Network Models

Introduction:

A network may be defined as a set of points/nodes, that are connected by lines or links. It is basically a way of going from one node which is considered as ***"origin"*** to another node which is referred to as the ***"destination"***.

A network routing problem consists of finding an optimum route between two or more nodes in relation to total time, cost, or distance. Network routing problems commonly arise in communication and transportation systems. We have transportation, electrical, and communication networks that are constant in our lives. Network representations also are widely used for problems in areas like production, distribution, project planning, resource management, and supply chain management. ***For example***, delays that occur at the railroad classification yards or telephone switchboards may be a function of the loads placed on them and their capacities.

Network representations provide a powerful visual and conceptual aid for portraying the relationships between the components of systems that it is used in virtually every field. Rapid advances in methodology and technology have led to a number of advances in solving network-based models. Many network optimization models actually are special types of linear programming problems. ***For example***, Transportation Problems can be effectively understood and solved with the usage of network models.

There are ***four network models*** which are widely used in most the field, they are

1. ***Shortest Path Model* –** It helps in ascertaining the shortest way to reach the destination from the destination, mostly used in navigation maps so as to let the customers know which can be the shortest route to reach the destination.
2. ***Maximum Flow Model* –** This model ascertains the maximum rides (flows) for a given journey by calculating how many rides can be done in a given period of time by travelling through the set nodes and arcs in a unified direction. The objective is to maximize the total amount of flow from the source to the sink
3. ***Minimum Spanning Tree Model* –** Mostly used to find the best path to lay down the telephone wiring, water connection etc.… Here the nodes are specified but not the arcs, the

key catch of the model is to identify the best path to lay down the job which also is counted as the shortest path by helping in reducing the usage of materials.

4. ***Minimum Cost Flow Model -*** The minimum cost flow problem holds a central position among network optimization models because it encompasses a broad class of applications and because it can be solved extremely efficiently. It is a mix of all the models studied above, unlike the maximum flow problem it tries to maximise the flow within limited constraints and unlike the shortest path problem, it focuses on minimizing the cost by finding the shortest distance to reach the distance from the origin. All the network models are considered to be the special cases of the "***Minimum cost flow model"***.

The use of the right network model based on the problem is the key, for example when it comes to minimization of the transportation cost in a transportation model "***Minimum Cost Flow Problem"*** would be the best to solve the problem and get the precise answer for minimization of the transportation cost.

Minimum Cost Flow Problem:

Probably the most important kind of application of minimum cost flow problems is to the operation of a company's distribution network. This kind of application always involves determining a plan for shipping goods from its sources i.e., plants ***(supply node***) to intermediate storage facilities i.e., warehouses ***(transshipment node***) as needed and then on to the customers (***demand node***).

In other applications, the objective might be to find a plan for minimizing the cost of obtaining supplies from vendors (***supply node***), storing these goods in warehouses (***transshipment node***) and then shipping the supplies to the company's processing facilities (***demand node***). Since the total amount that could be supplied by all the vendors would be eventually more than the company needs, the network includes a dummy demand node that receives all the unused supply capacity at the vendors.

The next kind of implication of the minimum cost flow problem can be related to "***coordinating product mixes at plants***". This application involves a company with several plants (***supply nodes***) that can produce the same products but at different costs. Each arc from a supply node represents the production of one of the possible products at that plant (***transshipment node***). Later this arc leads to the transshipment node that corresponds to this product. Thus, this transshipment node has an arc coming in from each plant capable of producing the product and later the arcs would head out to their respective customers (***demand nodes***) for this product. The objective here would be to determine how to categorize each plant's production capacity among the products so as to minimize the total cost of meeting the demand for the various products.

In a similar way as we saw above for the various applications on how a minimum cost flow model helped ascertain the best solution, likely it is also considered the best model to solve the "***transportation problem"*** and understand it more efficiently. The Plants (P1, P2…. Pn) can be considered as the "***supply nodes***" whereas the products being manufactured in these plants at a varied cost would be considered as the "***transshipment nodes***" lastly the warehouses (W1, W2…… Wn) would be taken as the "***demand nodes***" where the final products being produced at varied plants then be shipped to the warehouses as per the demand and supply constraints.

Conclusion:

All in all, each network model is unique in its way and has its own implications and usage. But the minimum cost flow model is considered to be a mix of all these as well as the most efficient model to solve especially the transportation problems where there are several constraints towards the source, sink and transshipment. It is considered to be most significant because the network model has enough arcs with abundant capacities to enable all flows generated at supply nodes to reach all the demand nodes. Also, the prime objective of a minimum cost flow model is to – ***"Minimize the total cost of sending available supply through the networks to meet the given demand".*** This is same as the objective function of a transportation model where the key thing is to minimize the transportation cost keeping the demand and supply constraints in view.

(Objective Function of Minimum Cost Flow Model = Objective Function of a Transportation Problem)

References:

1. https://www.britannica.com/topic/operations-research/Network-routing
2. QMM Introduction to Operations Research - McGraw Hill - 9th Edition.