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Optimization and Modelling of Dynamic Facility Location for Complexities and Simple Problems

Dr.V.Kandavel [#1], Dr.S.Guharaja [*2] Dr.G.Sankaranarayanan[#3] Dr.K.A.Sundararaman[#4]
Mr.R.Dhileepan kumarasamy[#5]
[#]*Associate Professor & Department of Mechanical Engineering& SSM Institute of Engineering and Technology, Dindigul- Palani Highway, Sindalagundu post, Dindigul, Tamilnadu, India.*

Abstract

In particular, the dynamic facility location is a system that promotes vibrant arrangement to be designed for single or multiple facilities. The present work deals with optimal location facilities for a given set of service points based on demand. The system depends on several parameters like the distance between facility locations, the cost of transportation, and the quantity of supply. The fuzzy and graph theory-based algorithm is used to find the demand with the optimal location of the facility in the dynamic facility location system, to minimize the distance of transportation and which in turn lowers the transportation cost. A numerical illustration is used to demonstrate the implementation of a fuzzy approach to determine the optimal location of the facility, and a case study is used for the implementation of the Graph theory.

Keywords - *Dynamic Facility location, Graph theory, Meta-heuristics, Fuzzy.*

I. INTRODUCTION

The dynamic facility location problem (DFLP) is further classified based on the cause of change and uncertainty in the conditions. Accordingly, the two categories of DFLP are (i) the conditions are deterministic and time-dependent and (ii) stochastic and time-dependent (Owen and Daskin 1998). DFLP has been proved its establishment in the area within dynamic in nature problems and also provides altering parameters and uncertain decision variables in an FLP which is common for an organization to consider relocating its facilities over the planning time horizon because the main parameters of models may change as a consequence of a lot of parameters like the interaction of customers and suppliers, distribution networks, business climate, and government legislation (A B Arbani & R Z Farahani 2012).

Parameters influencing the dynamic facility location problem

In the case of location time, facilities-relocation can be done at the discrete or continuous time. For the discrete-time facility, the relocation of one Facility or several facilities is allowed to define, predetermined, and discrete points of time. But for the continuous-time, the predetermined time points for relocation do not subsist, and in any time during these relocations are permissible during the planning horizon. Furthermore, in the case of relocation number, a single relocation called server is present, or multiple relocations (Farahani, Drezner, & Asgari, 2009). Lastly, for relocation costs, it is clear that this cost depends mainly on the facility's present and upcoming locations. Moreover, (Min and Melachrinoudis 1999) presumed that the relocation decision of a facility is affected by many factors and the most significant ones are as follows: (i).cost of land acquisition, permits for zone, building construction, moving equipment, and personnel, etc., (ii).accessibility and quick delivery to customers, (iii) reachability to suppliers, (iv) easy access to transportation networks, (v) tax incentives, (vi) quality of labor and (vii) labor-management relations. Based on these factors, a decision-maker might come up with the relocation problem's subsequent points to minimize the cost, when and where to relocate the facility, and how to uniformly clear the existing facilities without violating the organization's activities. In a two-echelon entity, how to fulfill the organization's targets for small periods, and what is the schedule for relocating capacity? Then, how much cost minimization be able to be compensated by dropping transit epochs and then how to take advantage of local incentives. (A B Arbani & R Z Farahani 2012)

In conclusion, as one of the most important derivations of FLRPs, it should be noted that Emergency Medical Services (EMSs) pertains to this perception to guarantee suitable retort time to events. (Alanis, Ingolfsson, and Kolfal 2010) have analyzed an EMS system by a two-dimensional Markov chain model. Moreover, Harewood 2002 took a case study of an ambulance operational problem with multiple point functions which are cost minimization and customer’s maximum coverage and (Maxwell, Restrepo, Henderson, and Topaloglu 2010) projected a decision making problem of ambulance redeployment solved by a dynamic programming method. Thus researchers consider two important measures that can fulfill these objectives in minimizing the total traveling cost of commodities and minimizing the maximum travel distance from demand points to their assigned point of distribution locations.

More complex problems considered in this discipline include the placement of multiple facilities, constraints on the locations of facilities, and optimization criteria. The facility location problem generally consists of a set of potential facility sites "L" where a facility can be opened and a set of demand points "D" that must be serviced. The objective is to pick a subset "F" from facilities to open, the sum of distances from each demand point to its nearest facility, and to minimize the sum of opening costs of the facilities.

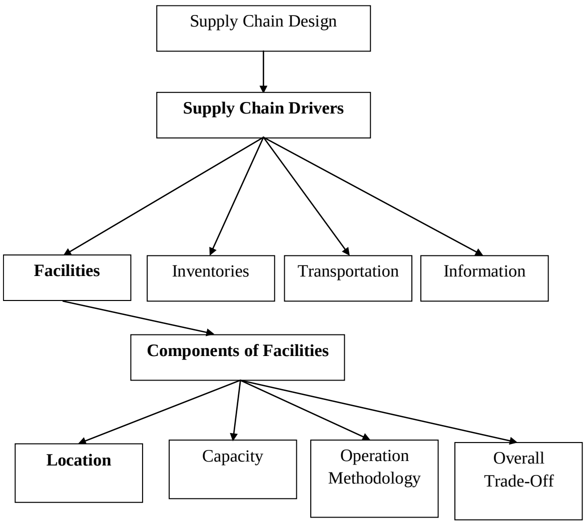

Fig 1: Facility locations with supply chain strategy

Fig 1: shows the importance of location in the implementation of supply chain strategy. The supply chain consists of four drivers namely, i) Facility ii) Inventory iii) Transportation iv) Information. The facility includes the four sub-components, and they are location, capacity, operation-methodology, and overall trade-off. The facility location is one of the significant fields which has a strong impact on the performance of the supply chain.

II. LITERATURE SURVEY

In a location problem, the decision-maker selects a site that is profitable for a defined time horizon. In a location–relocation problem, the decision-maker considers relocating the facility (modifying the current facility) over the planning time horizon in another approach; the dynamic models are grouped into two categories: (i) explicit (ii) implicit (Drezner et al. 1996). Explicit dynamic models are designed for problems in which facilities are opened /closed over a pre-specified time. In implicit problems, all the facilities are to be opened and remained open throughout the planning horizon. The decision to open or close a facility over time depends on the changes in the parameters, which include demand, travel time/cost, available facility, fixed and variable costs, profit, and the number of facilities to be opened. The dynamic facility location problem is further classified based on the cause of change and uncertainty in the conditions. Accordingly, the two categories of DFLP are (i) the conditions are deterministic and time-dependent (ii) stochastic and time-dependent (Owen & Daskin 1998).

A. Graph Theory Model (GTM)

Graph theory presents a methodology for applying annealing techniques to multisource absolute location problems on the graph. A class of new algorithms is described. Its development starts from the iterative cluster-and-locate algorithm and purely depends upon the relaxation of the internality constraints on allocation variables.

The other objective function, optimized by middle point, is very widely known in the literature about location problems; from the viewpoint of the application, it is important in the location of emergency facilities, while the goodness of a solution must be evaluated in the worst-case, which is for the farthest user.

B. Meta-Heuristic (SS, ITS, NABC, ACO, PSO, etc,)

In the direction of developing facility location using meta-heuristics such as Scatter Search algorithm (SS), Improved Tabu Search (ITS), Novel Artificial Bees Colony (NABC) algorithm, Ant colony algorithm (ACO) and Particle Swarm Optimization (PSO), etc., the facility allocation and relocation are observed. Several research guidelines are pointed out and discussed for the DFL. A problem with facility location will be close and applicable to the real-life or industrial scenario if we can incorporate all the existing objectives with all the uncertainty or fuzziness. Ranjan Bhattacharya & Susmita Bandyopadhyay (2010) dealt with this problem in this work is an initiation of research towards that direction.

C. Fuzzy Logic

Recently, the fuzzy purposes in FLPs are very promising, and different fuzzy approaches have been employed. Yang et al. (2007) proposed a method combining fuzzy multiobjective programming and a genetic algorithm to determine the optimal of fire station facilities. Chou et al. (2008) solved facility location problems using a system named fuzzy simple additive weighting system (FSAWS), which integrates with fuzzy set theory, the factor rating system, and simple additive weighting. Liu et al. (2008) solved the supply chain network design problem of Luzhou Ltd, a Chinese liquor industry using a multiobjective mixed-integer programming model to minimize total cost and maximize customer services.

Bashiri et al. (2009) solved a multi-facility location problem using a fuzzy group decision support system based on fuzzy inference and fuzzy analytic hierarchy process (FAHP) approach for obtaining weights between facilities, to minimise the total distance traveled between facilities. Sakir Esnaf et al. (2009) presented a fuzzy clustering-based method for multi-facility location problem which optimizes the transportation costs. They presented a solution procedure based on a modification of fuzzy parametric programming and the minimum deviation method. Many researchers have extensively deliberated the FLA problem in a deterministic, stochastic, or fuzzy environment.

D. *Research gap*

Based on the above survey, the conventional financial aspects of DFLPs are just reflected in the literature. However, sustainability is another emerging concept comprising of social and environmental criteria other than economic ones. Therefore, sustainable facility location-allocation and consequently, sustainable, dynamic facility location can be taken into consideration for sustainable location and relocation. Regarding this fact, a trade-off should be established between treating the varying parameters of the problem and maintaining the sustainability of the location decision (Arbani & Farahani 2012).

• The fuzzy modeling and their solution methods on DFLP are found scanty. The application of fuzzy modeling for practical problems is not much found in the literature.

• The graphical approach for solving DFLPs is very few, and they are also not addressing the real cases.

III. MODELLING OF FLPS

The Facility Location problem on general graphs is NP-hard to solve optimally, by reduction from the Set Cover problem. A number of approximation algorithms have been developed for the FLPs and many of its variants. There is no recognized algorithm for answering this NP-hard hitch in polynomial time, and even small instances may require long computation time. The Facility Location problem may be seen as a special case of Quadratic assignment problem (QAP) if one assumes that the flows connect all facilities only along a single ring, all flows have the same non-zero (constant) value.

A. *Dynamic Facility Location with Supply Chain Design*

The significance of facility location decisions with design restraints with an evaluation of conventional simulations includes the conventional permanent charge problems of facility location. Facility location decisions become very costlier and expensive for an organization in a long-term impact on the profit since it is very exclusive to close down a facility or move it to a different location.

A good location decision can help to improve responsiveness while keeping its costs low, which will maximize profit. Various factors may influence facility location decisions. Singh & Sharma (2006) developed a model of facility location problem with conflicting objectives of minimizing the total cost of an echelon and the total cost of the supply chain as a whole.

Table 1 illustrates the articles listed are classified according to two criteria: the type of industry the application that comes from and its context. Melo et al. (2009) The category Case study refers to a real-life scenario, even if it is not implemented in practice, while the category Industrial context stands for a study using randomly generated data for a specific industry.

TABLE I
Applications of facility location in SCM

Sl. No.	Applications of FLPs		
	Industry	**Context**	**Article**
1	Auto-motive	Case study	Fleischmann et al (2006)
			Karabakal et al (2000)
		Industrial context	Nozick and Turnquist (1998)
2	Chemical s	Case study	Canel and Khumawala (2001)
			Jayaraman and Ross (2003)
		Industrial context	Lowe et al (2002)
3	Food	Case study	Wouda et al (2002)
			Leven and Segerstedt (2004)
		Industrial context	Avittathur et al. (2005)
4	Military	Case study	Chan et al. (2001)
5	Other	Case study	Altiparmak et al. (2006)
		Industrial context	Pati et al. (2008)
			Wang et al. (2007)

B. Problem Definition and Working Model

In this research paper, it is aimed to build mathematical models for a variety of facility locations while considering all the issues relating to real-time facility location and to compare the efficiency of the prediction facility location models. The working model is shown in Fig. 2: is developed for suitable solution methodologies using the fuzzy and graph theory method for facility location problems from Sunil C & Peter M (2004).

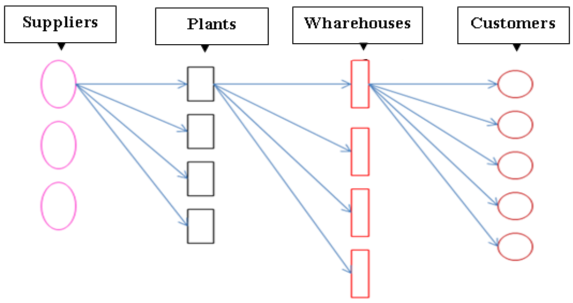

Fig 2: Working model

Dynamic facility location problems formulated the build new facilities or close down already existing facilities at two different distribution levels over a given time horizon. The objective is to identify plant and warehouse location as well as quantities shipped between various points that minimize the total weighted distance

C. Case Study

A case study conducted the data collected at Beverage plant, Central part of Tamilnadu. To validate the performance of the proposed methodologies in terms of solution quality and diversity level, a case study conducted, and to compare and identify suitable solution methods for facility location problems.

The following issues:

• A supply chain with multiple echelons: suppliers, plants, warehouses, customers, etc.

• Multiple products or families of products.

• Complex product flows several layers of plants and warehouses, exchange of products between plants or warehouses, direct deliveries to some customers, reverse logistics, remanufacturing, etc.

• The choice between several transportation modes, several production technologies.

• A variety of constraints: capacity constraints, budget constraints, etc.

• The complex structure of the costs: fixed and variable costs, linear or nonlinear costs.

• Hybrid strategic/tactical models with inventories: average inventory, safety stock, cyclic inventories.

• A supply chain with multiple echelons: suppliers, plants, warehouses, customers, etc.

• Multiple products or families of products.

• Complex product flows several layers of plants and warehouses, exchange of commodities between plants.

Therefore, a general objective problem can be defined to minimize a function f(x) with p shown in Eq.1, (p> 1), Decision variables, and Q objectives (Q>1), subject to several constraints.

Minimize $f(x) = [f1(x), f2(x),\ldots..,fQ(x)]$ (1)

Subject to $x \in X$

Where X is the feasible solution space and

$x = \{x1, x2, xp\}$.

The various detail about the plant id, warehouses are obtained by this window. Here, the grid view about the allocation guides to enter the following required input that needs to be allocated for each warehouse present in the supply chain network.

Finally, the output of the optimum cost and location of each facility and the movement of the order through various facilities at each level of the supply chain network can be obtained in a table form. These table forms denote the optimum cost and optimum network for the supply of the order quantity and the altered factory in case of failure occurrence in any production unit. The details of whole facilities in supply chain network to the order to till the delivery of the product to customer's market potential.

D. Fuzzy logic

Recently, the applications of fuzzy in FLPs are very promising, and different fuzzy approaches have been employed. Yang et al. (2007) proposed a method to determine the optimal fire station facilities by combining fuzzy multiobjective programming and a genetic algorithm. The main motivation for building this optimization model is to make tools available for producers to develop a robust supply chain network design. The modeling approach selected is a fuzzy value-at-risk (VaR) optimization model, in which the uncertain demands and transportation costs are characterized by variable possibility distributions.

The main objective of the function is regarding the problem, which is simply defined as the process of allocating the location to a facility for decision making.

The secondary purpose is to reduce the cost of the material in terms of its movement from the source to the firm.

The simplified formula for the objective function is given in Eq.4.1;

$$C = \left(\sum_{n=8}^{i} Rx * \sum_{n=8}^{i} Cx\right) / \sum_{n=8}^{i} Ax \rightarrow (2)$$

where Rx = resultant of the demand and supply

Cx= cost of transport
Ax= distance between source and firm
X is the set of preferences.
i is the number of preferences.
N=8 is the preference limit

The facility location alternative fuzzy sets are generally represented by the help of the degree that it holds. In general, the sets are taken as Sα, where α is degree value or simply called as crisp. The universal set or the primary set is as follows S1 = ø.

E. Graph Theory

Graph theory has wide applications in the specialization of communication, chemical, civil, electrical and mechanical engineering, architecture, management and control, operational research, computer science, sparse matrix technology, and combinatorial optimization. In recent years, due to the extension of the concepts and applications of the graph theory, the journals are (i) Graph Theory (ii) Journal of Combinatorial Theory A & B (iii) Discrete and Applied Mathematics (iv) SIAM Journal of Discrete Mathematics (v) European Journal of Combinatory.

In the facility location, the selection of warehouse location and allocation of the facilities is very important. One or more vehicles are used to cover all the places. The demands for all the allocated locations should be supplied, and it should be supplied at the required time. To maximize the serviceability and minimize the transportation cost and also to find the average traveling distance from the warehouse. Depending upon the time, the customer's demand is varied. The objective function formulated by (Cami & Deo 2008) is applied in this problem and is given in Eq.3

$$\text{Minimum } Z = \sum_{i=1}^{n} \sum_{j=1}^{m} t_i (1/d_j) \qquad (3)$$

where,

Z = Travelling cost

ti = t1,t2,t3……….tn (Transportation distance)

dj = d1,d2,d3……….dn (Demands)

i = 1,2,3,4……………n (distance travelled between locations)

j = 1, 2, 3, 4……………n (demand in between locations)

Subjected to,

The capacity of the warehouse ⩾ demand of the customer

Average distance travelled should be of minimum distance.

Facility location's decisions are critical to the efficient and effective operation of a supply chain. Plants and warehouses placed without proper planning will lead to high costs and poor service no matter how well inventory policies, transportation plans, and information sharing policies are revised, updated, and optimized. Facilities are located. The facilities tend to be closer to customers resulting in lower transport costs, but higher than facility costs.

F. Result and Discussions

The result that has been gained from the 3D plotter is assumed to be the theoretical value which can be implemented on any practical decision making progress to save its time and also help to reduce the cost. This can also be taken into account by saving some initial cost in account goods.

The output shown from the graph provides the detail and precise values in a simple and brief manner, which leads to achieving the accurate facility location. In accordance with the term of cost reduction, the optimization of facility location is done considering the total factors that are solely responsible for prime cost reduction. The process comprises three phases; the first one is the dynamic selection of the preferences; second is the formulation of a suitable method to solve the problem, and third is the usage of the solver tool to have a brief analysis.

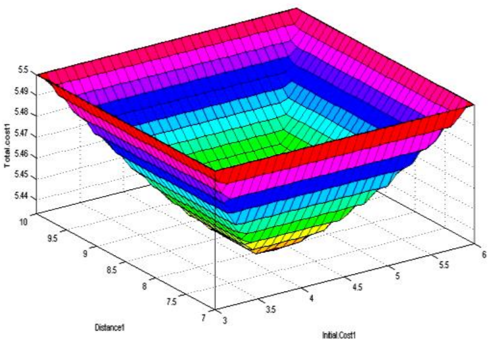

Fig 3: Representing the medium value for the optimal solution

The set of customers and their demands may change daily, resulting in daily route changes, while the facilities are likely to be fixed for years. This problem's main objective is to maximize serviceability and minimize transportation costs and the average traveling distance.

The minimum traveling distance is found by the tool graph theory. The minimum traveling cost is obtained using the objective function. Consider a fault understanding account of the dynamic facility location problem in which every city is required to be connected to facilities. It provides the first graph model for this problem; having an approximation is the requirement of the harmonic number. Models are along the lines for the widespread network problem.

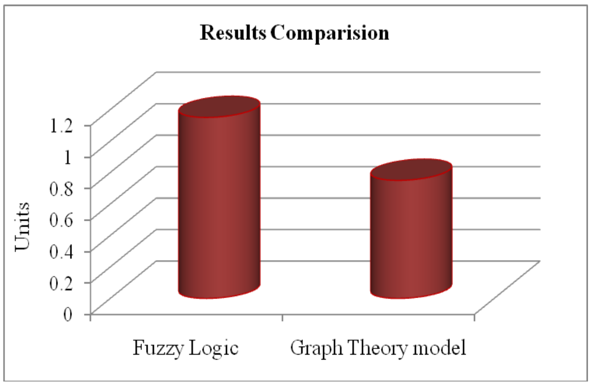

Fig 4: Results comparing fuzzy and graph theory models

Finally, the research paper concluded by the fuzzy and graph theory models are very useful and solve the model quickly with respective large and smaller manufacturing industry of supply chain models. Both fuzzy logic and graph theory model while noting its completing time and then process fuzzy for a larger amount of time, after which the quality of solution can be compared.

The second approach because it is more straightforward, only small industries application, the quality of the solution, wants to be compared. Furthermore, the research reveals that the receipt chance is very insignificant at the end of these results. Continuous implementation of the fuzzy logic is producing any improvement.

IV. CONCLUSIONS

Dynamic decisions are in complex environments. In such situations, the use of fuzzy and graph theory in the progressive condition is necessary; a different value is to be taken into account. More and more in the decision-making location, the theory of fuzzy can be of use.

Two different models of dynamic facility location problems are taken and analyzed over a given time horizon using graph theory and fuzzy logic. The first model is solved by graph theory, and the approach adapted the graph model. Another approach is proposed using fuzzy logic, which solves the problem under an uncertain number of future facilities.

• Graph theory can be applied for simple cases. The graph theory model requires both the location and the facility. In the case of the graph, the theory factors of the model are predictable.

• Moreover, when the complexities of the problem increase i.e., the factors are unpredictable fuzzy performs better. While comparing the results of fuzzy logic and graph theory, the results are better in case of fuzzy logic.

• The accuracy of the results obtained through the fuzzy algorithm is higher than the results obtained through the optimization methods. It can be used to solve the real demand for multiple facility location problems.

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