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Design of Sustainable supply chain based on the Kyoto Protocol with random parameters

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ABSTRACT

Emissions trading mechanism is one of the referred mechanisms under the Kyoto Protocol to control emission of environmental pollutants. This article looks at the strategic design of a supply chain in business environment of emission permits with respect to uncertain parameters and budget restriction. Demand and price of emission permits are as random influential parameters into the network design. Trading of emission permits on the open market has faced its price with high uncertainty to a large extent that this action can exacerbate industries uncertainty to these permits. Therefore a random two-stage programming model is offered in which price change of emission permit can be presented in the form of different scenarios and then the impact of the price change and the impact of budget changes on the network design can be checked and the value of random answers can be calculated. It can be predicted that using random planning with respect to emissions trading will make changes in the structure of the network and reduce costs.
KEYWORDS: Supply chain network design, green supply chain, emissions trading, two-stage planning.

1. INTRODUCTION

Supply chain network design is a fundamental decision in the supply chain management (SCM) including decisions on the number, location, capacity and technology of plants and distribution centers at the strategic level and decisions about flow of goods and raw materials and how to allocate the goods to clients at the tactical level [1]. Implementation of strategic decisions requires massive spending. Changes after establishing the plants and distribution centers hardly can be done and need high costs. The strategic decisions should be taken in such ways that have minimum distance with the optimum conditions by passage of time and changes in conditions. Target selection and identification of present and future conditions have great contribution in taking strategic decisions. Minimizing the network costs is considered as a purpose by most network designers [2]. But in addition to economic goals other goals can be considered into the network design. One of the targets in recent decades attracted the attention of producers is to minimize environmental pollution. Focus on minimizing environmental pollution in addition to economic issues into the supply chain network design caused the emergence of green supply chain network design concept that is capable of two of the three factors of sustainable development. Economic, environmental and social goals should be considered at the same time in the Sustainable development. Air Pollution Minimization [3] and Products gathering and recycling at the end of their useful life [4] are Examples of environmental targets and the impact of plant establishing in region growth [5] is an example of social targets. This study focuses on minimizing air pollution in production, warehousing and distribution sections based on emissions trading in which some parameters of the problem are uncertain.

For each chain a restriction of generating Pollutants, by the allocation of permits for emission, is defined which chains are allowed to buy and sell the permits. Each chain is allowed to produce contamination up to maximum permissible permits (after dealing permits).So each chain must decide to use better technology (from the environmental point of view) for the production and transportation and reduce pollutant or buy permits to meet the needs. Given that the dealing happens in the free market, the price of emission permits are determined on the basis of supply and demand and have high uncertainty. A way to deal with uncertainty in this problem is to place Mathematical expectation of parameters instead of them. Results obtained in this case are not necessarily optimal and can be far from optimal solutions or for some scenarios not feasible [6]. To solve this problem, different scenarios can be considered for parameters and two-stage random planning can be used with regard to the nature of the two-stage supply chain network decisions [7]. Bojarski et al. [8] presented a three-target model which includes: minimizing chain pollution, minimizing the amount of impact 2002, maximizing profits and decide about the location and capacity of plant and flowing of goods in the chain during different periods. Chaabane et al. [9] presented a two-target model which includes: minimizing costs (supply chain

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costs and emission permits costs) and minimizing the amount of greenhouse gases. They also added a decision to the subject which was about the type of technology used in the plants. abdallah et al. [10] presented a model in which environmental issues have been entered in model using emissions trading cost in the objective function; They have considered Pollution levels of distribution and supply providing a comprehensive model. Kannan et al. [11] designed a reverse logistics network and a decision about the location and capacity of the facility with the aim of minimizing the chain costs and expenses of the emissions trading cost. Chaabane et al. [12] have considered the output amount of greenhouse gases in goods production and supplied energy production for calculating the pollution by presenting a two-target model and have designed a closed supply chain network based on emissions trading. In all cases examined, all the parameters are modeled definitively. G.Guillén-Gosalbez and Grossmann [13] were first ones who entered uncertain environmental parameters into a mathematical model. They have assumed the amount of pollution uncertain for per unit of goods production or transportation in different parts of the supply chain then they have focused on minimizing the chain pollution with a probable limitation of chain pollution. Mspishvaee et al. [14] considered the decision about location, capacity and technology type on the network in a two-target model. They have solved uncertainty of production costs and pollution amount through the model. S.giarola et al. [15] were first ones who have modeled the uncertainty in the price of pollution permits transaction using a random two-stage planning. According to the conducted search, no paper has considered the uncertainty of permit price into green supply chain network design.

2. MATERIAL AND METHOD

2.1. Model formulation

2.1.1. Model description

The problem in the strategic level (the first step in a random two-stage planning) contains: selecting the location, capacity and manufacturing technology, determining the location and capacity of the distribution centers and selecting suppliers among the potential options and at the tactical level (the second step in a random two-stage planning) includes decisions in any scenario about: production rate, transportation rate, type of transportation vehicle, amount of raw materials purchased from each supplier and exchanged emission permits. Products can be made with different technologies and transported with different vehicles. Differences of technologies and transportation vehicle are in terms of pollution and costs. Customers Location should be specific and their demands should be answered. Goods can be sent to customers directly or through storage and transportation vehicles have minimum and maximum capacity. Exchanged permit Price and demand rate will clear at the end of the period and we have scenarios with a specific probability for each of them at the beginning. Deciding on the plants location, capacity and type of technology, capacity and location of warehouses and selection of suppliers will be done at the beginning of the period. At the end of the period after specifying the price of emission permits and demand rate we will discuss about production rate and customers allocating.

2.2. Notation

To formulate the problem following notation is used: sets

I Set of products, indexed by i

R Set of raw material, indexed by r

N Set of suppliers, indexed by n

M Set of plants, indexed by m

H Set of production technology type, indexed by h

U Set of plant's capacity, indexed by u

W Set of distribution centers, indexed by w

V Set of distribution (warehouses) centers Capacity, indexed by v

K Set of transportation vehicles type, indexed by k

J Set of customer, indexed by j

S Set of scenarios, indexed by s

Parameters

π_s Price, in dollars, of buying or selling emission permits in scenario s

d_{ijs} Demand of Product i on city j in scenario s

cap Maximum amount (in tons) of network pollution

f_{mhu} Fixed cost to establish plant m with technology h and capacity u

f'_{wv} Fixed cost to establish warehouse w with capacity v

f''_{n} Annual cost of contract with supplier n

cm_{imh} Cost to produce one unit of product i with technology h in plant m

cs_{rnm} Cost of one kilogram of raw material r from supplier n for plant m

ρ_i Time required producing per unit of product i

ρ'_i Volume of one unit of product i

$\propto_{ri}$ Amount of raw material r needed to build a unit of product i

c_{mhu} Production capacity at plant m with technology h and capacity u

c'_{vw} Storage Capacity in warehouse w with capacity v

c''_{rn} Power of supplier n for raw material r

lb_{abk} Minimum transport between a and b by vehicle k

em_{imh} Pollution produced per unit of product i at plant m with technology h

et_{iabk} Pollution produced for shipping per unit of product i from a to b by k vehicle

lt_{mh} Conversion factor for converting "establishing fixed cost" of plant m with technology h to "annual cost"

lt'_{w} Conversion Factor for converting" cost to establish warehouse w "to annual cost

b Available budget to build plants and distribution centers in the whole network

Decision variables

Q_{imhs} Produced number of product i in plant m with technology h in scenario s

R_{rnms} Amount of raw material r shipped from supplier n to plant m in scenario s

L_{iabks} Number of product i shipped from a to b by vehicle k in scenario s

E_s Transacted number of emission permit in scenario s

$$F_{mhu} \begin{cases} 1 \ \textit{if plant m is established} \text{ with technology h and capacity u} \\ 0 \quad \textit{otherwise} \end{cases}$$

$$F'_{wv} \begin{cases} 1 \quad \textit{if warehouse w is established} \text{ with capacity v} \\ 0 \quad \textit{otherwise} \end{cases}$$

$$F''_{n} \begin{cases} 1 \quad \textit{if supplier n is selected} \\ 0 \quad \textit{otherwise} \end{cases}$$

$$G_{abks} \begin{cases} 1 \ \textit{if} \text{ transportation vehicle type k } \textit{is used} \text{ between a and b in scenario s} \\ 0 \quad \textit{otherwise} \end{cases}$$

2.3. The model

The first stage can be stated as follows:

$$MIN \sum_m \sum_h \sum_u (lt_{mh} f_{mhu}) F_{mhu} + \sum_w \sum_v (lt'_{wv} f'_{wv}) F'_{wv} + \sum_n f''_n F''_n + E_S\big(Q(F, F', F'', S)\big) \qquad (1)$$

S.t.

$$\sum_{m}\sum_{h}\sum_{u} f_{mhu}F_{mhu} + \sum_{w}\sum_{v} f'_{wv}F'_{wv} \leq b \qquad (2)$$

$$\sum_{h}\sum_{u} F_{mhu} \leq 1 \qquad \forall m \qquad (3)$$

$$\sum_{v} F'_{wv} \leq 1 \qquad \forall w \qquad (4)$$

$$\sum_{m}\sum_{h}\sum_{u} c_{mhu}F_{mhu} \geq \sum_{i}\sum_{j} d_{ijs} \qquad \forall s \qquad (5)$$

$$\sum_{n} c''_{rn}F''_{n} \geq \sum_{i}\sum_{j} d_{ijs}\, \alpha_{ri} \qquad \forall\, r, s \qquad (6)$$

$$F_{mhu}, F'_{wv}, F''_{n} \in \{0,1\} \qquad \forall\; n, m, h, u, w, v \qquad (7)$$

So that for each scenario in the second phase:

$$Q(F,F',F'',s) = MIN \sum_{i}\sum_{m}\sum_{w}\sum_{k} ct_{imwk}L_{imwks} + \sum_{i}\sum_{w}\sum_{j}\sum_{k} ct_{iwjk}L_{iwjks}$$
$$+ \sum_{i}\sum_{m}\sum_{j}\sum_{k} ct_{imjk}L_{imjks} + \sum_{i}\sum_{m}\sum_{h} cm_{imh}Q_{imhs}$$
$$+ \sum_{r}\sum_{n}\sum_{m} cs_{rnm}R_{rnms} + \pi_s E_s \qquad (8)$$

s.t.

$$\sum_{i}\sum_{m}\sum_{w}\sum_{k} et_{imwk}L_{imwks} + \sum_{i}\sum_{w}\sum_{j}\sum_{k} et_{iwjk}L_{iwjks}$$
$$+ \sum_{i}\sum_{m}\sum_{j}\sum_{k} et_{imjk}L_{imjks} \sum_{i}\sum_{m}\sum_{h} em_{imh}Q_{imhs} - cap = E_s \qquad (9)$$

$$\sum_{i} \rho_i Q_{imh} \leq \sum_{u} c_{mhu}F_{mhu} \qquad \forall m, h \qquad (10)$$

$$\sum_{i}\sum_{m}\sum_{k} \rho'_{i}L_{imwks} \leq \sum_{v} c'_{wv}F'_{wv} \qquad \forall w \qquad (11)$$

$$\sum_{m} R_{rnms} \leq c''_{rn}F''_{n} \qquad \forall r, n \qquad (12)$$

$$\sum_{i}\sum_{h} \alpha_{ri}Q_{imhs} = \sum_{n} R_{rnms} \qquad \forall r, m \qquad (13)$$

$$\sum_{h} Q_{imhs} = \sum_{w}\sum_{k} L_{imwks} + \sum_{j}\sum_{k} L''_{imjks} \qquad \forall i, m \qquad (14)$$

$$\sum_{m}\sum_{k} L_{imwks} = \sum_{j}\sum_{k} L_{iwjks} \qquad \forall i, w \qquad (15)$$

$$\sum_{w}\sum_{k} L_{iwjks} + \sum_{m}\sum_{k} L_{imjks} \geq d_{ijs} \qquad \forall i, j \qquad (16)$$

$$lb_{mwk}G_{mwks} \leq \sum_{i} \rho'_{i}L_{imwks} \leq ub_{mwk}G_{mwks} \qquad \forall m, w, k \qquad (17)$$

$$lb_{wjk}\, G_{wkjs} \le \sum_{i} \rho'_{i} L_{iwjks} \le ub_{wjk} G_{wjks} \qquad \forall w, j, k \qquad (18)$$

$$lb_{mjk}\, G_{mjks} \le \sum_{i} \rho'_{i} L_{imjks} \le ub_{mjk}\, G_{mjks} \qquad \forall m, j, k \qquad (19)$$

$$F_{mhu}, F'_{wv}, F''_{n}, G_{mwks}, G'_{wjks}, G''_{mjks} \in \{0,1\} \qquad (20)$$

$$Q_{imhs}, R_{rmms}, L_{imwks}, L'_{iwjks}, L''_{imjks} \ge 0 \qquad \forall i, r, n, m, h, u, w, v, k, j$$

$$E_s \text{ is URS}$$

The objective function (1) in the first phase includes annual equation of network creation costs, the cost of contracts with suppliers and expected cost of the second stage. Constraint set Eq. (2) is funding restriction for establishing network facilities. Constraints set Eq. (3)-(4) are reasonable restrictions for creating a facility with unique technology and capacity in each location. Constraints set Eq. (5) - (6) ensure that the answer of the first stage is feasible for all scenarios in second stage. These equations are superfluous restrictions in extended random model. Phrase (8) is objective function for each scenario in the second stage. Constraint set Eq. (9) calculates the amount of required or surplus license. Constraints set Eq. (10)- (11) - (12) are restrictions for plants, warehouses and suppliers of raw material. Constraints set Eq. (13)- (14) - (15) are restrictions for balancing of goods and raw materials on the network nodes. Constraint set Eq. (16) is restriction of each customer demand for each commodity in each scenario. Constraints set Eq. (17)- (18) - (19) are restrictions of capacity for each type of transportation vehicle between any two nodes on the network.

3. CONCLUSION

A randomized two-stage programming model was presented for green supply chain network With regard to the uncertainty of demand and the price of emission permits. It can be shown that the price of emission permits affects the network structure and the network structure will change by its changing. Also With regard to the uncertainty and using random planning the cost of network design and utilization will reduce. In addition to impact on costs and pollution of different parts of the chain, Budget restriction affects network changing by changing emission permit price.

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