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Designing Mathematical Modeling of location Network and Optimal Planning for Supply Chain Demand

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Abstract

In the existing competitive market, proper supply chain management has attracted a lot of attention to increase profitability and customer satisfaction (Khorasani, 2014). Managers and decision-makers may employ policies to survive in this environment; however, the optimal outcome will only be achieved when a precise and comprehensive program is applied (Torabzadeh and Memarian, 2012). Therefore, a detailed design and systematic planning of the supply chain with considering all levels and units to increase the efficiency of the entire supply chain is necessary. On the other hand, since activities in the field of production and distribution directly affect the level of profitability and accountability of the supply chain, unified planning and simultaneous production-distribution is absolutely substantial. The globalization of business in recent years, companies provide their resources as well as more widely distributed products and parts. At the present time, customers need to receive their products faster and with higher reliability. In case, they observe that they often face with delays in delivering goods, they will look for other suppliers. In this study, two main objectives will be considered. The first goal is to reduce the total cost of building the warehouses in the supply chain, and the second goal is to maximize the level of customer satisfaction and service levels.

Keywords: locations, distribution warehouses, mathematical planning.

Introduction:

Effective supply chain management requires the determination of set of criteria and proper improvement models (Khorasani et al, 2015; Elyasi M. et al, 2012b). Moreover, utilization of modern management and effective market trade assists firms to generate benefits. (Khorasani and Almasifard, 2017; Jafarzadeh H. et al, 2017). One of the main factors of efficient supply chain management is facilities location planning. Locating the facilities and routing of the vehicles are interrelated; Maran Zana (1964) showed that the location of factories, product caches, and supply of products are often influenced by transportation costs. Maranzana (1964) research is one of the first study on location-routing. Moreover, the emphasis is on finding the shortest route rather than routing the desired vehicle in many cases. In addition, Rand (1976) revealed that many activists (traders) are from the risks of sub-optimization by locating separate depots

and vehicle routing is well-known, both groups of scientists and traders often ignore this connection. Locating means, usually without routing infrastructure. Three possible reasons for this matter can be determined as follows: (1) When there is no routing problem locating issues, many practical situations are created. In this case, the location-routing process is not an appropriate case for resolution. (2) Some research objectives for location-based routing are based on the inadequacy of routing infrastructure. Meanwhile, locating is considered as a general strategy, while it regards routing as a tactical problem (simple and brief). Paths can be calculated any times; nonetheless, the locations of warehouses remain usually for a very long period. Therefore, their idea is that the combination of location and routing in the context of the same planning for different programs is inappropriate. The authors consider the critics such as using locating routing in paths that are allowed to change. They can reduce the additional costs of a project (Salhi and Naji, 1999, Elyasi M. et al, 2012a; Jafarzadeh H. et al, 2014).

Conceptually, problem of locating routing is much more complicated than the classic positioning problem. Berman (1995) showed that the centrality of communication between executive teams of demand points are facilities in the problem of locating routing. The movement among them all is still unknown Furthermore, it is required to locate unique points of demand with the desired distances in classical placement issues (Hasani, R. et al, 2013; Moradinasab N. et al, 2018).

Clearly, locating routing problem relates to the issue of classic locator and routing of the vehicle. Both issues are referred to as special cases of locating routing problem. If it is necessary for all customers to be directly connected to a warehouse then the locating routing problem becomes a standard positioning problem. On the other hand, if we keep the storage location constant, locating routing problem will be simplified for vehicle routing problem (VRP).

The problem of locating- routing is mathematically modeled as a composite optimization problem. From the training point of view, it forms part of dispersion management (distribution). We note that this is a NP-hard problem (non-deterministic polynomial-time hard), which also includes another NP-hard problem (1- facilities locating and 2- Vehicle Routing Problem).

Review of previous research

Chalida et al (2016) in a study examines the amount of investment to build gas fuels station to increase consumer satisfaction as well as reducing greenhouse gases. In this study, two methods for optimizing the construction site based on probable variables were presented. The result of this study could help reduce greenhouse gases by 27% by constructing optimal locations. Also, consumer satisfaction increases by 45%.

Hajipour et al (2016) presented a multivariate math model based on probable variables for selecting the optimal location of fuel station. In this paper, researchers using cost variables, demand function sought to reduce waiting times in queuing systems. In order to solve this research, Pareto innovative multipurpose method was used. Rooney et al., (2014) provided a sustainable alternative energy management model for remote communities in the Amazon region suitable for community isolation, due to the high cost of exploitation and maintenance for supply to specific consumers are out of reach at small sites using biomass.

Zhan Zhav Jay et al (2013) explore how to create optimization colleagues and the intelligent collection industry in supply chain networks. They employed mathematical models and genetic algorithms, they also developed a model to minimize losses due to delivery delays. Variables used in this research: daily operation time, expected ratio of center manufacturer, industry cycle time, total delay to loss, industry indicator, number of industries, colleagues indicators, number of colleagues in the industry, IS index, ISS number, total number ISS, correct value of n by deleting decimal, operating time for industry colleagues,

time of operation for J industry colleagues at ISK, ISK Industry, delivery time, industry colleagues, delivery time of the associates industry at ISK, the total time of the process from the industry colleagues, the total time of the process from the industry colleagues at ISK.

Biswierger Sarkar et al (2013) studied locating issues for facilities. In the first step, they provided a two-dimensional model. Then, adding a product type, the model has been upgraded to 3D mode and eventually arrived at a four-dimensional model by entering the mode of transportation. They also addressed the issue of reducing the cost of the supply chain network.

Atefeh Baghlian et al (2013) developed a randomized mathematical formula for designing a multi-product supply chain including multi-capacity production facilities, distribution centers and retailers in uncertain markets. In this study, they looked for a discrete set as potential locations for distribution centers and retail outlets. In addition, they examined the impact of strategic location decisions on operational inventory and supply chain decision-making.

Javid Jazzdani et al (2013) studied the location of dairy facilities and dynamic supply chain planning by minimizing the cost of facilities, traffic and transportation of raw / processed milk and dairy products under the uncertainty of demand. They have dynamically proposed the model by changing the transportation network, the investment costs of the facility, the time value of money, and changes in the production process.

Mahmood Ebadian et al (2013) used a simulation method to optimize the bioethanol production chain. In this study, they found that there were additional costs of storage and transportation that would disrupt the optimal cycle of the bioethanol production chain.

Shabani and Solati (2013) examined the integrated integer nonlinear planning to improve the cost competitiveness of forest biomass to produce electricity against wood biomass. In this research, the authors provided a dynamic optimization model developed to maximize the overall value of the supply chain based on the configuration of the forest supply chain and the construction of a biomass power plant. The model presented by these researchers suggested that the investing in a new ash recovery system has economic and environmental benefits for the power plant.

In another study, Fengli-Zhang et al (2012) used the simulation method, relying on the key activities of the production of biotahanol and supply chain. Key activities in this research were harvest / processing, transportation and storage. This model used as system performance criteria for raw materials costs, energy usage and greenhouse gas emissions. Finally, the paper showed that a given model is a useful tool for supply chain management, including the selection of optimal biofuel location facilities, logistics design, inventory management, and information exchange.

Gritt Walter et al (2012) studied the design of regional production networks for the second generation of artificial biofuels in Germany. This research presented the implications for plant benefits as well as a strategy for installing and building capacity. Moreover, they provided an advice to the policy makers and the potential investors. Mashbeh, Ahmadi Javid et al (2010) proposed model that optimized location, allocation, capacity, inventory, and routing decisions simultaneously in a random supply chain system. The results of this study indicated that the proposed model has been considerably effective and efficient. The variables examined in this model are as follows: number of customers in the set, average annual customer demand, annual customer demand variance, annual fixed fee for opening and commissioning the distribution center with the required capacity level, capacity with the distribution center level, transportation costs, annual transportation capacity of a vehicle, the number of visits per car in each year, the cost of inventory per unit of product per year at the distribution center, fixed costs per order of the distribution center and the supplier, lead time, distribution center per year, fixed fee on the shipment from the supplier to the distribution center, cost per unit of transportation from the supplier to the distribution center, customer confirmation percentage, left percentiles, normal standard, random variable, Z, agent weight, transport costs, agent weight, inventory costs.

This study endivoured to provide a model with the usability potential with, which results in highest returns, taking into account real-world variables.

Statement of the research problem

In this research, the design of a multi-level distribution network with inaccurate applications is considered. The variables used in the model include the amount of goods transferred from the factory to the distributor, the amount of goods transmitted from the distributor to the customer, and the design variables. Also, model constraints include satisfying demand by a set of distributors rather than focusing on one of them, factory capacity limitations, capacity of distributors, number of distribution centers and open factories.

This study defined a variable different from that used in previous research to develop a fuzzy linear programming model with different variables from existing models. Such issues are Np-hard issues. In this research, inappropriate demand with appropriate fuzzy numbers is modeled using membership function and the exact equivalent complex integer programming for that writing will be written.

The model will be solvable with optimization software such as Lingo and GAMA, but it loses its performance for large-scale issues. The research conducted in this study utilized the meta-innovative methods and operational research software that provide an answer to the optimal answer applied for large issues. Bandar decomposition method which is an exact solution method, is considered for problem solving.

4. General procedure of research (research stages)

4-1- Introductory and familiarization stage

1. Introduction to supply chain distribution network
2. Design of supply chain distribution network (proposed case study in the automotive industry).

4-2. The modeling and solving stage

1. Determine model assumptions
2. Mathematical modeling (definition of variables, parameters, determine goal and constraints).
3. Differentiating the definite and uncertain parameters
4. Determining the values of the parameters, solving the model and checking the quality of the solutions (sensitivity analysis)
5. Mathematical modeling

In this section, we will design a mathematical model for the problem under study. In the following, we introduce the indexes and variables used in this model.

5-1- Indexes

C : Product collection
P : Manufacturing complex
J : Distribution centers
I : Customer set
H : Time series set

5.2 Parameters

FC_{ph} : fixed factory annual cost p per period h
FC'_{jh} : annual cost of the distribution center j in the period h

LC_{pchj} : Cost of goods transportation c in the period h from factory p to distribution center j

LC'_{jchi} : cost of goods transportation c in the period h from the distribution center j to the customer i

$\tilde{d}_{ich}$: Customer demand i for goods c in the period h

α_{pc} : Factory capacity p for goods production c

α'_{jc} : Distribution center capacity j for goods c

P_{upper} : upper limit of the existing factories

J_{upper} : upper limit of the existing distribution centers

5-3 Decision variables

X_{pchj} : Transportation of goods c in the period h from factory p to distribution center j

Y_{jchi} : Transportation of goods c in the period h from the distribution center j to the customer i

Z_{ph} : If the plant p produces in the period h, it equals one, otherwise it is zero

Z'_{jh} : If the distribution center j in the period h distribution equals one, otherwise it is zero

LQ_{chj} : The remaining amount of goods c in the period h at the distribution center j

4-5 Target function

$$Min \quad Z = \sum_{p=1}\sum_{c=1}\sum_{h=1}\sum_{j=1} LC_{pchj} \cdot X_{pchj} \cdot \alpha'_{jc}$$
$$+ \sum_{p=1}\sum_{c=1}\sum_{h=1}\sum_{j=1} LC'_{jchi} \cdot Y_{jchi} \cdot \tilde{d}_{ich}$$
$$+ \sum_{p=1}\sum_{h=1} FC_{ph} \cdot Z_{ph} + \sum_{p=1}\sum_{h=1} FC'_{jh} \cdot Z'_{jh}$$

The above objective function includes: the cost of transportation from the factory to the customer centers at different times, the shipping costs of a distribution center or distribution centers at different intervals, depending on the volume of goods moving to customers and at the end of the cost fixed factory setting and distribution centers according to their existing capacity.

5.5. Constraints

$$\sum_{j-1}^{j} Y_{jchi} \le 1 \qquad \forall i,c,h \qquad (1)$$

$$\sum_{j-1}^{j} X_{pchj} \cdot \alpha'_{jc} \le Z_{ph} \cdot \alpha_{ph} \qquad \forall p,h,c \tag{2}$$

$$LQ_{chj} = \sum_{j-1}^{j} X_{pchi} \cdot \alpha'_{jc} - \sum_{j-1}^{j} Y_{jchi} \cdot d_{ich} + LQ_{c(h-1)j} \qquad \forall j,h,c \tag{3}$$

$$\sum_{j-1}^{j} Y_{jchi} \cdot d_{ich} \le LQ_{chj} \le Z'_{jh} \cdot \alpha'_{jh} \qquad \forall j,h,c \tag{4}$$

$$\sum_{p=1}^{p} Z_{ph} = P_{upper} \qquad \forall h \tag{5}$$

$$\sum_{j=1}^{j} Z'_{jh} = J_{upper} \qquad \forall h \tag{6}$$

$$Z_{ph}, Z'_{jh} \in \{0,1\}, \qquad 0 \le X_{pchi}, Y_{jchi} \le 1 \tag{7}$$

Constraint (1) shows a small fraction of the demand for each commodity in each planning horizon according to existing customers. However, a potential customer can supply their products from a set of distributors rather than focusing on a distributor. Constraint (2) ensures that the amount of goods shipped from the factory to distributors does not exceed the capacity of the plant during the time period specified. Constraint (3) indicates that the left amount for each commodity and distributor in each period can be reduced by the total amount shipped to customers from a distributor and the total amount of freight calculated in previous periods added to the left. Constraint (4) is like constraint (2), but with the difference to ship the goods from the distributor to the customer. Constraint (5) and (6) representing the maximum observance, respectively, are the power of production and distribution.

Designed Example

Examples of the research are related to the distribution company of food industry, which is evaluated in this section using the model presented in the previous section. In this example, the company surveyed is a complete production unit that produces 3 different product types. For these products, they need a warehouse of manufactured goods and distribution centers for these goods to various cities. Customers of this company are considered in each of the 3 provinces of the country. For this purpose, there are seven locations for set up warehousing and three locations for the establishment of distribution centers.

By solving the model, it is determined the best places to build warehouses and distribution centers and the production and delivery schedule between the factory, the warehouses, and the distribution centers of this company. In the following, input values are expressed for the parameters defined in the mathematical model.

Table 1: input data of used indexes

no	Parameter	amount	Unit of measurement
1	C	3	product
2	P	1	factory
3	J	3	Potential Distribution Centers

4	I	4	Place of customers
5	H	2	Season (time period)

According to the field research data, the input parameters of the model are as follows.

Table 2: fixed factory annual cost p per period h

factory	time period	
	1	**2**
1	4000	5500

Table 3: annual cost of the distribution center j in the period h

distribution centers	time period	
	1	**2**
1	432	534
2	324	365
3	132	435

Table 4: Cost of goods transportation c in the period h from factory p to distribution center j

distribution centers	time period	
	1	**2**
1	23	22
2	32	41
3	12	17

Table 5: Cost of goods transportation 2in the period h from factory p to distribution center j

distribution centers	time period	
	1	**2**
1	23	18
2	17	13
3	27	21

Table 6: Cost of goods transportation 3in the period h from factory p to distribution center j

distribution centers	time period	
	1	**2**
1	22	20
2	8	11
3	16	8

Table 7: cost of goods transportation 1 in the period 1 from the distribution center j to the customer i

distribution centers	customer		
	1	**2**	**3**
1	4	3	2
2	3	2	3
3	2	1	5

Table 8: cost of goods transportation 2 in the period 1 from the distribution center j to the customer i

distribution centers	customer		
	1	**2**	**3**
1	3	6	9
2	4	7	11
3	5	4	2

Table 9: cost of goods transportation 3 in the period 1 from the distribution center j to the customer i

distribution centers	customer		
	1	**2**	**3**
1	4	7	6
2	8	5	7
3	4	3	4

Table 10: cost of goods transportation 1 in the period 2 from the distribution center j to the customer i

distribution centers	customer		
	1	**2**	**3**
1	8	5	7
2	12	5	3
3	4	3	6

Table11: cost of goods transportation 2 in the period 2 from the distribution center j to the customer i

distribution centers	customer		
	1	**2**	**3**
1	7	6	3
2	3	6	4
3	6	13	8

Table 12: cost of goods transportation 3 in the period 2 from the distribution center j to the customer i

distribution centers	customer		
	1	**2**	**3**
1	5	9	1
2	2	5	4
3	1	3	3

Table 13: Customer demand i for goods c in the period 1

goods	customer		
	1	2	3
1	12	43	23
2	23	24	44
3	32	12	13

Table 14: Customer demand i for goods c in the period 2

goods	customer		
	1	2	3
1	18	15	25
2	17	27	32
3	29	16	14

Table 15: Factory capacity 1 for goods production c

factory	goods		
	1	2	3
1	323	325	534

Table 16: Distribution center capacity j for goods c

distribution centers	goods		
	1	2	3
1	56	87	93
2	43	78	67
3	44	76	84

6-1 Solving the model

Because of the complexity of the model in terms of the number of variables, constraints and data, the model was programmed in the space of the collections in the GOM software version 24, model input data call from Excel, so computational efficiency of the model increased. The output is as follows:

Table 17: Optimal value of cost

no	Parameter	amount
1	Cost of transportation from factory to customer centers at different time intervals	390
2	Cost of transportation from a distribution center or distribution center at different intervals	270
3	The fixed cost of setting up the plant and distribution centers according to their available capacity	550
4	Total cost	210

According to the outcomes presented, the advantages of this research are that the final output of the model is not just one answer, i.e., different answers are presented. This mode allows the company's management to choose between different path and different times; from a different time, analysis, if the company pays more to build, produce, and distribute, customer satisfaction will increase. And vice versa, as much as we reduce construction, customer satisfaction also decreased.

Therefore, finding the exchange rate between costs and customer satisfaction is one of the key management decisions in this area.

Conclusion:

In this study, location analysis in multilevel supply chain was investigated. In this issue, there is a need for a comprehensive supply chain approach to determine strategic decisions, therefore, indicators such as the amount of production, storage volume and distribution in supply chain were also investigated. These surveys help to provide a more comprehensive view of the location of warehouses and distribution centers in the supply chain. Accordingly, in this research, a new mathematical model for multilevel location in the supply chain was presented. In this model, considering the fixed and variable annual costs, it attempted to minimize the total cost of the supply chain. Since determining the optimal location of warehouses depends on the amount of production and distribution, therefore, the variables of production and storage rates are also considered in the mathematical model. Also, in order to determine the optimal location of distribution centers, the importance of sending goods at the chain level is important. Therefore, the variables of distribution decision among the chain members are also considered in the mathematical model. Determining the exact amount of demand for manufactured products in a supply chain is always one of the most difficult tasks and will surely have errors. For this reason, the demand for products is uncertainty in this model. This uncertainty has been introduced in the form of several time periods for non-deterministic parameters. The results show that despite the uncertainty in demand, if the company sustains more conventional charges for the establishment of warehouses and distribution centers, customer satisfaction will increase. According to the mathematical model, the constraints such as the production balance in different periods, factory production capacity, strength of warehouses and distribution centers and the supply chain constraints accordingly, restrictions such as the relationship between the distribution and establishment of warehouses and distribution centers are among the most important limitations of this issue. All in all, the optimization of facilities locations enables firms to diminish their costs. This cost reduction leads to increase in power of corporation to obtain more efficient trade (Almasifard and Khorasani, 2017). In order to continue this topic in the future research, the following suggestion are proposed as: considering the uncertainty in demand as fuzzy numbers, studying the effect of whipping leather on multilevel location in the supply chain, comparing the algorithm of birds with other macro-algorithms in solving the problem, examining the proposed model for susceptible and perishable goods, integration of the issue with the issue of vehicle routing to determine the route of movement of vehicles distributing goods.

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