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Cost Minimization and Environmental Impact Reduction on the Basis of Green Supply Chain Management Concept

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Abstract

The Green supply chain management (GSCM) is an effective way to differentiate a company from its competitors. Companies that have adopted GSCM practices with a focus on distribution activities have successfully improved their business and environmental performance on many levels. Due to the concern of Environmental performance index (EPI) of Bangladesh the major activities of the Green supply chain management namely; green forward logistics and green carbon emission rate are being covered here. In this study, a mathematical model to solve the Green supply chain management problems which are emerged because of environmental responsibilities was proposed and developed. Minimization of transportation cost for forward logistics, amount of GHG gas emission rate and penalty cost for this emission were determined by using Lingo 14.0. Minimization of transportation cost was determined Tk. 28710 and penalty cost for GHG emission was Tk. 4567.

Keywords: Green Supply Chain Management, Green Purchasing, Green Manufacturing, Green Distribution, Forward Logistics.

1. Introduction

Traditionally supply chain starts with raw material suppliers and end with customers including manufacturing process, logistical support, storage, and distribution. The supply chain refers to all those activities associated with the transformation, flow of goods, and services including their attendant information flows from the sources of materials to end users. In 20th century, the voice agent environmental pollution has become stronger. So, eco-friendly manufacturing and transportation system has become an important factor for organizations. As a results, the concept of green supply chain management (GSCM) is generated. Green Supply chain is the internal, and external practice of emission of less greenhouse gases, solid waste management, and air pollution. Green supply chain management (GSCM) is used not only to balance the economy with ecology but also maximum utilization of resources, energy, fuel enhance, and company branding. Therefore, the enterprises need to develop a closed loop relationship with suppliers of recycled materials, and recycled parts. In this study, a GSCM network optimization problem where CO_2 gas emissions according to trucks options, and recyclable products are considered to become a mirror of greenness were analyzed. A penalty cost to prevent more CO_2 gas emissions, and to encourage the customers to use recycle able products with small profit are determined.

2. Literature review

Supply Chain Management (SCM) as a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and distribution of these finished products to customers. The supply chain as the network of organizations that are involved through upstream and downstream linkages in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer. Numerous articles dealing with the theory and practice of SCM have been published over the reviewed period of last 18 years, but the topic is still under considerable development and debate. The need for an inter-disciplinary approach, combining the technical and relational aspects from the respective fields of system dynamics and collaboration in order to deliver superior order replenishment performance [1]. Vendor coordination models that have used quantity discount as coordination mechanism under deterministic environment and classified the various models. Their sample addressed manufacturing and consumer goods industries, and the research articles reviewed by them focused on a more narrowly defined operations management approach to Supply Chain Management [2]. A GSC (Green Supply Chain) aims at confining the wastes within the industrial system in order to conserve energy and prevent the dissipation of dangerous materials into the environment [3]. Significant growth has taken place both in the practice and theory of supply chain management since this attempt, making it necessary for reviews of current knowledge and literature. There is a large of amount of literature on supply chain network design concerned with environmental issues through the GSC networks. GSCM involves environmental criteria, or concerns, into organizational purchasing decision, and long term relationships with suppliers. Evaluation Framework of Environmental Impacts and Costs of Transport (EFECT) which is a generalized methodological framework for evaluating the impacts resulting from transportation projects with a specific orientation to environmental impacts [4]. The innovative aspect of the methodological framework is the combination of Multi-Criteria Analysis (MCA) with Cost-Benefit Analysis (CBA) methods to come up with an overall assessment of transport initiatives impacts over different geographical regions and time periods. The components and elements of GrSC management, and how they serve as a foundation for the decision framework have been discussed [5]. The range of the supply chain to include re-use and recycling throughout the life cycle of products and services [6]. Using their definition, they proposed the multiple attribute utility theory method assessing a supply chain considering this approach to be one of the GSC methods [7]. The challenges and opportunities facing the supply chain of the future, described sustainability, effects on supply chain design, management, and integration. Traditional, and GSCs are compared, contrasted via focusing several important opportunities in GSC management in depth, including those in manufacturing, bio-waste, construction, and packaging [8]. In Wang and Hsu study, the integration of forward and reverse logistics was investigated, and a generalized closed-loop model for the logistics planning was proposed by formulating a cyclic logistics network problem into an integer linear programming model [9]. Moreover, the decisions for selecting the places of manufactories, distribution centers, and dismantlers with the respective operation units were supported with the minimum cost. Kannan et al. developed a multi echelon, multi period, multi product CLSC (closed-loop supply chain) network model for product returns and the decisions are made regarding material procurement, production, distribution, recycling and disposal. The proposed heuristics based genetic algorithm (GA) is applied as a solution methodology to solve mixed integer linear programming model (MILP) [10]. Yang et al. developed a model of a general CLSC network, which includes raw material suppliers, manufacturers, retailers, consumers and recovery centers [11].

In this study a mathematical model was proposed and developed for an integrated supply chain network. Minimization of transportation cost for forward logistics and penalty cost for GHG gas emission was determined from the mathematical model by using Lingo 14.0.

3. Methodology

3.1 Mathematical model formulation

In this section a supply chain network was considered, based on five assumptions and the network structure. A mathematical model was developed to describe the goal of this study. Definitions of variables and parameters in the green supply chain network are summarized below:

Table 1. Indices

I the number of supplier 1,2,3,….i I	L the number of customers with 1,2,…..i L
J the number of plants with 1,2,……j J	R the number of raw end materials with 1,2,…r R
K the number of distribution centers (DCs) with 1,2,…….k K	T the number of trucks with 1,2,……t T

Truck rental fee parameters:

H_t^{ij} the rental fee of truck t during the transportation supplier i and plant j

H_t^{jk} the rental fee of truck t during the transportation plant j and distributi on center (DC) k

H_t^{j} the rental fee of truck t during the transportation plant j and warehouse

H_t^{k} the rental fee of truck t during the transportation ware house and distributi on centre (DC) k

H_t^{l} the rental fee of truck t during the transportation ware house and customer l

H_t^{kl} the rental fee of truck t during the transportation distributi on centre (DC) k and customer l

Greenhouse gas emission parameters in forward logistic:

CO_2^{ijt} unit CO_2 emission for truck t during the transportation supplier i and plant j

CO_2^{jkt} unit CO_2 emission for truck t during the transportation plant j and distributi on centre (DC) k

CO_2^{jt} unit CO_2 emission for truck t during the transportation plant j and warehouse

CO_2^{klt} unit CO_2 emission for truck t during the transportation distributi on centre (DC) k and customer l

CO_2^{kt} unit CO_2 emission for truck t during the transportation ware house and distributi on centre (DC) k

CO_2^{it} unit CO_2 emission for truck t during the transportation ware house and customer l

Capacity parameters of facilities:

Ca_r^i capacity of product r at supplier i

Ca_r^j capacity of product r at plant j

Ca_r capacity of product r at warehouse

Ca_r^k capacity of product r at distributi on centre (DC) k

Truck Capacity parameters in forward logistic:

Ca_t^i transportation capacity of truck t departs from supplier i

Ca_t^j transportation capacity of truck t departs from plant j

Ca_t transportation capacity of truck t departs from warehouse

Ca_t^k transportation capacity of truck t departs from distributi on centre (DC) k

Forward logistics variables:

X_{rt}^{ij} transported raw material r via truck t from supplier i to plant j

Y_{rt}^{jk} transported product r via truck t from plant j to distributi on centre (DC) k

Z_{rt}^{j} transported product r via truck t from plant j to warehouse

Q_{rt}^{k} transported product r via truck t from warehouse to distributi on centre (DC) k

W_{rt}^{l} transported product r via truck t from warehouse to customer 1

E_{rt}^{kl} transported product r via truck t from distributi on centre (DC) k to customer 1

Objective Function:
Minimizing transportation cost in forward logistic:

$$\sum_i \sum_j \sum_r \sum_t X_{rt}^{ij} H_t^{ij} + \sum_j \sum_k \sum_r \sum_t Y_{rt}^{jk} H_t^{ij} + \sum_j \sum_r \sum_t Z_{rt}^{j} H_t^{ij} + \sum_k \sum_r \sum_t Q_{rt}^{k} H_t^{ij} +$$
$$\sum_i \sum_r \sum_t W_{rt}^{l} H_t^{ij} + \sum_k \sum_l \sum_r \sum_t E_{rt}^{kl} H_t^{ij}$$

Facility capacity constraints in forward logistic:

$$\sum_j \sum_t X_{rt}^{ij} \leq Ca_r^i; \quad \forall_{i,j}$$
$$\sum_j Z_{rt}^{j} + \sum_k \sum_t Y_{rt}^{jk} \leq Ca_r^j; \quad \forall_{j,k}$$
$$\sum_k \sum_t Q_{rt}^{k} + \sum_l \sum_t W_{rt}^{l} \leq Ca_r; \quad \forall_r$$
$$\sum_l \sum_k E_{rt}^{kl} \leq Ca_r^k; \quad \forall_{k,l}$$

The equilibrium constraints in forward logistic:

$$\sum_j \sum_t X_{rt}^{ij} = \sum_k Z_{rt}^{j} + \sum_k \sum_t Y_{rt}^{jk}$$
$$\sum_k Z_{rt}^{j} = \sum_k \sum_t Q_{rt}^{k} + \sum_l \sum_t W_{rt}^{l}$$

$$\sum_{k}\sum_{t} Y_{rt}^{jk} + \sum_{k}\sum_{t} Q_{rt}^{k} = \sum_{l}\sum_{k} E_{rt}^{kl}$$

$$\sum_{l}\sum_{t} W_{rt}^{l} + \sum_{l}\sum_{k} E_{rt}^{kl} = De_{r}^{l}$$

Minimum total carbon emission in forward logistic:

$$P_{g}^{CO2}\Big(\sum_{i}\sum_{j}\sum_{r}\sum_{t} X_{rt}^{ij}\, CO2^{ikt} + \sum_{j}\sum_{k}\sum_{r}\sum_{t} Y_{rt}^{jk}\, CO2^{jkt} + \sum_{j}\sum_{r}\sum_{t} Z_{rt}^{j}\, CO2_{t}^{jt} + \sum_{k}\sum_{r}\sum_{t} Q_{rt}^{k}\, CO2^{lt} + \sum_{i}\sum_{r}\sum_{t} W_{rt}^{l}\, CO2^{kt} + \sum_{k}\sum_{l}\sum_{r}\sum_{t} E_{rt}^{kl}\, CO2^{klt}\Big)$$

Facility capacity constraints:

$$\sum_{j}\sum_{t} X_{rt}^{ij} \le Ca_{r}^{i}; \quad \forall_{i,j}$$

$$\sum_{j} Z_{rt}^{j} + \sum_{k}\sum_{t} Y_{rt}^{jk} \le Ca_{r}^{j}; \quad \forall_{j,k}$$

$$\sum_{k}\sum_{t} Q_{rt}^{k} + \sum_{l}\sum_{t} W_{rt}^{l} \le Ca_{r}; \quad \forall_{r}$$

$$\sum_{l}\sum_{k} E_{rt}^{kl} \le Ca_{r}^{k}; \quad \forall_{k,l}$$

The equilibrium constraints:

$$\sum_{j}\sum_{t} X_{rt}^{ij} = \sum_{k} Z_{rt}^{j} + \sum_{k}\sum_{t} Y_{rt}^{jk}$$

$$\sum_{k} Z_{rt}^{j} = \sum_{k}\sum_{t} Q_{rt}^{k} + \sum_{l}\sum_{t} W_{rt}^{l}$$

$$\sum_{k}\sum_{t} Y_{rt}^{jk} + \sum_{k}\sum_{t} Q_{rt}^{k} = \sum_{l}\sum_{k} E_{rt}^{kl}$$

$$\sum_{l}\sum_{t} W_{rt}^{l} + \sum_{l}\sum_{k} E_{rt}^{kl} = De_{r}^{l}$$

4. Data Analysis and Result

RFL group is a leading plastic material manufacturer consisting more than 100 distribution center, and more than 1000 retailer. To avoid excessive complexity, we consider one supplier, one plant, one warehouse, two distribution center, three retailers were considered as customer in our calculation. Two different type of trucks were also considered. One is light truck and another one is heavy truck.

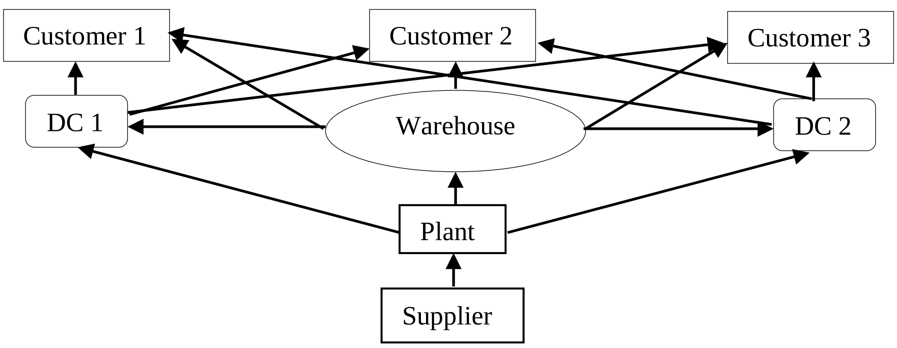

Fig. 1. Model network of forward logistics

4.1 Transportation cost calculation in forward logistic

Unit transportation cost of proposed supply chain network through supplier, plant, warehouse, distribution center and customer was shown in table 2 to 4. Table 5 and 6 showed that unit materials capacity and transportation equipment capacity for distribution of materials and product. Customer demand was shown in table 7.

Table 2. Transportation cost of supplier-plant-warehouse-DC (Tk./unit)

	Supplier	Plant	Warehouse	
	Plant	Warehouse	DC 1	DC 2
Truck (L)	1.67	0.80	1.49	1.98
Truck (H)	1.80	0.78	1.31	1.76

Table 3. Transportation cost of plant-DC, warehouse-customer (Tk./unit)

Plant			Warehouse		
	DC 1	DC 2	Customer 1	Customer 2	Customer 3
Truck (L)	1.2	1.1	0.81	1.89	2.37
Truck (H)	1.02	0.97	0.97	1.80	2.32

Table 4. Unit Transportation cost of DC-Customer (Tk./unit)

	Distribution Centre					
	DC 1			DC 2		
	Customer 1	Customer 2	Customer 3	Customer 1	Customer 2	Customer 3
Truck (L)	1.79	1.00	2.62	1.05	2.38	1.13
Truck (H)	1.43	0.96	2.90	1.01	2.23	1.06

Table 5. Material capacities of Suppliers-Plants-Warehouse-Distribution Centers (unit)

	Supplier	Plant	Warehouse	Distribution Centre	
				DC 1	DC 2
Material Capacity	13000	12000	8400	6000	5500

Table 6. Transportation equipment capacity (unit/truck)

	Supplier	Plant	Warehouse	Distribution Centre
Truck (L)	6000	5000	4500	4200
Truck (H)	7800	7200	6600	5500

Table 7. Customer Demand (Unit)

Customer	Customer 1	Customer 2	Customer 3
Demand (Unit)	4950	2850	3200

Traditionally, the company uses the light weight truck as their logistical support. Total transportation cost of this logistic system is Tk. 77,806.5. The same Linear programming model with LINGO 14.0 was solved, and the optimum value is Tk. 28710.0.

4.2 GHG emission and penalty calculation for forward logistic

CO_2 emission rate for trucks through supplier, plant, warehouse, distribution center and customer was shown in table 8 to 10. Minimization of total transportation cost in forward logistic and minimization of total CO_2 emission and penalty cost was shown in table 11. Also table 11 include the iterations number required to produce the optimization result in Lingo 14.0.

Table 8. CO_2 emission rate for trucks in supplier-plant-warehouse-DC (unit)

	Supplier	Plant	Warehouse	
	Plant	Warehouse	DC 1	DC 2
Truck (L)	8.23	1.74	7.59	8.39
Truck (H)	6.70	1.62	7.05	8.11

Table 9. CO_2 emission rate for trucks in plant-DC, warehouse-customer (unit)

	Plant		Warehouse		
	DC 1	DC 2	Customer 1	Customer 2	Customer 3
Truck (L)	7.65	7.52	5.07	7.40	18.2
Truck (H)	6.92	6.63	5.16	7.19	17.35

Table 10. CO_2 emission rate for trucks in DC-customer (unit)

	Distribution Centre					
	DC 1			DC 2		
	Customer 1	Customer 2	Customer 3	Customer 1	Customer 2	Customer 3
Truck (L)	9.23	5.22	22.7	5.40	16.20	8.43
Truck (H)	8.92	4.90	20.70	4.96	15.57	8.20

Table 11. Result evaluation

Definition	Value	Iteration number	Time required (sec)
Minimization of total transportation cost in forward logistic	Tk. 28710	3	0.05
Minimization of total CO_2 emission and penalty cost	Tk. 4567	2	0.04

With using LINGO 14.0 optimum carbon emission is 1,11,340.00 grams. For a small plant penalty is imposed after emission of 20kg CO_2. Penalty is counted for (111340.0-20000 = 91340gram) CO_2 emission. Total penalty cost is Tk. 4567.

5. Discussion

Companies have made tremendous strides in automating transaction processing and data capture related to green supply chain and logistics forward operations. While these innovations have reduced cost by reducing manual effort. In this study cost minimization and GHG gas emission penalty cost for forward logistics was determined according to the mathematical model by using Lingo 14.0. After iteration 3, minimization of total transportation cost in forward logistics was Tk. 28710 generated in 0.05 sec. Also minimization of total CO_2 emission and penalty cost was Tk. 4567 generated after iteration 2.

6. Conclusion

Changes in the state of the environment, leading to subsequent public pressure and environmental legislation have necessitated a fundamental shift in supply chain practices. The distinguishing feature of the proposed model is considering the environmental effects on supply chains. In this study, a mathematical model to solve the Green supply chain management problems which are emerged because of environmental responsibilities was proposed and developed. This study helps organizations to take decisions for transportation concern with the environmental effect.

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8. References

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