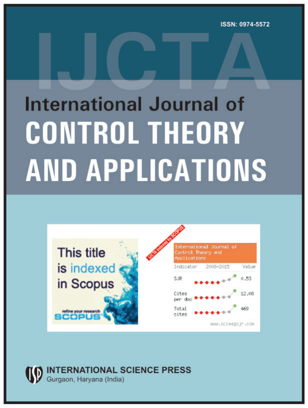

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Dynamic Facility Location-allocation and Relocation with Solving the Competitive Service using Graph Theory: A Case Study

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Abstract: The facility Location-allocation and Relocation problem on general graphs is NP-hard to work out optimally, by decrease from the set cover problem. Many of approximation algorithms have been formulated for the facility Location-allocation problem. A mathematical structure has been used to model pair wise relations between locations. The main objective of this problem is to maximize the serviceability and minimize the transportation cost and the average travelling distance. The minimum travelling distance found by the tool graph theory. The minimum travelling cost obtained by using objective function. Basic concepts of Graph Theory are discussed which are relevant to solving problems of locating economic activities within a service or manufacturing facility. The location problem is formulated in terms of Graph Theory knowledge and a solution procedure proposed. A case study is provided and finally boundary conditions are elaborated.

Keywords: Facility Location, Location-allocation, Relocation, Graph Theory.

1. INTRODUCTION

Facility location is well established research area within operations research. Numerous papers and books are witnesses of this fact. The question of the applicability of location models has always been under discussion. Facility location models have been gradually proposed within the supply chain context (including reverse logistics), thus opening an extremely interesting and fruitful application domain. Facility location-allocation problem is a crucial issue to construct efficient facilities to the customer. In order to determine the delivery location of distribution network, huge data is required e.g. demand of customer, transportation costs and so on.

Moreover, new elements such as marketing and competition with other companies should be considered. Various algorithms have been proposed to solve the problem. Facility of location and graph theory is used to develop the current facility or modify the exits facility in supply chain management.

A. Supply Chain Management

Fierce competitions in today's global markets, the introduction of products with shorter life cycles, and the heightened expectations of customers have forced business. Enterprises to invest in, and focus attention on, their supply chains and continuing advances in communications and transportation technologies (e.g., mobile Communication, Internet, and overnight delivery), has motivated the continuous Evolution of the supply chain and of the techniques to manage it effectively. In a typical supply chain, raw materials are procured and items are produced at one or more factories, shipped to warehouses for intermediate storage, and then shipped to retailers or customers.

Consequently, to reduce cost and improve service levels, effective supply chain strategies must take into account the interactions at the various levels in the supply chain. The supply chain, which is also referred to as the logistics network, consists of suppliers, manufacturing centers, warehouses, distribution centers, and retail outlets, as well as raw materials, work-in-process inventory, and finished products that flow between the facilities. In this work, present and explain concepts, insights, practical tools, and decision support systems important for the effective management of the supply chain. Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfy service level requirements. This definition leads to several observations.

First, supply chain management takes into consideration every facility that has an impact on cost and plays a role in making the product conform to customer requirements: from supplier and manufacturing facilities through warehouses and distribution centers to retailers and stores. Indeed, in some supply chain analysis, it is necessary to account for the suppliers' suppliers and the customers' customers because they have an impact on supply chain performance.

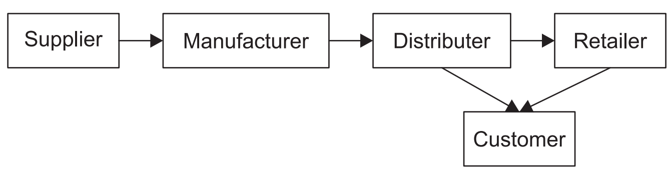

Figure 1: Supply Chain Management

A supply chain is the alignment of firms that bring products or services to market. It is consists of all stages involved, directly or indirectly in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers but also transporters, warehouse, retailers and customers themselves.

Supply chain management is the management of the flow of goods. It includes the movement and storage of raw material, work-in-process inventory, and finished good from point of origin to point of consumption. Supply chain management is "the design, planning, execution, control and monitory of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand and measuring performance globally

B. Facility Location

The facility location problem, also known as location analysis or *k* center problem is a branch of operations research and computational geometry concerned with the optimal placement of facilities to minimize transportation costs while considering factors like avoiding placing hazardous materials near housing and competitor's facilities. The techniques also apply to cluster analysis. A simple facility location problem is the Weber problem, in which a single facility is to be placed, with the only optimization criterion being the minimization of the weighted sum of distances from a given set of point sites. More complex problems considered in this discipline include the placement of multiple facilities, constraints on the locations of facilities, and more complex optimization criteria. In a basic formulation, the facility location problem 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 goal is to pick a subset F of facilities to open, to minimize the sum of distances from each demand point to its nearest facility, plus the sum of opening costs of the facilities. The facility location problem on general graphs solves optimally, by reduction from the set cover problem. A number of approximation algorithms have been developed for the facility location problem and many of its variants. Without assumptions on the set of distances between clients and sites (in particular, without assuming that the distances satisfy the triangle inequality), the problem is known as non-metric facility location and can be approximated to within a factor .This factor is tight, via an approximation-preserving reduction from the set cover problem.

C. Static Facility Location

In static facility location space only consider which doesn't changes with respect to time. By space, a planning area where facilities are located is referred.

D. Dynamic Facility Location

In dynamic facility location, time is considered as a major element. Depending upon time, facilities can be changed. Static facility location problem can be transformed to an equivalent problem to dynamic facility location problem. Both of space and time can be analyzed by discrete and continuous aspects. Dynamic models have a leading role in strategic planning and decision making for FLP, and they are gradually becoming more important due to their vast applicability.

E. Dynamic Facility Location- Allocation and Relocation Problem (DFLAR)

The DFLAR not only looks for the optimal location of facilities, but also tries to optimally assign there facilities to customers in order to fulfill their demand. This problem minimizes the total costs incurred by the allocation of clients. DFLAR problem is to locate a set of new facilities such that the transportation cost from facilities to customers is minimized. In capacitated problems, the allocation of facilities to customer may be constrained due to the capacity limitation of facility, cost, time etc.

F. Graph Theory

Graph Theory Graph theory is a branch of mathematics started by Euler as early as 1736. It took a hundred years before the second important contribution of Kirchhoff had been made for the analysis of electrical networks. Cayley and Sylvester discovered several properties of special types of graphs known as trees. Poincare defined in principle what is known nowadays as the incidence matrix of a graph.

Graph Theory has found many applications in engineering and science, such as chemical, civil, electrical and mechanical engineering, architecture, management and control, communication, operational research, sparse matrix technology, combinatorial optimization, and computer science. In recent years, due to the extension of the concepts and applications of the graph theory, many journals such as Journal of Graph Theory, Journal of Combinatorial Theory A & B, Discrete and Applied Mathematics, SIAM Journal of Discrete Mathematics, European Journal of Combinatory.

There are many physical systems whose performance depends not only on the characteristics of their components, but also on their relative location. As an example, in a structure, if the properties of a member are altered, the overall behavior of the structure will be changed. This indicates that the performance of a structure depends on the characteristics of its members. On the other hand, if the location of a member is changed, the properties of the structure will again be different. Therefore the connectivity (topology) of the structure influences the Performance of the whole structure. Hence it is important to represent a system so that it's topology can be understood clearly. The graph model of a system provides a powerful means for this purpose.

A graph consists of a set N(S) of elements called nodes (vertices or points) and a set M(S) of elements called members (edges or arcs) together with a relation of incidence which associates each member with a pair of nodes, called its ends. Two or more members joining the same pair of are known as a multiple member, and a member joining a node to it is called a loop. A graph with no loops and multiple members is called a simple graph. If N(S) and M(S) are countable sets, then the corresponding graph S is finite. Since the great majority of the results in this book pertain to finite graphs with no loop and multiple members, only simple finite graphs are needed, which are referred to as graphs.

The above definitions correspond to abstract graphs; however, a graph may be visualized as a set of points connected by line segments in Euclidean space. The points are identified with nodes, and the line segments without their end points are identified with members. Such a configuration is known as a topological graph. Graph theory is the study of graphs, which are mathematical structures, used to model pair wise relation between objects. A graph in this context is made up of vertices or nodes and lines called edges that connect them.

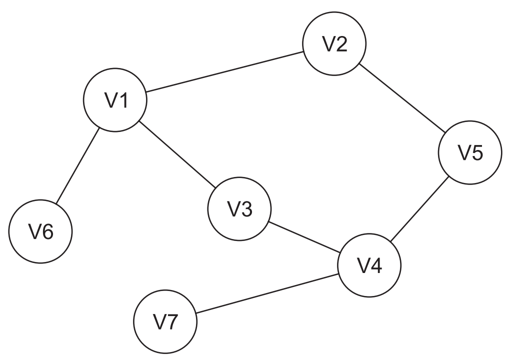

Figure 2: A Simple Graph

A graph may be undirected, meaning that there is no distinction between the vertices associated with each edge or its edges may be directed from one vertex to another. Graph theory is a theory developed to aid in solving of mathematical problems containing vertices. The points and lines are carefully positioned for easy calculation. It is the branch of mathematics concerned about how networks can be encoded and their properties measured. It has been enriched in the last decades by growing influences from studies of social and complex networks. In transport geography most networks have an obvious spatial foundation, namely load transit and rail network which tend to be defined more by their links than by their nodes. This is not necessarily in the case for all transportation networks.

Graph is a mathematical representation diagram. It consists of set of objects called vertices and another set whose elements are called edges. A Graph is also called a linear complex, or one dimensional complex. A Graph has neither self loop nor parallel edges are called a simple graph. In some graph-theory literature, a graph is defined to be only a simple graph, but in most engineering applications it is necessary that parallel edges and self loops be allowed; this is why our definition includes graphs with self loop and/or parallel edges. Some authors use the term general graph to emphasize that parallel edges and self loops are allowed. It should also be noted that, in drawing a graph, it is immaterial whether the lines are drawn straight or curved, long or short: what is important is the incidence between the edges and vertices.

Vertex typically means a corner or a point where lines meet. Example Square has four corners each is called as vertex. The vertices are represented as points and each edge as a line segment joining its end vertices. It is also referred to as a node, a junction, 0 cells, or a 0-simplex.

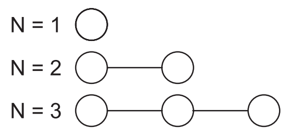

Figure 3: Vertices

Edges called as line which is joining its end vertices. It's also called as element, a branch. In geometry, an edge is a line segment joining to vertices in a polygon, polyhedron, or higher-dimensional poly tope. In graph theory, an edge is an abstract object connecting two graph vertices, unlike polygon and polyhedron edges which have a concrete geometric representation as a line segment.

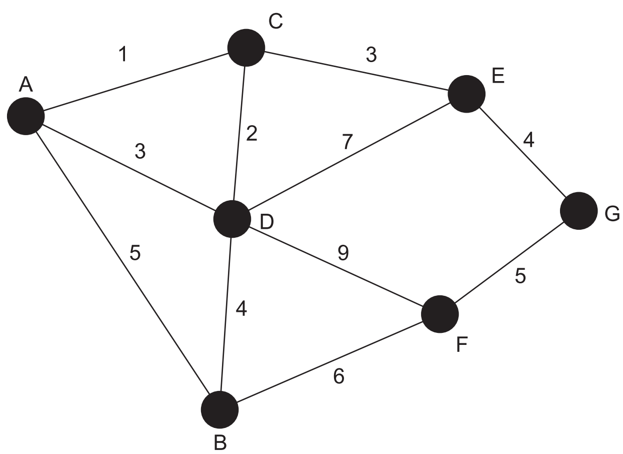

Figure 4: Vertices Connected by Edges

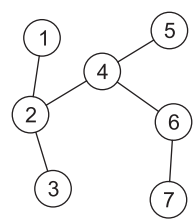

Figure 5: Simple Connected Tree Graph

Tree is a connected graph without any circuits. A graph must have at least one vertex and therefore so must TREE. Some authors NULL TREE, a tree without any vertex we have excluded such an entity from being a tree. Similarly, as we are considering only finite graphs, our tress are also finite. Trees appear in numerous instances. The genealogy of a family is often represented by means of tree. A river with its tributaries and sub tributaries can be represented by a tree. The sorting of mail according to zip code and sorting of punched cards are done by according to a tree.

Graphs provide a uniform model for many structures, for example, maps with distances or Face book relationships. Algorithms on graphs are therefore important to many applications. They will be a central subject in the algorithms courses later in the curriculum; This is start with undirected graphs which consist of a set V of vertices (also called nodes) and a set E of edges, each connecting two different vertices. A graph is connected if we can reach any vertex from any other vertex by following edges in either direction. In a directed graph edges provide a connection from one node to another, but not necessarily in the opposite direction. More mathematically, we say that the edge relation between vertices is symmetric for undirected graphs. In this lecture we only discuss undirected graphs, although directed graphs also play an important role in many applications.

So far we have discussed the tree and its properties, when it's occur as a graph by itself. Now we shall study the tree as a sub graph of another graph. The concept of sub graph is akin to the concept of subset in set theory. A sub graph can be thought of as being contained in another graph. The Graph has a numerous sub graphs. Obviously, some of these sub graphs will be trees. Out of these trees a particularly interested in certain type of trees, called Spanning Tree. It is also quite appropriate to call a spanning tree a maximal tree sub graph. It is to be noted that a spanning tree is defined only for a connected graph, because a tree is always connected, and is disconnected graph of 'n' vertices cannot find a connected sub graph with 'n' vertices.

If a graph is a weighted (i.e., if there is a real number associated with each edge of graph), then the weight of a spanning tree of a graph is defined as the sum of the weights of all branches in trees. In general, different spanning trees of graph will have different weights. Among all the spanning trees of graphs, one with the smallest weight is of practical significance. A spanning tree with the smallest weight in a weighted graph is called a shortest spanning tree.

2. LITERATURE REVIEW

Carlson D, Ronnqvist M (2005) proposed, the location and allocation of regional distribution center is the key problem of logistics distribution network, it concerns that whether the distribution system can perform efficiently. The paper sets up a mathematic location model of generalized transportation costs on basis of economic scale and then solves location and allocation problem of regional distribution center by means of Fuzzy Graph theory. The problem is challenging because two types of facilities are involved and cooperate with each other. This paper proposed a static and transportation facility location allocation algorithm, called STFLS, to solve the problem. The method uses two steps of searching for static facility and transportation facility locations Experiments demonstrate the efficiency and practicality of the algorithm.

Dynamic location problems were first described in a single facility location context. In the first paper in this field (Nathalie Bostel, Oliver Peton A, 2008), the objective was to locate one warehouse in order to maximize profits over a finite planning horizon. The author solves a series of static location problems (one for each time period) and then resorts to dynamic programming. In dynamic facility location problems, there are two main criteria affecting the decision to identify the right location for a facility: Drezner Z, Hamacher H.W (2004) cost for which a trade-off must be set between expenditures incurred by developing new facility or revising the current facility and profits supposed to be acquired as a result of such development. For such facilities, several instances can be pointed out such as warehouses, distribution centers, hospitals, recreation centers, schools, and depots planned for being operable for decades and S.P. Singh et. al., (2006) time for which the opening and closing of facilities are considered over the planning horizon.

Canel C, Khumawala B.M. (2001) Proposed a minimum spanning tree from all the spanning trees with the current minimum spanning tree algorithm, so we hope to present a new algorithm to improve it. The new algorithm is mainly used the binary code and the characteristics of the minimum spanning tree to get all the minimum spanning trees. At first, it eliminates some of the non spanning trees according to the number of the graph edges. It eliminates some of the non-spanning trees according to the judgment of the graph connectivity. In fact, the nature of the algorithm is to look for the best in the global scope. At last, we can find all the minimum spanning trees of the connected graph in view of the algorithm. Kruskal ("On the Shortest Spanning Sub tree of Graph and the Traveling Salesman Problem-1956") and Prim ("Shortest Connection Networks and Some Generalizations-1967") proposed study of shortest spanning trees.

Finally compares the solution of Fuzzy Graph theory with the one of dynamic cluster analysis through an example it shows that the uses of Fuzzy Graph theory in solving this problem can decrease the calculating scale and time evidently, especially when the fuzzy equivalent matrix cannot be ascertained this algorithm is feasible and effective. Static and transportation (Melo M.T. et. al., 2009). This paper solves a static and transportation facility location-allocation problem defined as follows: given a set of locations Loc and a set of demand objects D located in Loc, the goal is to allocate a set of static facilities Sand a set of transportation facilities T to the locations in Loc, which minimizes both the average travelling distance from D to S and the maximum transportation travelling distance between D and S through T. From above literature review, the facility location problems are solved by fuzzy logic, etc., the graph theory used to solve the network problem, transportation problem. But in this problem we use graph theory in facility location-allocation problem.

3. OBJECTIVE

In facility location, the selection of warehouse location and allocation of the facilities is very important. One are more vehicles are used to cover the all the places. The demands for the all the allocated locations should be supplied and it should be supplied at the required time. The main objective of this problem is to maximize the serviceability and minimize the transportation cost and also the average travelling distance from the ware house. Depending upon the time the customer's demands varied. To fulfill their requirements facilities are allocates. Graph theory is used to determine the minimum travelling distance. Spanning tree is a tool of graph theory in this problem.

A. Objective Function

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

where,

Z = Travelling cost

$t_i = t_1, t_2, t_3, ..., t_n$ (Transportation distance)

$d_j = d_1, d_2, d_3, ..., d_n$ (Demands)

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

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

Subjected to,

I. Capacity of the warehouse ≥ demand of the customer.

II. Average travelled distance should be minimum

B. Methodology

To connect 'n' cities ($v_1, v_2, ..., v_n$) through a network of roads the cost c_{ij} of building a direct road between v_i and v_j is given for all pairs of cities where roads can be built. There may be pairs of cities between which no direct road can be built. The problem is then to find the least expensive networks that connect all n cities together. It is immediately evident that this connected network must be a tree: otherwise, we can always remove edges and get a connected graph with smaller weight. Thus the problem of connecting n cities with a least expensive network is the problem of finding a shortest spanning tree in a connected weighted graph of n vertices. To find the shortest spanning tree in a graph, hard and by computer.

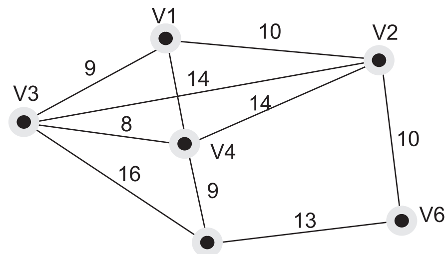

Figure 3: Model Graph

The Above matrix is distances travelled to each action and construct another matrix in terms of demand. One demand matrix also formed by the above procedure. And then minimum distance is achieved in the network.

From the above matrix, we have to find the shortest route. Following procedures are used to find the shortest travelling distance. They are

(a) First find the starting point (V1).

(b) From the starting point the minimum travel distance is noted from the matrix (V3).

(c) Then the next minimum travel distance noted from the previous point.

(d) The procedure is continued until cover the all cities.

Shortest travelled distance for the above problem should be,

V1-V3-V5-V4-V2-V6

4. CASE STUDY

A Sri Varu Vijay trader located at Palani road in Dindigul, Tamilnadu, India. The company started at 2009. The company provided the distributed service in an around the Dindigul like a Palani, Chinnalapatty, etc., To provide fast track service in the area, the shortest distance between one city to another city to minimize the travel distance is found out. The data have been collected from that company, which are demand of the customer at various sites and then travelling distance of the vehicle. The above data are used to analyze the existing travelling distance and demand of the customer.

By using graph theory technique, the shortest travelling distance is found out; at the same time the demand of customer is considered the objective function is used to determine the minimum travelling distance and minimum cost of travelling. Then the existing travelling distance and new travelling distance, are compared to get the suitable solution from above comparisons.

Table 1
Details of Cities

Vertices	*Place*	*Demand*	*Distance from Dindigul*
V1	Dindigul	–	–
V2	Chinallapatty	75	13
V3	Sempati	16	100
V4	Nilakottai	150	∞
V5	Vadipatti	175	36
V6	Natham	200	34
V7	Vadamadurai	100	17

Vertices	*Place*	*Demand*	*Distance from Dindigul*
V8	Vedachandur	150	29
V9	Oddanchatram	100	31
V10	Palani	250	∞

The above map is used to find the shortest distance in between distance. In this map, there are several path is possible to travel different cities in different distances. The distances reach to Natham from Dindigul in different way. Such that V1-V6-V1-V3-V10-V9-V8-V7-V6 etc.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	–	13	16	8	36	34	17	24	31	8
V2	13	–	7.2	22	25	8	8	8	8	8
V3	16	7.2	–	18	8	8	8	8	8	8
V4	8	22	18	–	16	8	8	8	8	8
V5	36	25	8	16	–	8	8	8	8	8
V6	34	8	8	8	8	–	51	8	8	8
V7	17	8	8	8	8	51	–	23	8	8
V8	24	8	8	8	8	8	23	–	24	8
V9	31	8	8	8	8	8	8	24	–	28
V10	8	8	57	8	8	8	8	8	28	–

Figure 4: Matrix for Case Study

Facility location problem is used where to locate the warehouse, minimization transportation cost, increase the service. But in this case study we are handled last two only. Because both are depends one with each other. If travelling distance increase, the company doesn't supply the products at correct time. When a vehicle travels from warehouse to destination, it shouldn't carry the same route again. If it travel same route, it will increase the travel distance which create the increase the travelling cost. The company follows the route of V1-V2-V5-V4-V3-V10-V9-V8-V6. The transport cost of company automatically increased. Due to that problem, service of the company was affected. To rectify the above problem, graph theory technique is used to find the shortest travelling distance

5. RESULT AND DISCUSSION

There are many possible paths are obtained by using program. And few shortest paths are listed below.

Table 2
Results

S.NO	*SHORTEST POSSIBLE PATH*	Z_{min}
1	V1-V2-V5-V4-V3-V10-V9-V8-V6	1.350
2	V1-V5-V4-V3-V10-V9-V8-V7-V6	1.678
3	V1-V5-V4-V2-V3-V10-V9-V5-V7-V6	1.804
4	V1-V3-V10-V9-V8-V7-V6	5.504

5	V1-V6-V7-V8-V9-V10-V3-V2-V5	2.218
6	V1-V6-V7-V8-V9-V10-V3-V4-V5-V2	2.300
7	V1-V6-V7-V8-V9-V10-V3-V4-V2-V5	2.310
8	V8-V9-V10 V1-V5-V4-V3-V2 V7-V6	1.684
9	V7-V8-V9-V10 V1-V2-V3-V4-V5 V6	1.15
10	V2-V4-V5 V1-V3-V10-V9 V8-V7-V6	1.757

From the table, ninth value is minimum, so it should be the optimum solution. By using programming, possible paths are founded and then minimum travel distance is noted.

Shortest route is:

V7-V8-V9-V10
|
V1-V2-V3-V4-V5
|
V6

6. CONCLUSION

Facility locations decisions are critical to the efficient and effective operation of a supply chain. Poorly placed plants and warehouses can result in excessive costs and degraded 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 facility costs.

This work reviewed two different approaches to formulating integrated location/routing models. 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. The main objective of this problem is to maximize the serviceability and minimize the transportation cost and the average travelling distance. The minimum travelling distance found by the tool graph theory. The minimum travelling cost obtained by using objective function

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