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Predictive Distribution Model by the Use of Graph Theory in Logistics and Supply Chain Management

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***Abstract*: Graph Theory is an important branch of engineering mathematics, which tries to solve the problems in mathematics by the use of graphs that are structures involving the visual representation of problems. This paper deals with concept of logistics and supply chain-management, which are solved by the use of graph theory. Further, it also deals with the connection of logistics with real life situations and describes the use of graph theory in logistics and supply chain management. The following paper deals with creating a predictive distribution model using graph theory for the use of logistics and supply chain management.**

***Keywords*: Distribution, Graph Theory, Logistics, Predictive Model, Supply-chain Management.**

1. Introduction

Logistics is the process of planning, implementation and controlling the efficient, cost effective flow and storage of raw materials in process inventory, finished goods and related information from the points of consumption for the purpose of conforming to customer's requirement. Logistics involves the integration of information, transportation, inventory, warehousing, material handling and packaging. Logistics means having the Right thing at the Right place at the Right time. According to logistics world (1997), logistics is the science of planning, organizing and management activities that provide goods or services. As per the classical definition of logistics going by the pre-requisites of the modern industry, there are seven R'S in logistics around which the whole logistics industry revolves. They are:

- Right Product
- Right Quantity
- Right Condition
- Right Place
- Right Time
- Right Customers
- Right Cost

There are many practical real life logistics problems, for example: Mail delivery, Garbage collection, the snow plugging problem, salt gritting on icy roads during winter, street inspection, road maintenance, school bus routing etc. All those problems can be solved by graph theory algorithms.

2. Graph theory

Graph theory is a very important branch of mathematics. The origins of graph theory can be traced to Leonhard Euler who devised a problem in 1735 that came to be known as the "Seven Bridges of Konigsberg". In this problem, a person had to cross all the bridges only once and in continuous sequence, a problem that Euler proved to have no solution by representing it as a set of nodes and links. This led the foundation of graph theory and its subsequent improvement. It is a symbolic representation of a network by the use of vertices and edges and its connectivity.

A. Graph labeling

The symbolic representation of a graphical structure can be done by unique methods called graph labeling. Graph Labeling of a graph G is an assignment of integers to either the vertices or edges or both subject to certain conditions. The general and specific labeling of vertices and edges play a very vital role in graph theory. One of the important and distinct ways of labeling a graph is called Graceful labeling. This is used in building models of a real life situation for structural modeling and graceful mapping. Graph labeling is a very powerful tool to formulate the mathematical models for explaining purposes across various disciplines.

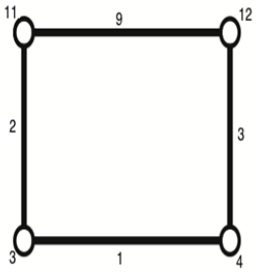

Fig. 1. Graph labelling

3. Definitions

A graph G is an ordered pair (V, E) where V is a set of elements called vertices and E is a set of unordered pairs of distinct vertices from V called edges. A Graph is formed by vertices and edges connecting the vertices.

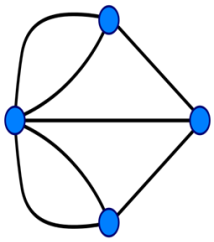

Fig. 2. Graph

The edges of graph can be directed or undirected .A graph with all directed edges are called Directed graph, otherwise it is called undirected Graph.
A graph is simple if it has no parallel edges or loops.
A graph with no edges (i.e. E is empty) is empty.
A graph with no vertices (i.e. V and E are empty) is a null graph.
Edges are adjacent if they share a common end vertex.
Two vertices u and v are adjacent if they are connected by an edge, in other words, (u, v) is an edge. The degree of the vertex v, written as d(v), is the number of edges with v as an end vertex. By convention, we count a loop twice and parallel edges contribute separately.
A pendant vertex is a vertex whose degree is 1. An edge that has a pendant vertex as an end vertex is a pendant edge
An isolated vertex is a vertex whose degree is 0
Loop: The edge which starts and ends in the same vertex is called Loop.
Walk: A walk is a trail if any edge is traversed at most once
Trail: A trail is a path if any vertex is visited at most once except possibly the initial and terminal vertices when they are the same.

4. Supply chain management

The term supply chain refers to the entire networks of companies that work together to design produce, deliver and service products.

There are three kinds of flows in a supply chain:

- Material
- Information
- Money (Capital)

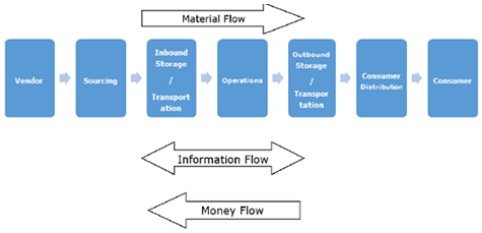

Fig. 3. Supply chain management

5. Relation of graph theory with logistics and supply chain management

The Graph theory is a very adequate tool for resolving logistical problems. Let us highlight some of the problems that are resolved through the graph theory and are applicable for modeling of some problems in logistics which are appearing in everyday life:

The Chinese Postman Problem is an example in which we are trying to search for a walk so that we go through every connection in the graph only once and do so in the shortest possible way, using the direct or undirect graph. For better understanding we could imagine a postman who is walking the streets (in our case the graph) and wants to deliver the mail for each house (vertex on the given graph) in the shortest time possible and then return to the post office (starting point). The postman is trying to save time, effort and money by finishing his job using the shortest route.

The Traveling Salesman Problem is very similar to the *Chinese Postman Problem* at the first sight. It considers the case in which we want to search for a walk using direct or undirect graph in the way to cross every vertex of the graph at least once using the shortest possible way. The salesman has to visit all the vertices in the way that he uses the shortest path (the sum of all connections used must be minimal) and return to the starting point. We can imagine that a salesman starts at point a. If the distances between every pair of points are known the question is; what is the shortest route the salesman could take to visit all the other points and return to point a?

The solution consists of the following points.

- Search for the minimum spanning tree considers the case in which we want components of unconnected graphs to be connected by using only some given edges.
- Search for the shortest path comes to use when we want to find the distance or the shortest way between two vertices in weighted graph.

Finally, we could state that the problems mentioned above show us the problems of the real world very nicely. The solutions of the problems of the graph theory are also very likely to show us the solutions of logistical problems in everyday life.

Following are some important real-life practical logistics problems that can be solved using graph theory:

- The paths of the snowplows can be modeled with the help of the graph theory. For this purpose we usually use one of the variations of the Chinese postman problem.
- The construction of cable or electricity network, water supply lines etc. can be resolved with the search of minimum spanning tree.
- The routes and order of transporting goods from warehouses to shops can be modeled with the merchant problem.
- The planning of the phone cable network that is connecting several different objects is modeled with the search of minimum spanning tree.
- Searching for the shortest route is already one of the common problems in everyday life.
- Popular GPS technology is seen on many motor

vehicles as a method of searching for the easiest way to determine the right path to the chosen point on the map.

Solutions obtained through the graph theory are very helpful to the people who are resolving logistical problems. In fact, access to the relevant data for resolving problems would not be possible without such methods. According to one of the many definitions, logistics task is among other things to ensure sufficient amounts of goods are adjusted to recipients and are in the right place at the right time.

There are many practical real-life logistics problems (military logistics, logistics management, business logistics, production logistics and others) which can be solved by graph theory algorithms.

For example, a practical example of an application of the Chinese Postman Problem is planning of bus routing. In order to save the cost on the fuel, the bus company can model the bus stop as the vertex and the road as the edge in the bus route, then using the graph theory to obtain the optimal route that can meet the target of using the minimum of fuel but crossing every road at least once. Other applications include trash collection, road sweeping, snow-plowing, highway lawnmowers, transmission line inspections, school bus routing, etc.

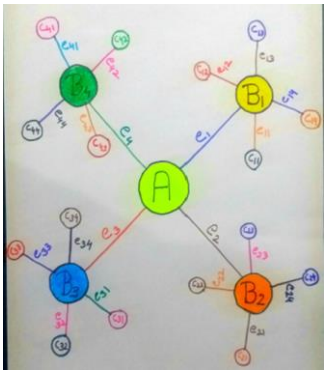

Fig. 4. Graphical Representation of logistics

Graph theory seems to be the appropriate method to quantify the vulnerability of supply chain management.

Graphs have two basic elements: the node (or vertex) and the edge (or link). By considering vulnerability drivers as vertices and the interdependencies between them as edges, a graph can be plotted for a specific supply chain. Graph modeling to measure vulnerability assists in converting supply chain vulnerability to an index. The use of this index will allow supply chain managers to better manage vulnerability. The manager can ascertain the level of total vulnerability that exists and take appropriate measure.

This is a Graphical Representation of logistics, which shows supply chain management.

In the above graphical representation of logistics model which shows supply chain management, A represents a wholesales textile company and B1, B2, B3, B4 represent distributers. They distribute goods to small Retailers as shown in graph by c11, c12…….etc. This is a model of distribution process which shows the distribution of goods at various stages and various problems that ca arise during distribution. To make distribution proper is to remove the problems that arise during this process such as lack of communication, transportation problem, lack of responsibility, lack of networks, lack of coordination.

Fig. 5. Supply chain

6. Conclusion

Here we connect logistical solution by the means of graphical representation, graph labeling and path algorithms. This particular concept is very important to solve many problems of supply chain management. By using the combination of travelling salesman problem and Chinese postman, we can create the least time least distance model for a particular distribution industry.

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