle kilometres travelled per person Newer fleet, lower emissions Road surfaces maintained	Significantly less car ownership Mixture of two-/three-wheelers Lower vehicle kilometres travelled per person Older fleet, higher emissions Poorly maintained vehicles Low maintenance of local roads
Distribution of sources	Industry normally segregated from residential areas	Industry in close proximity to residential areas
Emissions	Reliable emissions in parts	Large uncertainties, greater understanding is needed
Heating/cooking fuel	Usually gas, electricity, but others used	Coal, wood, oil, biofuels, gas Reliant on local sources
Pollutants of concern	PM_{10}, $PM_{2.5}$, O_3, NO_2	Additional pollutants: SO_2, VOCs and Pb
Infrastructure for air pollution control	Well developed in some regions, stringent	Less developed, fragmented, poorly controlled emissions
Economic	Loose dependence of economy on polluting industry	Strong coupling (e.g. local jobs depend on polluting industry)
Implementation of legislation	Robust	Can be poor
Urban planning, governance	Links becoming stronger	Fragmented, patchy
Pollution monitoring	Well structured in parts	Requires firmer coordination

Source:World Atlas of Atmospheric **Pollution** - Page 20 - Google Books

We take forward this discussion by first evaluating the previous work done by the researchers in this field in the following section. We proceed further to define the problem and focus of our study and propose a model for a single product, with the underlying assumptions and hence present Real life case studyin section 3. Section 4 describes the methodology used for goal programming. In Section 5, we presentthe numerical implementationof real life case study in order to highlight the features of the proposed model. The paper ends with concluding remarks.

2. Literature Review

GSCM is becoming increasingly important for Indian manufacturers due to increased awareness about business and environmental performance and corporate responsibility.Organizations have started focusing their attention on issues like minimizing the generation of hazardous waste, recovery of valuable materials from the waste and preventing the environmental deterioration(Kannan, Sasikumar, Devika.2010). GSCM has been discussed by the researchers in context of problems in the supply chain, like Hazardous waste and sewage spill,industrial waste, carbon emissionor environmental concerns and these issues have highlighted the importance of a proper design of the distribution and reverse logistics network. The design of the distribution and reverse logistics network has to fulfill the different objectives from the economic, social, and environmental perspective(Hamdy**,** Fors, Harraz2007).Recently, customers have attached greater value to less obvious dimensions, such as low-risk supply chains (45), better visibility across supply chain (Wagner and Bode 2008), socially responsible supply chains (Boyd, , Spekman, Kamauff and Werhane 2007), or green supply chains (Neto*et al.*2008). A major issue in the reverse distribution is integration of forward and reverse supply chain. Returns information captured should be integrated with forward supply chain information to achieve optimum planning and reduction of costs. The whole support network can then be designed in such a way that it can service both the forward and reverse logistics processes efficiently. This is in line with the concept of a closed-loop supply chain design. In recent years, there has been increasing interest in closed loop supply chains. Many authors have addressed the issues on closed loop supply chain for different cases.

Collection and recycling of product returns has gained increasing importance as a profitable and sustainable business strategy due to growing green supply chain management concept practices[ ]. Organizations worldwide have adopted different strategies to implement these practices.Verstrepen*et al.* (2007) assumes that a proper supply chain structure has to be formulated to minimize the system-wide cost (or to maximize profit) by best-planned movements of goods within the supply chain as the physical structure of a supply chain clearly will influence its performance, and it is very important to design an efficient supply chain to facilitate the movements of goods.Saman and Guoqing(2012) proposed a network and a mathematical model to maximize the total cost savings by determining the quantity of parts to be processed at each remanufacturing facilities, and the number of purchased parts from external supplier. Salema, P´ovoaand Novais (2007) developed a conceptual model for simultaneous location–allocation of facilities for a cost effective and efficient reverse logistics network. A closed-loop structure of a network was proposed in order to integrate the environmental issues into a traditional logistics system by Kim *et al.* (2006). The researchers proposed an integer linear programming model based on decisions for selecting the places of manufactures, distribution centers, dismantlers and cost with special concerns on operations of 3*R* in the green supply chain logistics and the location selection optimization.Fleischmann, Beullens, and Bloemhof-Ruwaard, and Wassenhove (2001) highlighted the importance of increased segregation at the source and environmental benefits through increased wastepaper recovery by putting the focus onthe formulation of a mixed integer goal programing model for proper management of recycling logistics.Researchers also suggested a model for remanufacturing that determines the location of remanufacturing/distribution facilities, the transhipment, production, and stocking of the optimal quantities of remanufactured products and cores (used parts) recoverable products environmentsFrancas and Minner (2009).Since few studies have addressed the problem of determining the number and location of initial collection points in a multiple time horizon, while determining the desirable holding time for consolidation of returned products into a large shipment, Ulaga, and Eggert (2006) have suggesteda mixed-integer, nonlinear programming model and a genetic algorithm that can solve the reverse logistics problem involving both spatial and temporal consolidation of returned products. A mathematical model has been proposed by Pishvaee , Farahani and Dullaert(2010)for design of a RL network with deterministic parameters in a nine-echelon network for an integrated closed- loop supply chain in which the returned products need to be consolidated in the warehouse before they are sent to reprocessing centres for inspection and dismantling; this model assumes that the dismantled parts are either sent for remanufacturing or to the secondary market as spare parts, or are recycled or simply disposed of.An RL network consisting of collection centers and two types of rework facilities set up by original equipment manufacturers (OEMs) or their consortia for a few categories of product returns under various strategic, operational and customer service constraints in the Indian context has been discussed by Pati , Vrat,and Kumar (2008). A network design of recovery network by formulating a mixed-integer linear program (MILP)for single-product two-echelon forward and reverse supply chain model has been proposed bySalema, P´ovoa , and Novais(2009) in which the researchers have highlighted the importance of forward facility location model appropriate logistics structures for the arising flows of used and recovered products in context of copier remanufacturing and paper recycling. Aras, Boyaci, andVerter (2010) developed a MILP for a multi echelon, multi period, multiproduct closed loop supply chain which integrates strategic network design decisions with operational decisions related to procurement, production, distribution, and end of life disposal, and solved it using a genetic algorithm.Jayaraman, Guide J, and Srivastava (1999) have also experimented with a model for the integrationof macro level strategic network design decisions with micro level tactical decisions including production, storage, and distribution planning by taking the concept of macro and micro timescales into consideration.A study on model for remanufacturing that determines the location of remanufacturing/distribution facilities, the transhipment, production, and stocking of the optimal quantities of remanufactured products and cores (used parts) recoverable products environments has been taken up by Francas and Minner (2009). A closed loop of flow of material from customer to the remanufacturer and vice-versa (Mutha and Pokharel2009)and the capacity decisions and expected performance of two alternative manufacturing network configurations when demand and return flows are uncertain have also been taken for study by researchers.An integrated, reverse logistics supply chain planning process with modular product design that produces and markets products at different quality levels to maximize profit by considering the collection of returned products, the recovery of modules and the proportion of the product mix at different quality levels is required for overall planning process.Lee , Gen and Rhee (2009)focussed ona single supplier for minimizing shipment costs of a CLSC and opening costs of disassembly centers and processing centers and which could determine the optimal numbers of disassembly and processing centers without including inventory costs such as holding costs (Wang , Hsu 2010).A general closed loop network based on return - recovery pair and product life cycleto optimize the closed-loop network and to determine the units of products to be produced, disassembled, repaired and purchased from external suppliers while maximizing the profit has alsobeen designed by Meixell and Gargeya (2005). Researchers have paid attention to environmental issues within CLSCs and offered a comprehensive mathematical model minimizes costs associated with distribution, processing and facility set-up Thirie(2000) and support both product design and logistics network, simultaneously.The list of environmental performance metrics of a supply chain includes emissions, energy use and recovery, spill and leak prevention and discharges is discussed in study by Srivastava(2007). Factors such as the used-product return ratio and corresponding subsidies from governmental organizations for reverse logistics have been discussed to improve the chain-based aggregate net profits can be by 21.1% (Krikke, Bloemhof-Ruwaard, and Van Wassenhove (2003).Issues like Legislation, environmental consciousness, take-back policy, warranty returns, and economic aspects involved in reverse logistics have also managed to capture researcher's attention (Elwany,Fors, Harraz 2007). But Hervani, Helms, and Sarkis (2005) argues that organizations are focused on the design of supply chains of production, purchasing, transportation and profit and has neglected the environmental aspects.Beamon (1999), described the current state of the natural environment, investigated the environmental factors, presented performance measures for the GrSC and discussed the procedure to achieve it. Through another study, it was observed that greening the various phases of the supply chain leads to an integrated green supply chain and hence it leads to competitive and economic performance (Rao and Halt 2005). Sarkis (2003) focused upon the major components and elements of GrSC management and how they can serve as a decision framework foundation. He proposed ANP based dynamic non-linear decision model, for GrSC decisions making. Meixell and Gargeya (2005) proposed decision support models to assess and fit well between the research literature and related practical issues of the area. To deal with the integrated logistics operational issues of GrSCM, an optimization based model was proposed. A multi-objective linear programming model is used to optimize the integrated logistics and used product reverse logistics systematically in a GrSCm. There is a growing need for integrating environmentally sound choices into supply-chain management research and practice.

Based on the above literature, it is identified that there is a research potential to make use of closed loop supply chain network for the case of Toaster to recover material like steel, brass, safety bolts, heating elements etc. to convert it into a raw material. Reviewing the above mentioned literature on closed-loop logistics, it is noted that the existing models did not mention the problem of greening the CLSC in the way it is introduced in this study by considering the different mode of transportation with the help of 3PL in forward and vehicle routing problem, VRP, in reverse chain of the CLSC. The purpose of this research work is to develop an integrated, multi objective model for multi echelon CLSC to optimize the distribution and minimize the effect on environment due to transportation related activities. The modelling of this closed loop supply chain network is done in the context of 6 bread Toaster. This paper is different from previous approaches because it considers the minimal use of vehicles (using full truckload transportation in forward chain and less than truck load in reverse chain) and its impact on the design of a closed-loop supply chain, where products are remanufactured to usable functionality and re-enter the primary market.

3. **Problem definition and model description**

The CLSC problem discussed in this paper is an integrated multi-objective multi-echelon problem in a forward/reverse logistic network, which requires more efforts to analyse than both forward and backward logistic simultaneously. Here we are considering the flow of a product in the network. The model considers modular product structure and every component of the product has an associated recycling rate, specifying the rate at which the component can be recycled. For instance, a rate of 100% indicates that the used product can be fully recovered or transformed into a new one, whereas a rate of 50% denotes that the product can only be partially recovered. In the network suppliers are responsible for providing components to manufacturing plants. The new products are conveyed from plants to customers via distribution centres (d/c) to meet their demands. Returned products from customers are collected at collection centres where they are inspected. After testing in collection centres, the repairable and recyclable products are shipped to plants and dismantlers respectively, after completing the demand of secondary market of used products. At plant repairable used products are repaired and supplied back to distribution centres as new product. Dismantled components at dismantlers are driven back to suppliers if they are repairable else to disposal site to be disposed of.

The company chosen for this study is Electric home appliance manufacturingcompany,for Toaster, located in Delhi. The main scope of this study is to estimate the feasibility of reclaiming the components and recycling the materials from end of life or used Toaster of the company itself. To design the GSCM for the company, we structure the following CLSC network: Chain members are classified into two groups namely forward supply chain members and the used product reverse supply chain members. A four layer forward supply chain is proposed in corresponding layers, including raw material supply, plants, distribution centers and end-customers respectively. Similarly a 5 layer used product reverse supply chain is specified, which includes regional collection centers, , repairing centersa dismantling point operated by the company itself, for the company products only, a spare market zone, single decomposition center working for all suppliers and a disposal location of waste respectively.

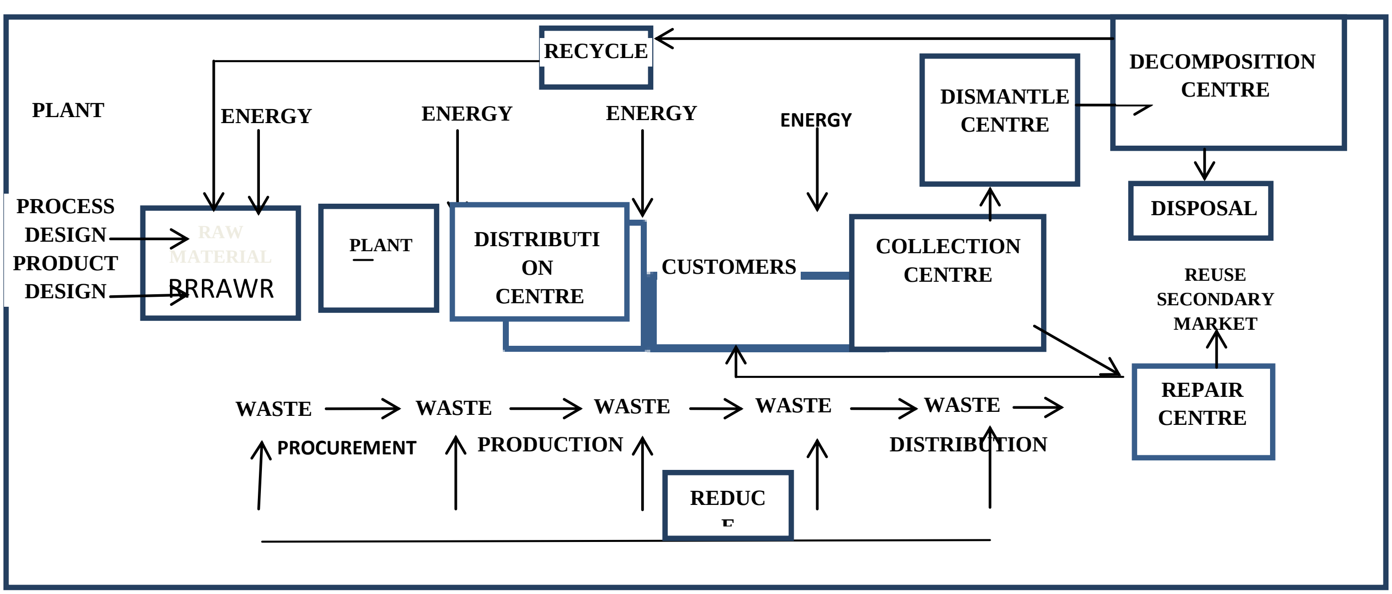


Fig.1 Close loop supply chain network

In the forward supply chain, for manufacturing new Toaster, major raw materials are procured from different suppliers. Once the Toaster is produced in different plants, it has to be distributed to the customers through the distribution centres. The products offered are given with a warranty and in case of some problem the product is repaired with in the warranty period. After its end of life, customer returns the product at their regional collection centre. The used Toaster collected at the collection points are transhipped to centralized dismantling centre where returned products are dismantled into its components. These components are then inspected for quality failure and sorted for potential repair or recycling. After inspection, the reusable components after repairing at repairing centre are sold in the spare market while the remaining components are transhipped to the decomposition centre to extract the material which can be recycled and the useless material (not able to recycle) disposed of . In the forward supply chain, we have considered that a decision maker would rent full trucks for forward flow from 3PL whereas transportation in reverse logistics is to be carried out by company owned vehicles. Stages in the reverse chain are single echelon except the multiple regional collection centres and therefore the transportation of returned products from multiple collection centres to the company's centralized dismantler centre is modelled in order to minimize the total distance covered by vehicle while collecting goods from more than one collection centre in proper manner, satisfying space capacity limitation. Rest of the transportation related activities between two stages are carried by company owned vehicles accordingly.

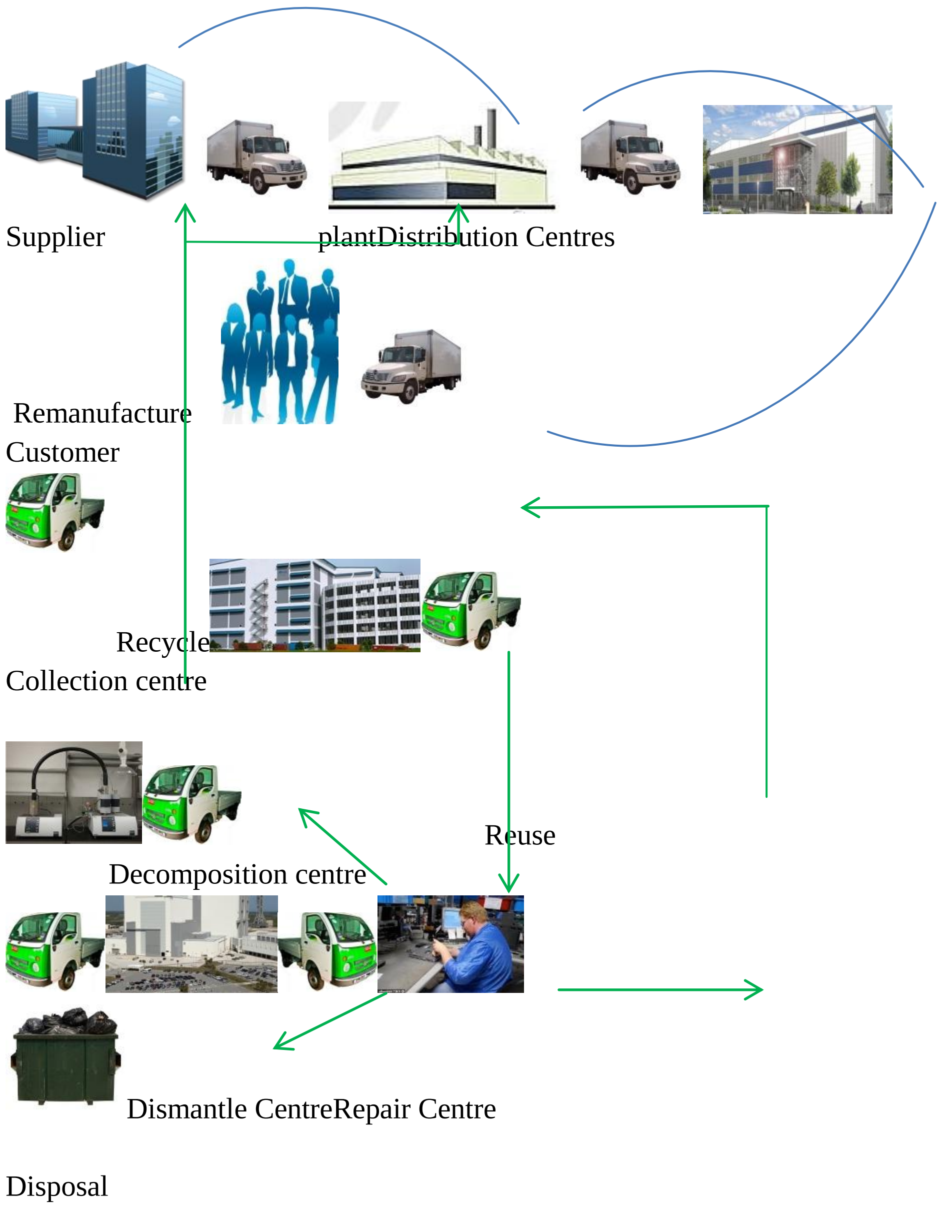


Fig.2 Pictorial representation of organization flow

The proposed model is a multi-objective problem addressing a multi echelon, single product, single period closed loop supply chain. Here we try to maximize revenue incurred by selling finished product and repaired components in spare market and profit earned by using recycled material, minimize the total supply chain cost comprising purchasing, production, distribution, collection, disposal, disassembly , recycling cost and transportation related costs and last objective is to minimize the number of trucks used in forward supply chain and distance travelled in reverse logistics.To specify the study scope and facilitate model formulation, assumptions are postulated below:

1. Demand at customer end is deterministic; hence there is no shortage of the product.

2. Locations of suppliers, facilities, distributors, disassemblers, and redistributors are known and fixed.
3. The flow is only allowed to be transferred between two consecutive stages. Moreover, there are no flows between facilities at the same stage.
4. Costs parameters (material, manufacturing, transportation, recycling, repairing, disassembly, and disposal costs) are known for each location.
5. All operations of CLSC are under capacity limitations.
6. The sum of disassembly and recycling costs of parts is less than purchasing cost of new ones.
7. Single unlimited capacity centralized dismantling centre is maintained by the industry itself.
8. The un-recyclable returned material will be sent to the disposal site after some pre-treatment process. Pre-treatment cost for the disposable materials are included in the disposal cost itself.
9. Buy back cost given to end customer on returning a used product will remain same for all customers irrespective of used products condition.
10. Transportation cost of collecting returned products from collection centres is borne by the company and is directly proportional to the total distance covered.
11. The estimated emission rate of CO_2 for all type of vehicle available is known

Sets:

S	set of component's suppliers index by s, $s=1, 2... S$
P	set of manufacturing plants index by p, $p=1, 2... P$
K	set of distribution centers (d/c) index by k, $k==1, 2... K$
E	set of first market customer zones index by e, $e=1, 2… E$
C	set of collection centers (CC) index by c, $c==1, 2.., C$
M	set of dismantlers (d/m) position index by m, $m==1, 2... M$
H	set of second market customer zones index by h, $h=1,2,…,H$
F	set of disposal sites (d/p) index by f, $f=1,2,…,F$
A	set of sub-assemblies index by a, $a=1,2,…,A$
N	set on nodes in the network ($N = S \cup P \cup K \cup E \cup C \cup M \cup H \cup F$)

Parameters:

SC_{sa}	Unit purchasing cost of sub assembly a by supplier s
PC_p	Unit production cost of product at manufacturing plant p
OC_k	Unit operating cost of product at d/c k

IC_c	Unit inspection cost of product at collection center$c$
RPC_p	Unit repairing cost of used product at manufacturing plant p
DMC_m	Unit dismantling cost of product at d/m position m
RCC_{sa}	Unit recycling cost of sub assembly a at supplier s
DPC_{fa}	Unit disposal cost of sub assembly a at disposal site f
D_e	Demand of product at first customer e
D_h	Demand of used product at second customer h
TPC^t	Unit transportation cost per mile of product or component shipped from one node to another via type of truck t
D_{ij}	Distance between any two nodes $i, j \in N$ of given CLSC network
CAP_{sa}	Capacity of supplier s for sub assembly a
$PCAP_p$	Production capacity of plant p
$KCAP_k$	Capacity of distribution center$k$
$CCAP_c$	Capacity of collection center$c$
$MCAP_m$	Capacity of dismantler m
$FCAP_f$	Disposal capacity of disposal site f
$RPCAP_p$	Repairing capacity of plant p
$RCCAP_s$	Recycling capacity of supplier s
PF_a	Unit profit made in the network from recycling component a
PF	Unit profit made in the network from repairable product
PR_e	Unit price of product at customer e
PR_h	Unit price of product at customer h
ER^t	Per mile emission rate of CO_2 gas from the type of transport $t \in T$

Rr	Return ratio at the first customers
Rc_a	Recycling ratio of component a
Rp	Repairing ratio
W	Weight of product in kg
W_a	Weight of component $a \in A$ in kg
U_a	Utilization rate of component $a \in A$

Decision variables:

x_{ija}^{t} Quantity of component a shipped from node i to node j, $i,j \in N$ in the network via transport of type $t \in T$

x_{ij}^{t} Quantity of product shipped from node i to node j, $i,j \in N$ in the network via transport of type $t \in T$

W_{ij}^{t} Weighted quantity transported from node i to node j, $i,j \in N$ in the network via transport of type $t \in T$

$$X_i = \begin{cases} 1, & \text{if facility i, } (i \in P \cup K \cup C \cup M) \text{ is opened} \\ 0, & \text{otherwise} \end{cases}$$

$$L_{ij}^{t} = \begin{cases} 1, & \text{if a transportation link is established between any two locations } i \text{ and } j,\ i, j \in N \text{ via mode } t \\ 0, & \text{otherwise} \end{cases}$$

Model

Maximize,

$$\begin{aligned} \boldsymbol{Z_0} = & \sum_k \sum_e \sum_t x_{ke}^{t} PR_e + \sum_c \sum_h \sum_t x_{ch}^{t} PR_h + \sum_m \sum_s \sum_a \sum_t PF_a x_{msa}^{t} + \sum_c \sum_p \sum_t PF x_{cp}^{t} - \Big(\sum_s \sum_p \sum_a \sum_t x_{spa}^{t} SC_{sa} + \sum_p \sum_k \sum_t x_{pk}^{t} PC_p + \sum_k \sum_e \sum_t x_{ke}^{t} OC_k \\ & + \sum_e \sum_c \sum_t x_{ec}^{t} IC_c + \sum_c \sum_p \sum_t x_{cp}^{t} RPC_p + \sum_c \sum_m \sum_t x_{cm}^{t} DMC_m + \sum_m \sum_s \sum_a \sum_t x_{msa}^{t} RCC_{sa} + \sum_m \sum_f \sum_a \sum_t x_{mfa}^{t} DPC_f + \sum_s \sum_p \sum_t TPC^t D_{sp} x_{sp}^{t} \\ & + \sum_p \sum_k \sum_t TPC^t D_{pk} x_{pk}^{t} + \sum_k \sum_e \sum_t TPC^t D_{ke} x_{ke}^{t} + \sum_e \sum_c \sum_t TPC^t D_{ec} x_{ec}^{t} + \sum_c \sum_p \sum_t TPC^t D_{cp} x_{cp}^{t} + \sum_c \sum_m \sum_t TPC^t D_{cm} x_{cm}^{t} \\ & + \sum_c \sum_h \sum_t TPC^t D_{ch} x_{ch}^{t} + \sum_m \sum_s \sum_a \sum_t TPC^t D_{ms} x_{msa}^{t} + \sum_m \sum_f \sum_a \sum_t TPC^t D_{mf} x_{mfa}^{t} \Big) \end{aligned}$$

Minimize,

$$\begin{aligned} \boldsymbol{Z_1} = & \sum_t ER^t \Big(\sum_s \sum_p D_{sp} L_{sp}^{t} W_{sp}^{t} + \sum_p \sum_k D_{pk} L_{pk}^{t} W_{pk}^{t} + \sum_k \sum_e D_{ke} L_{ke}^{t} W_{ke}^{t} + \sum_e \sum_c D_{ec} L_{ec}^{t} W_{ec}^{t} + \sum_c \sum_p D_{cp} L_{cp}^{t} W_{cp}^{t} + \\ & \sum_c \sum_m D_{cm} L_{cm}^{t} W_{cm}^{t} + \sum_c \sum_h D_{ch} L_{ch}^{t} W_{ch}^{t} + \sum_m \sum_s D_{ms} L_{ms}^{t} W_{ms}^{t} + \sum_m \sum_f D_{mf} L_{mf}^{t} W_{mf}^{t} \Big) \end{aligned}$$

Subject To

(Flow balancing Constraints)

$$\sum_{s}\sum_{t} x_{spa}^{t} + \sum_{c}\sum_{t} x_{cp}^{t} * U_a = \sum_{k}\sum_{t} x_{pk}^{t} * U_a \qquad \forall\ p, a \qquad (1)$$

$$\sum_{p}\sum_{t} x_{pk}^{t} = \sum_{k}\sum_{e} x_{ke}^{t} \qquad \forall\ k \qquad (2)$$

$$\sum_{k}\sum_{e} x_{ke}^{t} >= D_e \qquad \forall\ \mathrm{e} \qquad (3)$$

$$\sum_{c}\sum_{t} x_{ec}^{t} = Rr * D_e \qquad \forall\ e \qquad (4)$$

$$\sum_{c}\sum_{t} x_{ch}^{t} <= D_h \qquad \forall\ h \qquad (5)$$

$$\sum_{p}\sum_{t} x_{cp}^{t} = Rp * (\sum_{e}\sum_{t} x_{ec}^{t} - \sum_{h}\sum_{t} x_{ch}^{t}) \qquad \forall\ c \qquad (6)$$

$$\sum_{m}\sum_{t} x_{cm}^{t} = (1 - Rp) * (\sum_{e}\sum_{t} x_{ec}^{t} - \sum_{h}\sum_{t} x_{ch}^{t}) \qquad \forall\ c \qquad (7)$$

$$\sum_{s}\sum_{t} x_{msa}^{t} = Rc_a * U_{a*} \sum_{c}\sum_{t} x_{cm}^{t} \qquad \forall\ m, a \qquad (8)$$

$$\sum_{f}\sum_{t} x_{mfa}^{t} = (1 - Rc_a) * U_{a*} \sum_{c}\sum_{t} x_{cm}^{t} \qquad \forall\ m, a \qquad (9)$$

Capacity constraints

$$\sum_{s}\sum_{t} x_{spa}^{t} <= CAP_{sa} \qquad \forall\ s, a \qquad (10)$$

$$\sum_{k}\sum_{t} x_{pk}^{t} <= PCAP_p * X_p \qquad \forall\ p \qquad (11)$$

$$\sum_{e}\sum_{t} x_{ke}^{t} <= KCAP_k * X_k \qquad \forall\ e \qquad (12)$$

$$\sum_{e}\sum_{t} x_{ec}^{t} <= KCAP_k * X_k \qquad \forall\ c \qquad (13)$$

$$\sum_{c}\sum_{t} x_{cp}^{t} <= RPCAP_p * X_p \qquad \forall\ p \qquad (14)$$

$$\sum_{c}\sum_{t} x_{cm}^{t} <= MCAP_m * X_m \qquad \forall\ m \qquad (15)$$

$$\sum_{m}\sum_{t} x_{msa}^{t} <= RCCAP_s \qquad \forall\ s, a \qquad (16)$$

$$\sum_{m}\sum_{a}\sum_{t} x_{mfa}^{t} <= FCAP_s \qquad \forall\ f \qquad (17)$$

$$w_{sp}^{t} = \sum_{a} x_{spa}^{t} * w_{a} \qquad \forall\ s, p, t \qquad (18)$$

$$w_{pk}^{t} = x_{pk}^{t} * w \qquad \forall\ p, k, t \qquad (19)$$

$$w_{ec}^{t} = x_{ec}^{t} * w \qquad \forall\ e, c, t \qquad (20)$$

$$w_{ke}^{t} = x_{ke}^{t} * w \qquad \forall\ k, e, t \qquad (21)$$

$$w_{cp}^{t} = x_{cp}^{t} * w \qquad \forall\ c, p, t \qquad (22)$$

$$w_{ch}^{t} = x_{ch}^{t} * w \qquad \forall\ c, h, t \qquad (23)$$

$$w_{cm}^{t} = x_{cm}^{t} * w \qquad \forall\ c, h, t \qquad (24)$$

$$w_{ms}^{t} = \sum_{a} x_{msa}^{t} * w_{a} \qquad \forall\ s, m, t \qquad (25)$$

$$w_{mf}^{t} = \sum_{a} x_{mfa}^{t} * w_{a} \qquad \forall\ m, f, t \qquad (26)$$

Maximum number of activated locations constraints

$$\sum_{p} X_{p} <= P \qquad (27)$$

$$\sum_{k} X_{k} <= K \qquad (28)$$

$$\sum_{c} X_{c} <= C \qquad (29)$$

$$\sum_{m} X_{m} <= M \qquad (30)$$

Linking- shipping constraints

$$L_{sp}^{t} <= \sum_{a} x_{spa}^{t} \qquad \forall\ s, p, t \qquad (31)$$

$$L_{pk}^{t} <= x_{pk}^{t} \qquad \forall\ p, k, t \qquad (32)$$

$$L_{ke}^{t} <= x_{ke}^{t} \qquad \forall\ k, e, t \qquad (33)$$

$$L_{ec}^{t} <= x_{ec}^{t} \qquad \forall\ e, c, t \qquad (34)$$

$$L_{cp}^{t} <= x_{cp}^{t} \qquad \forall\ c, p, t \qquad (35)$$

$$L_{ch}^{t} <= x_{ch}^{t} \qquad \forall\ c, h, t \qquad (36)$$

$$L_{cm}^{t} <= x_{cm}^{t} \qquad \forall\ c, m, t \qquad (37)$$

$$L_{ms}^{t} <= \sum_{a} x_{msa}^{t} \qquad \forall\ s, m, t \qquad (38)$$

$$L_{mf}^{t} <= \sum_{a} x_{mfa}^{t} \qquad \forall\ m, f, t \qquad (39)$$

Shipping linking constraints

$$\sum_{a} x_{spa}^{t} <= MI * L_{sp}^{t} \qquad \forall\ s, p, t \qquad (40)$$

$$x_{pk}^{t} <= MI * L_{pk}^{t} \qquad \forall\ p, k, t \qquad (41)$$

$$x_{ke}^{t} <= MI * L_{ke}^{t} \qquad \forall\ k, e, t \qquad (42)$$

$$x_{ec}^{t} <= MI * L_{ec}^{t} \qquad \forall\ e, c, t \qquad (43)$$

$$x_{cp}^{t} <= MI * L_{cp}^{t} \qquad \forall\ c, p, t \qquad (44)$$

$$x_{cm}^{t} <= MI * L_{cm}^{t} \qquad \forall\ c, m, t \qquad (45)$$

$$x_{ch}^{t} <= MI * L_{ch}^{t} \qquad \forall\ c, h, t \qquad (46)$$

$$\sum_{a} x_{msa}^{t} <= MI * L_{ms}^{t} \qquad \forall\ s, m, t \qquad (47)$$

$$\sum_{a} x_{mfa}^{t} <= MI * L_{mf}^{t} \qquad \forall\ m, f, t \qquad (48)$$

$$x_{ija}^{t}, x_{ij}^{t} >= 0$$

$$X_{i}, L_{ij}^{t} \in \{0, 1\}$$

The first objective is to maximize the total profit including the total income and profit obtained by introducing recycled materials back into the (forward) supply chain (which is used as an incentive for the companies to choose and use recyclable products) minus the total cost which includes cost of purchasing components from suppliers, production cost incurred at plants, operating costs incurred at d/c, inspection cost for the returned products in collection centres, remanufacturing cost of recoverable products in plants, dismantling cost in dismantling the product, recycling cost at supplier and disposal costs for scrapped products. Second objective is to minimize the CO_2 emission by choosing various available type of transport.

Constraints are divided in five sets: first set is consisting of flow balancing constraints. Constraint (1) assures that the flow entering in the manufacturing plant is equal to the flow exit from it. Constraint (2) is for d/c. Constraint (3) insures that demands of all first customers are satisfied. Constraint (4) insures the flow entering in collection centre through a customer will be equal to demand of the customer multiplied by return ratio. Constraint (5) insures that flow entering to each second customer from all collection centres does not exceed the second customer demand. Constraint (6) and (7) imposes that, the flow exiting from each collection centre to all plants and dismantler is equal to the amount remaining at each collection centre after satisfying second customer demand multiplied by the repairing ratio and (1- repairing ratio) respectively. Constraint (8) and (9) shows that, the flow exiting from each dismantler to supplier and disposal sites are equal to the flow entering from all CC multiplied by recycling ratio and (1- recycling ratio) respectively. Constraint (10)-(17) insures that flow either exiting or entering at any facility does not exceed the respective facility capacity. Constraints (27)–(30) limit the number of activated locations, where the sum of binary decision variables which indicate the number of activated locations, is less than the maximum limit of activated locations. Constraints (31)-(39) insure that there are no links between any locations without actual shipments during all periods. Constraints (40)-(48) ensure that there is no shipping between any non-linked locations.

4. Multi-objective Methodology: Goal Programming

The basic approach of **goal programming** is to establish a specific numeric goal for each of the objectives, formulate an objective function for each objective, and then seek a solution that minimizes both positive and negative deviations from set goals simultaneously or minimizes the amount by which each goal can be violated. There is a *hierarchy of priority levels* for the goals, so that the goals of primary importance receive first priority attention, those of secondary importance receive second-priority attention, and so forth.

Generalized model of goal programming is:

$$\min a = \left\{ g_1\left(\overline{\eta_1}, \overline{\rho_1}\right), ..., g_k\left(\overline{\eta_2}, \overline{\rho_2}\right) \right\}$$

$$s.t \quad f_i\left(\overline{x}\right) + \eta_i - \rho_i = b_i \qquad \forall i = 1, 2, ..., m$$

$$\overline{x}, \overline{\eta}, \overline{\rho} \geq 0;$$

x_j is the j[th] decision variable, a is denoted as the achievement function; a row vector measure of the attainment of the objectives or constraints at each priority level, $g_k\left(\overline{\eta}, \overline{\rho}\right)$ is a function (normally linear) of the deviation variables associated with the objectives or constraints at priority level k, K is the total number of priority levels in the model, b_i is the right-hand side constant for goal (or constraint)i, $f_i(\overline{x})$ is the left-hand side of the linear goal or constraint i.

We seek to minimize the non-achievement of that goal or constraint by minimizing specific deviation variables. The deviation variables at each priority level are included in the function $g_k\left(\overline{\eta}, \overline{\rho}\right)$ and ordered in the achievement vector, according to their respective priority. Algorithm of sequential goal programming:

Step 1: Set k = 1 (k represents the priority level and K is the total of these).

Step 2: Establish the mathematical formulation as discussed above using positive and negative deviations for priority level k only.

Step 3: Solve this single-objective problem associated with priority level k. and the optimal solution of $g_k\left(\overline{\eta}, \overline{\rho}\right)$ is a*.

Step4: Set k=k + 1. If k>K, go to Step 7.

Step 5: Establish the equivalent, single objective model for the next priority level (level k) with additional constraint $g_k(\overline{\eta}, \overline{\rho}) = a_s^*$.

Step 6: Go to Step 3.

Step 7: The solution vector x*, associated with the last single objective model solved, is the optimal vector for the original goal programming model.

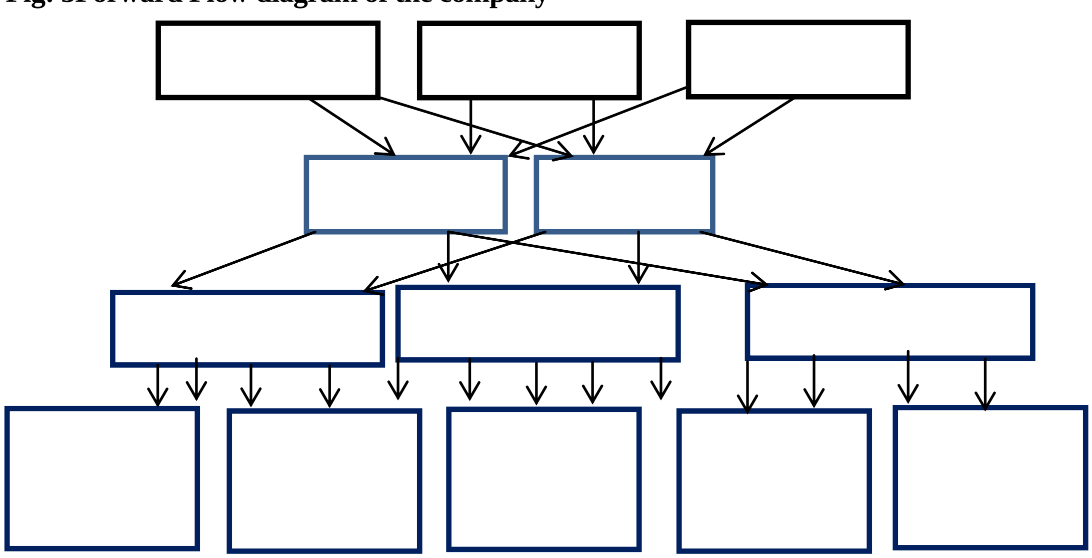
5. Numerical Illustration

In this section, a numerical example is presented in order to demonstrate the applicability of the model. In considered CLSC, a product which is made up of six components

Table 1: Data for various rates

Components	1	2	3	4	5	6
Utilization rates	1	4	1	2	1	3
Recycling rate	1	0.5	7.5	1	0.3	0

Fig: 3Forward Flow diagram of the company



1,2 ,3 ,4 ,5 and 6 with respective utilization rate of 1,4,1,2,1,and 3 and recycling rate of 1, 0.5, 7.5, 1, 0.3 and 0 flows between various facilities. In forward direction, there is a set of 3 suppliers that can provide components to 2 potential locations of manufacturing plants. 3 potential location of d/cs are there in the network to cater the demand of 2000, 2700, 3250, 2550 and 2700 units from respective 5 zones of first customer market at a unit selling price of 11000, 10500, 10000, 10750, and 10500. In backward direction, potential locations of CC, dismantlers and disposal sites are 3, 2 and 1 respectively. Beside it demand of 500, 350 and 550 units of used product from respective 3 zones of second customers can be satisfied at unit selling price of 7500, 8000 and 7000. As for transportation, road-based transportation is used to carry out the shipping operations, for which there are three types of trucks available which are 0–3, 4–7 and 8–11 years old, respectively. We assume that the older the trucks, the cheaper their rental fees, but, at the same time, the greater their CO_2 emissions, due to decreasing engine efficiency. Unit transportation costs for the different types of trucks used are 1, 0.85 and 0.70 for truck types 1, 2 and 3, respectively. Emission rate of CO_2 found to be 1.3, 2.8 and 3.1 grams/ mile for truck types 1, 2 and 3, respectively. Profit raised in the network by repairing the product is 5500/unit and by recycling a unit of component 1, 2, 3, 4 and 5 are 250,50,90,55 and300 respectively.

Table 2 :**Information relating to the transportation**

Truck types	Number of operational years	Unit transportation cost	Emission rate of CO_2
1	0-3	1	1.3gms/mile
2	4-7	0.875	2.8gms/mile
3	8-11	0.70	3.1gms/mile

Other parameters are set as follows: Rr=0.60, Rp=0.25 and Rc_a =(1,1,1,1,1,0). Set of unit purchasing costs of components (in order) from supplier 1,2 and 3 are (460, 0, 190, 125, 0, 80), (480, 120, 200, 150, 650, 100) and (470, 95, 0, 0, 620, 90) resp. Unit recycling costs of components (in order) at supplier 1, 2, and 3 are (20,0,60,10,0,0), (25,90,55,20,390,0) and (0,65,0,0,380,0) respectively. Price 0 means that component service is not provided by respective supplier. 2500 and 3000 are unit production cost, and 1500 and 2200 are unit repairing costs of the product at plant 1 and 2 respectively. Unit operating costs at d/c 1, 2 and 3 are 500, 550 and 600 respectively. Unit Inspection costs at collection centers 1, 2and 3 are 100, 100 and 120 respectively. Unit dismantling cost at d/m 1 and 2 are 125 and 110 respectively. Unit disposal cost of component 6 is 15.

Paremeters

- Rr=0.60, Rp=0.25 and Rc_a =(1,1,1,1,1,0).
- Price0 means that component service is not provided by respective supplier
- Unit production costs of the product at plant 1 and 2 respectively-2500 and 3000
- Unit repairing costs of the product at plant 1 and 2 respectively-1500 and 2200
- Unit dismantling cost at d/m 1 and 2 are 125 and 110 respectively.
- Unit disposal cost of component 6 is 15.
- Unit operating costs at d/c 1, 2 and 3 respectively -500, 550 and 600
- Unit Inspection costs at collection centers 1, 2and 3 respectively-100, 100 and 120

Table 3: Various cost involved in the flow

Supplier	Set of unit purchasing cost of components	Unit recycling cost of components	Unit operating cost at d/c	Unit inspection cost
1	(460, 0, 190, 125, 0, 80)	(20,0,60,10,0,0),	500	100
2	(480, 120, 200, 150, 650, 100)	(25,90,55,20,390,0)	550	100
3	(470, 95, 0, 0, 620, 90)	(0,65,0,0,380,0)	600	120

Data on capacities at various facilities are as follows: Supplier1 can supply at most of 8000, 0, 9000, 12000, 0 and 14000 units of component 1,2,3,4,5 and 6 resp. Capacity of supplier 2 and 3 of components are (7500,40000, 5000, 27000, 7700, 15000) and (0,20000, 0, 0, 7500, 1400) resp. Recycling capacities of supplier 1, 2 and 3 are (3000,0,2900,4000,0,0), (2000,15000,2000,6000,2500,0) and (0,8000,0,0,2500,0) resp.. Production capacities of plants are 8000, 7500 and repairing capacities are 2000, 1800 resp. Capacities of d/c's are 4800, 5000 and 5500, of CC's are 3500, 3000 and 2500; of dismantlers are 5000, 5000 and of disposal site is 250000.

Data on distance (in miles) between any two facilities is as follows:

D_{ij}= {D_{11}, $D_{12,}$ D_{13},…,D_{21}, D_{22}, D_{23},…..}

D_{sp}= {200,190,310,350,290,280}, D_{pk}= {120,100,135,170,190,200},

D_{ke}= {24,17,22,21,18,29,19,21,20,31,33,25,28,15,28},

D_{ec} = {6,9,8,8.5,7,10,11,12,13,9,8,9.5,11,9,8}, $D_{cp\,=}$ {150,120,135,110,130,100}

$D_{cm\,=}$ {8.5,9,11,12,10,11}, D_{ch}= {15,21,19,24,16,18,20,22,21}

$D_{ms\,=}$ {100, 150, 120, 95, 154, 130}, $D_{mf\,=}$ {80,75}

The above data is employed to validate the proposed model. A LINGO code for generating the proposed mathematical models of the given data was developed and solved using LINGO11.0 [20]. Problem is solved individually with each objective subject to given set of constraints. Thus, Profit and amount of CO_2 emission would be 66625630 and 252121600 resp. Which are set as the aspiration levels for profit and emission functions. Then multi-objective programming problem combining all the objectives and incorporating the individual aspirations is solved which results in infeasible solution hence goal programming technique has been used to obtain a compromise solution to the above problem.Giving weightage 0.5 and 0.5 to profit and CO_2 objective resp., a compromised solution of allocation of facilities and transporting vehicle is obtained.

Total profit thus generated in the network is Rs. 55454580 and amount of CO_2 emitted is 10681.55. The flow between facilities using different type vehicles is given below.

X_{spa}^{t} : $x_{111}^{2} = 2499$, $x_{113}^{2} = 3499$, $x_{114}^{2} = 10002$, $x_{116}^{2} = 14000$, $x_{121}^{1} = 5501$, $x_{123}^{1} = 5501$, $x_{124}^{1} = 1998$, $x_{211}^{2} = 3570$, $x_{212}^{2} = 4552$, $x_{213}^{2} = 2570$, $x_{214}^{2} = 2136$, $x_{222}^{1} = 21728$, $x_{224}^{1} = 4202$, $x_{224}^{3} = 4802$ $x_{225}^{1} = 4070$, $x_{226}^{3} = 15000$, $x_{312}^{2} = 19724$, $x_{315}^{2} = 6069$, $x_{316}^{2} = 4207$ $x_{322}^{1} = 276$ $x_{325}^{3} = 1431$ $x_{326}^{1} = 1503$

X_{pk}^{t} : $x_{11}^{2} = 4800$, $x_{12}^{3} = 2900$, $x_{23}^{3} = 5500$

x_{ke}^{t} : $x_{13}^{1} = 2100$, $x_{15}^{1} = 2700$, $x_{21}^{1} = 2000$, $x_{23}^{1} = 900$, $x_{32}^{3} = 2700$, $x_{33}^{3} = 250$, $x_{34}^{3} = 2550$

x_{ec}^{t} : $x_{11}^{3} = 1200$, $x_{22}^{1} = 1620$, $x_{33}^{3} = 1950$, $x_{41}^{3} = 150$, $x_{42}^{1} = 1380$, $x_{51}^{1} = 1070$, $x_{53}^{3} = 550$

x_{cp}^{t} : $x_{11}^{1} = 255$, $x_{21}^{1} = 750$, $x_{31}^{2} = 625$

x_{cm}^{t} : $x_{11}^{3} = 765$, $x_{21}^{3} = 2250$, $x_{31}^{1} = 1875$

x_{ch}^{t} : $x_{11}^{2} = 500$, $x_{12}^{2} = 350$, $x_{13}^{2} = 550$

x_{msa}^{t} : $x_{111}^{1} = 2890$, $x_{113}^{3} = 2890$, $x_{114}^{3} = 3780$, $x_{121}^{3} = 2000$, $x_{122}^{3} = 11560$, $x_{123}^{3} = 2000$, $x_{124}^{3} = 6000$, $x_{125}^{3} = 2390$, $x_{132}^{3} = 8000$, $x_{135}^{3} = 2500$

x_{mfa}^{t} : $x_{116}^{3} = 14670$

6. Conclusions, Managerial implications and future Research:

One of the important planning activities in supply chain management (SCM) is to design the configuration of the supply chain network. Besides, due to the global warning recently attention has been given to reverse logistic in SCM. Modelling of a CLSC network design problem can be a challenging process because there is large number of components that need to be incorporated into model. Here in the paper, trade-offs between operational and environmental performance measures of transportation product were investigated. Due to global warming, this paper focused on CO_2 emissions, One of the main findings of this paper is that, costs of environmental impacts are still not as apparent as operational measures, as far as their relative importance in a emission rate function are concerned. Operational costs of handling products, both in forward and reverse networks, seem to be dominant ignoring emissions rate. Another interesting result is relevant to the promotion of reusable products, the use of which seems to lessen the operational costs of the chain, but places a burden on the environmental costs.Through this study we would to distil the key ideas and procedures that can help organizations to work out on their transport issues and do even better in terms of CO2 emissions and costs.

This research has been limited to a fixed entity with a limited scope. This research could easily be extended for flexible or variable demand. The scope of study could beconsidered from regional perspective also, since we have focussed our research in Delhi /NCR area. Future research could also be carried out in other parts of India. We have recommended the use of CNG three-wheelers for the environmental safety as well as cost efficiency. The availability of CNG is a limitation in India, since it is only available in metro cities and not in other parts of India. Further research is also recommended for the scope and benefits of CNG trucks for longer distances for commercial purpose.

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