

Location, Allocation and Routing Problem with a greener perspective

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Abstract--The main concern of this paper is to model the location and the allocation of the warehouses to the demand points such that that the distance travelled by the transportation vehicle with higher load is reduced. Considering the greener perspective a novel approach is introduced by considering the carbon emissions from the transportation vehicles. In this paper, a model has been proposed for location and allocation of warehouses which is aimed at reducing the carbon emissions by proper location of the warehouses.

Keywords-- Allocation , Carbon emissions, Distance travelled, Greener, Higher load, Location, Transportation vehicle.

1 INTRODUCTION

One of the major challenges for all the industries and factories at present in any developing nations is the location of their warehouses. A warehouse is a place where there is storage of large number of raw materials or finished goods .The finished goods will have to be distributed throughout the area where there is a demand for their products. So one of the main objectives of the company is to locate the warehouses so that they will have both the fixed and the variable costs minimized due to reduced transportation and also to provide customer satisfaction by faster delivery of the products. So the warehouse will have to be located at a point where it is within certain limiting distance from the demand points so that faster delivery is done and the cost of transportation and also fuel consumption is significantly reduced. Thus cost saving incurred by the fuel energy for the company on a overall basis is minimized. In order to meet the requirements the warehouses will have to be allocated properly among the demand points. For a large-scale industry the demand will be higher throughout the targeted region. This brings so many demand points that will have to be covered by the distributing warehouses. Hence proper location and allocation of the demand points to the warehouses has to be done by the company for it to

minimize costs. Allocation involves the efficiency with which the warehouse serves the purpose of distribution. A perfect allocation of the demand points to the warehouses reduces the operating cost along with other costs associated with the maintenance of the warehouses. The impression of the company's standard is seen through their services. So for a company to strike attention among people through quality service and to make themselves profitable in the production and distribution process, the location-allocation and routing model is inevitably a necessary one.

2 LITERATURE SURVEY

There are quite a few literatures available in location-allocation along with the routing. It does not match with the practical scope of the problem which is widely practiced in the industry now a days. Few among them are discussed in this section to overview works done so far.

Or and Pierskalla[13] concentrated on the location and allocation of the blood bank to different hospitals and discussed how to route the periodic supply through vehicles so as to reduce the costs with constraints in the capacity of the vehicles and also on the limits of the number of deliveries it can make. Jacobsen and Madsen[3] suggested on the model for serving the newspapers throughout different locations or transfer points. The ideas considered by them include the number and the location of the transfer points and the tour structure to reduce the distance and also the location of printing press so as to provide to the retailers and the transfer points. Nambiar[12] involved in locating and operating central rubber processing factories producing high quality natural rubber involving the collection stations and their routing.

Madsen[8] provided a solution for the location - allocation problem in which the customers are served by

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tours rather than individual trips. A newspaper delivery system of 4500 customers is solved in this type of model. He developed, implemented and compared three new heuristic methods for the problem. Perl[14] also proposed a model for location - allocation problem using a heuristic approach in which the problems are divided into a number of sub-problems and each sub problems are solved accounting the dependence between them. Federgruen and Zipkin[2] dealt with the allocation of resources to the demand areas of several locations using a fleet of vehicles for random demand locations, considering holding and shortage costs along with the transportation cost

Aykin[1] considered the hub location and routing and the service types for the routes between the origin and the demand points. Marianov et al.,[9] also proposed the location of a hub in competitive environment where the customer capture is sought when the current cost like time or distance is saved. Wasner and Zapfel[18] described the parcel service providers as a generalized hub location and vehicle routing model.

Min et al.,[10] provided a solution for the integrated logistics systems that has emerged as a management philosophy that recognizes the interdependence of the location of facilities, the allocation of suppliers and customers to the facilities, and the vehicle route structure around depots. Kratica et al.,[5] suggested a solution to solve the uncapacitated warehouse problem using Simple Genetic Algorithm and 'Add' heuristic. They presented the solution of reducing the cost by adding or reducing the warehouse thereby reduce the fixed cost and the variable costs associated with it. Johnson et al.,[4] applied the interactive heuristic to a set of customers currently served by a subset of kitchens and show that the system generates catchment areas that are more compact and require fewer vehicles than are used by existing kitchens.

Rahman and Smith[15] concentrated on the building of health care units in vast geographical area where people may not be able to get balanced service throughout. It gives a view about the sustainability of the service and the overall development of the nation. Wu et al.,[19] presented a method for solving the multi-depot routing problem. They have divided the bigger problem the into two sub problems to make it simple. One for the location allocation problem and the other for the vehicle routing problem . Each sub-problem was then solved in a sequential and iterative manner by the simulated annealing algorithm embedded in the general framework for the problem-solving procedure.

Smith[16] proposed a model to set up 3 level services so that the distance travelled by the customer till the last

service is reduced and also setting up health care so that there will be equal balance of services for the poor. This plan can increase the trust factor that the customers have on the service. Liu and Lin[17] discussed the combined location routing and inventory problem to allocate depots from several potential locations, to schedule vehicles' routes to meet customers' demands, and to determine the inventory policy based on the information of customers' demands, in order to minimize the total system cost. Lashine et al.,[6]. Nagy and Salhi[11] in their paper, surveyed the location of the warehouses taking into account the vehicle routing aspect. Both exact and heuristic methods are used. Verter[17] suggested the location of the warehouses so as to reduce the fixed cost and the variable costs associated with it during the transportation of products from the ware houses to the destination point considering the unit transportation cost.

Though there are papers that present a solution for the location and allocation of retailers to the warehouse, finding the number of vehicles to the demand and routing to minimize the cost none of the papers dealt the problem with a greener perspective. It is imperative to fill this gap with a novel concept which we tried in our model.

3 PROBLEM DEFINITION

The distribution of the products or serving the given set of customers from the chosen warehouses is the problem of concern. The main objective is to reduce the distance between the warehouses and the customers so that delivery is made easier. We have also introduced the concept of reduction in carbon emissions during the travel of vehicle from the origin to the destination point taking into account the greener perspective of the problem.

For the location and allocation consider the set $I = \{ 1, 2, \dots, b \}$ of warehouses to be allocated at different areas and the demand points to be the set $J = \{ b+1, \dots, n \}$ of customers . The constraints are given in such a manner that the capacitated warehouses are located in places where the distance of travel from the warehouse to the destination is minimized. Then the demand points are allocated to the warehouses depending upon the capacity and the amount of loads or products that has to be delivered to the customers.

The completion of constraints for the location and allocation of the warehouses persuades the way for designing of the route. Routing involves designing a path from the warehouses to the allocated demand points or customers so that the distance of transportation is reduced along with the reduction of carbon emissions into the atmosphere. The reduction of carbon emissions into

atmosphere makes clear that there is also a reduction in the fuel consumption involved. Considering the greener perspective, the vehicle carrying larger load will consume greater fuel and has greater carbon emissions into the atmosphere. So the distribution of the products or loads should be in such a way that the heavier load should be distributed earlier so that the distance travelled by the vehicle with heavy load is reduced thereby reducing fuel consumption and the emission of polluting gases (carbon emissions) into the atmosphere. This optimizes the distance travelled taking into account the carbon emissions providing a greener perspective of the location and allocation problem. The solution produced will be the result of optimization of the distance to be travelled and the carbon emissions.

4 OBJECTIVE FUNCTION

$$\text{Min } Z = \sum_i^n \sum_j^n \sum_k^m d_{ij} \cdot c_{ij} \cdot x_{ijk}$$

- (1) where d_{ij} - distance between i^{th} node to j^{th} node
 c_{ij} - carbon emission between i to j per km based on load factor
 $x_{ijk} = 1$ if and only if j^{th} node is immediately served after i^{th} node by vehicle k

4.1 Assumptions

1. Euclidean distances are taken to be actual distances
 2. All vehicles are uncapacitated.
 3. All warehouses are having equal capacities.
 4. Only 1 vehicle is allotted to each warehouse.
 5. Total number of warehouses $b =$ Total number of vehicles m .
 6. 1st warehouse is allotted to 1st warehouse and 2nd warehouse is allotted to 2nd warehouse.
- (i, j)- customers and warehouses nodes
 1 to $b \in (i, j)$ are warehouses
 $b+1$ to $b \in (i, j)$ are customers

4.2 Constraints and Allocation

$$bC_{\beta} \geq \sum_{\alpha}^a D_{\alpha} \quad (2)$$

- D_{α} - Demand at customer α
 C_{β} - Capacity of warehouse β
 b - integer number of warehouses
 a - number of customers

$$\sum_{\beta}^b \sum_{\alpha}^a y_{\alpha\beta} = a \quad (3)$$

$$\sum_{\beta}^b y_{\alpha\beta} = 1 \quad \forall \alpha \quad (4)$$

$$\sum_{\alpha}^n D_{\alpha} y_{\alpha\beta} \leq C_{\beta} \quad (5)$$

4.3 Constraint routing

Vehicle starting at depot

$$\sum_{j=1}^n x_{ijk} = 1 \quad \forall i, k \quad (6)$$

when ($i=k$) $i \in (1, b)$

hence there is only 1 vehicle for each warehouse for $i=1$ warehouse $k=1$ vehicle and $i=2, k=2$ and so on.
 vehicle ending at depot

$$\sum_{i=1}^n x_{ijk} = 1 \quad \forall j, k \quad (7)$$

when ($j=k$) $j \in (1, b)$

$$\sum_{j=1}^n x_{ijk} = 1 \quad \forall i, k \quad (8)$$

$$\sum_{j=1}^n x_{jik} = \sum_{j=1}^n x_{ijk} \quad \forall i, k \quad (9)$$

$$\sum_i^n \sum_j^n x_{ijk} - \sum_{\alpha}^a y_{\alpha\beta} = 1 \quad \forall k, \beta \quad (10)$$

$$\sum_j L_{ji} - \sum_j L_{ij} = D_i \quad \forall i \quad (11)$$

$$L_{ij} \geq D_j x_{ij} \quad \forall i, j \quad (12)$$

$$x_{ijk} = \{0, 1\} \quad \forall i, j, k \quad (13)$$

$$y_{\alpha\beta} = \{0, 1\} \quad \forall \alpha, \beta \quad (14)$$

$$x_{ijk} = 1 \quad \text{if node } j \text{ is served immediately after node } i \text{ with vehicle } k$$

$$= 0 \quad \text{otherwise}$$

$$y_{\alpha\beta} = 1 \quad \text{if customer } \alpha \text{ is served by warehouse } \beta$$

$$= 0 \quad \text{otherwise}$$

L_{ij} = Load between i to j

D_i = Demand at node i

C_{ij} = carbon emission travelling from i to j per km

d_{ij} = Distance between i to j

C_{ij} = variable matrix depends on load between i to j

(1) minimizes the overall carbon emission

(2) number of warehouse to be setup

(3) the allocation of warehouses to customers

(4) each customer served by 1 warehouse

(5) capacity of warehouse not to be exceeded

(6) vehicle starting point. There is one vehicle for each warehouse

(7) vehicle ending point

(8) All nodes are served

- (9) Entering node is equal to leaving node
- (10) Routing to all warehouses
- (11) Flow conservation constraint
- (12) Load on vehicle should satisfy demand of entire route to be still served

5 METHODOLOGY

The location and allocation of the warehouses is modeled according to the constraints reducing the distance of the

warehouse from the demand points. While locating the warehouses the demand of the respective nodes is also considered. The Warehouse has to be positioned nearer the higher demand nodes.

The main consideration is that when the vehicle travel with a higher load the carbon emission and the fuel consumption is more when compared to the vehicle that travels with a lesser load.

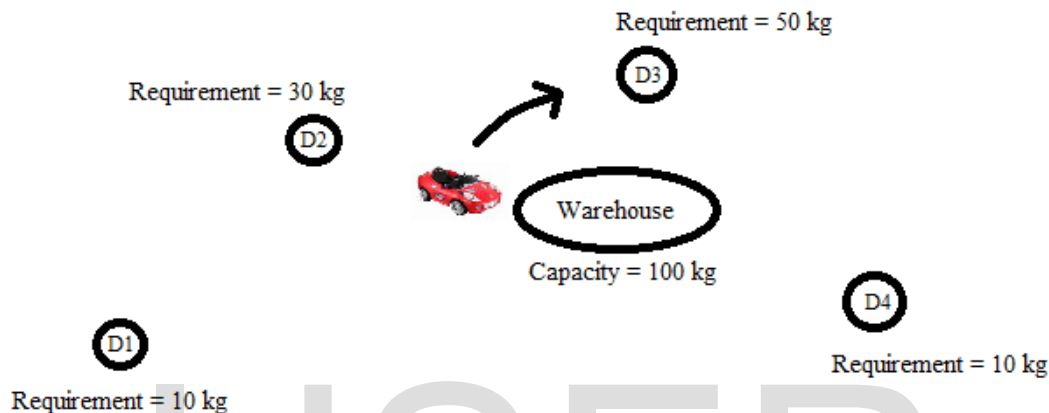


Fig.1. Location of warehouse and demand points

The routing follows the location and allocation of warehouses. In the routing problem as seen in the above fig.1 the capacity of the warehouse is 100kg and requirements of the customers as mentioned. So, for the vehicle which is to distribute the loads to these customers will have to reach the customer whose requirement is 50 kg first just in order to deliver the maximum load first. This reduces the distance travelled by the vehicle with high load (since it reduces 50 kg on the reach of the first customer) thereby the carbon emission due to the fuel usage is reduced when compared to other customers chosen as first destination. The reduction in the fuel consumption reduces the emission of polluting gases into the atmosphere.

As seen from the above diagram the distance will be the same when the transportation is from W-D4-D1-D2-D3-W or W-D3-D2-D1-D4-W. The latter is chosen because in this case the weight of 50kg is reduced in the first destination itself so the vehicle travels lesser distance with higher loads and thereby reducing the carbon emissions overall. On optimization the warehouse will be located closer to the demand point D3 as seen from the above fig.1.

6 CONCLUSION AND FUTURE RESEARCH DIRECTIONS

In this paper location, allocation and routing of the warehouses are modeled in order to minimize the overall fuel consumption and also optimizing the distance covered by transportation for a warehouse to distribute goods. Thus this paper not only provides for the location and allocation of the warehouses considering the demand points but also considers the greener perspective.

In future the routing could be done considering the quality of the roads travelled by the transport vehicle. The travel in well maintained and smooth roads can reduce the fuel usage rather than travelling in a muddy or a damp road with poorly maintained conditions. This can improve the functioning of the system and saves time. The risk of wheel tyre wear can also be reduced when compared. Multiple vehicles for a single warehouse and split deliveries can also be included to increase the practical usage of the problem.

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