

# Vehicle Routing Approach for Improvement in the Supply Chain of Milk Industry

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**Abstract**—To make a business profitable, there is a need of optimum utilization of resources. In India, major milk distribution and marketing is done by co-operative dairies which has an objective of minimizing the overhead and intermediaries cost in milk distribution. In the procurement, processing and delivery of milk and milk products, transportation cost is a major component. In the present work, a variant of VRP, Heterogeneous Fleet Vehicle Routing Problem with Time Window (HFVRPTW) is used to design an optimal route for a heterogeneous fleet of vehicles to procure milk from the farmers located at different places inside as well as outside Varanasi district (Uttar Pradesh), India within given time interval and transport it to the processing center at Ramnagar. The plant procures milk from co-operative societies with known supply using minimum-cost vehicle routes which originates and terminates at a depot. The objective is to minimize the procurement cost by minimizing the distance travelled by vehicles and hence minimizing the transportation cost and thereby increase the profit of the plant. HFVRPTW is used along with p-center approach to solve the problem. By the implementation of the proposed approach, the cost involved will be minimal and a share of the profit hence obtained can be given to the farmers by which they can have better income.

## 1. INTRODUCTION

A Supply chain management (SCM) consists of all parties who are involved, either directly or indirectly, in fulfilling customer request. These parties include vendors, manufacturers, warehouses, distributors and retailers. So SCM is a system of organizations, people, technology, information, activities etc. which gets involved in moving a product or service from supplier to the end customer. SCM while viewed in terms of activities involved, has been defined as the designing, planning, execution, control and monitoring of the 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. SCM addresses many issues like supplier selection, changing of partners such as distribution of finished and semi-finished products etc. It also addresses the delivery issues related to the determination of network of distribution and routes of vehicles, number of vehicles required in delivery process etc. While addressing the

distribution network planning, SCM focusses on Vehicle Routing Problem (VRP). The vehicle routing problem (VRP) is a combinatorial optimization and integer programming problem which asks “What is the optimal set of routes for a fleet of vehicles to traverse in order to deliver to a given set of customers?” Vehicle routing problem (VRP) is viewed as an important tool for the reduction of transportation cost by designing optimal routes for a geographically dispersed network of customers. In VRP, one or more vehicles start from a depot to serve customers in an order and return back to depot. Many researches have used different heuristic approaches and found the solution of the vehicle routing problem, for different set of constraints. Having constraints in the problem definition, the aim is to find the solution that does not violate any constraint. Such a solution is called a feasible solution. Nowadays, research on Heterogeneous Vehicle Routing Problem with Time Windows (HVRPTW) is given more importance as it includes the real life scenario of using more than one type of vehicle for transportation of products within a pre-specified time window for the vehicle to visit that node. The demand for the required service location is assumed to be originating from a set of demand points. The problem here is considered to be un-weighted. So, the magnitude of demand from each node is not taken into account in this study. The p-center approach is another used method in supply chain management. Here, among a number of geographically dispersed locations termed as nodes, some nodes are allocated as p-centers where the demand of a number of nodes assigned to that p-center is accumulated. The p-center location problem over a continuous area of demand is an interesting problem with various practical applications.

“Logistics management is that part of supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of and the point of consumption in order to meet customer’s requirements”<sup>[1]</sup>. Logistics management is beneficially about choosing the most effective routes for transportation, and discovering the most competent delivery

methods with the help of software and IT resources to proficiently handle the related processes. The design of transportation network impacts the supply chain. Designing issue does not limit itself to deciding on establishing the right infrastructure but also about taking the right decisions including the scheduling and routing of vehicles. A well designed transportation network allows a supply chain to achieve the desired degree of responsiveness at a lower cost.

**2. PROBLEM AND FORMULATION**

This project proposes the model for the Heterogeneous Fleet Vehicle Routing Problem with Time Window (HFVRPTW), which is a more realistic and generalized form of VRP. The heterogeneous vehicles are assumed to have varying capacities. Each vehicle is assumed to have hiring costs which vary according to their capacity. The travelling cost is constant for all the vehicles. The objective is to find a route for the vehicles to travel so as to procure milk from the nodes and bring it to the dairy absorbing minimum cost. The demand on each node is assumed to be known. The quantity procured from any route must not exceed the capacity of the vehicle assigned to that route.

For the mathematical formulation of the problem, the following notations are used.

**2.1 Indices:**

$i, j$ = Nodes(Co-operative milk societies)

$l$ = Number of workers in the vehicle

$p$ = Vehicle type

**2.2 Parameters:**

$C_p$ = Hiring cost of ‘ $p$ ’ type of vehicle

$C_{dp}$ = Cost of covering unit distance without load

$C_l$ = Cost of hiring a worker

$C_{mp}$ = Cost of transporting unit good by unit distance

$CS_i$ = Cost of setting up a  $p$ -center

$N$ = Total number of nodes

$P$ = Maximum number of types of vehicles

$L$ = Maximum number of workers that can be allotted to ‘ $p$ ’ type of vehicle

$d_{ij}$ = Distance of a node ‘ $i$ ’ from the node ‘ $j$ ’

$D_t$ = Distance to be travelled by a vehicle

$N_p$ = Maximum permissible number of vehicles

$t_{sil}$ = Service time at node ‘ $i$ ’ with ‘ $l$ ’ workers

$t_{ij}$ = Travelling time from node ‘ $i$ ’ to ‘ $j$ ’

$q_i$ = Amount of milk procured from node ‘ $i$ ’

$b_i$ = Latest allowed start time for service at node ‘ $i$ ’

**2.3 Variables:**

$t_i$ = Service start time of a node ‘ $i$ ’

$Y_{ip}$ = Load in the vehicle ‘ $p$ ’ when vehicle reaches node ‘ $i$ ’

$Y_{ijp}$ = Load in the vehicle on transit from node ‘ $i$ ’ to ‘ $j$ ’ on vehicle type ‘ $p$ ’

$$X_{ijlp} = \begin{cases} 1 & \text{if vehicle travels from 'i' to 'j' with 'l' workers on vehicle 'p'} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{ij} = \begin{cases} 1 & \text{if 'j' is assigned to 'i'} \\ 0, & \text{otherwise} \end{cases}$$

Using the notations described above, the HVRPTW is formulated as follows:

**2.4 Objective function:**

Minimize

$$z = \sum_{p=1}^P \sum_{j=2}^N \sum_{l=1}^L C_p X_{1jlp} + \sum_{p=1}^P \sum_{i=1}^N \sum_{\substack{j=1 \\ j \neq i}}^N \sum_{l=1}^L C_t d_{ij} X_{ijlp} + C_l \sum_{p=1}^P \sum_{j=2}^N \sum_{l=1}^L l X_{1jlp}$$

**2.5 Constraints:**

- 1)  $\sum_{j=2}^N \sum_{p=1}^P Y_{1jp} = 0$
- 2)  $\sum_{j=2}^N \sum_{l=1}^L X_{1jlp} \leq N_p, p=1,2,\dots,P$
- 3)  $\sum_{i=1}^N \sum_{l=1}^L \sum_{p=1}^P X_{ijlp} = 1, j=2,3,\dots,N$
- 4)  $\sum_{i=1}^N X_{ijlp} = \sum_{\substack{k=1 \\ k \neq j}}^N X_{jklp}, j=2,3,\dots,N; l=1,2,\dots,L; p=1,2,\dots,P$
- 5)  $t_j \geq (t_i + t_{sil} + t_{ij})X_{ijlp}, i=2,3,\dots,N; j=1,2,\dots,N; l=1,2,\dots,L; p=1,2,\dots,P$
- 6)  $t_j = t_{ij}X_{1jlp}, j=2,3,\dots,N; l=1,2,\dots,L; p=1,2,\dots,P$
- 7)  $Y_{ijp} \geq (Y_{ip} + q_i) \sum_{l=1}^L X_{ijlp}, i=2,3,\dots,N; j=1,2,\dots,N, j \neq i; p=1,2,\dots,P$
- 8)  $Y_{ijp} \geq Y_{jp}X_{ijlp}, i=2,3,\dots,N; j=1,2,\dots,N, j \neq i; p=1,2,\dots,P$
- 9)  $t_i \leq b_i, i=1,2,\dots,N$
- 10)  $X_{ijlp} \in \{0,1\}, i=1,2,\dots,N; j=1,2,\dots,N; l=1,2,\dots,L; p=1,2,\dots,P$

$$11) Y_{ijp}, t_j, Y_{ip} \geq 0 \quad ,i=1,2,\dots,N; j=2,3,\dots,N; l=1,2,\dots,L; \\ p=1,2,\dots,P$$

The objective function have four terms. The first term represents the total cost on hiring the number of vehicles required for procurement of milk. The second term gives the total cost in transportation. The third term gives the total cost for hiring the required number of labors. Constraint 1 shows that each vehicle, when starting from the depot, is empty. Constraint 2 ensures that the maximum number of vehicles does not exceed the given limit of maximum permissible number of vehicles. Constraint 3 ensures that every node is visited by only one vehicle. Constraint 4 shows that one vehicle once visited a node, then it visits the next node with the same number of workers in the vehicle. This shows the flow conservation of the vehicle. Constraint 5 shows the time to reach a node. Constraint 6 helps to determine the vehicle arriving time at nodes which are visited by the vehicle just after leaving the depot. Constraint 7 helps to determine the quantity of milk in the vehicle with which it travels between two nodes ‘i’ and ‘j’ after procuring from node ‘i’. Constraint 8 ensures that service begins at nodes in the specified time windows. Constraint 9 to 11 define the nature of decision variables involved.

In the case of p-center problem, there are a set of geographically dispersed locations or nodes from which the milk is being procured for the dairy. These nodes or locations are to be separated into different clusters. Now, for each cluster, a node is assigned as p-center where the milk from the nodes in the corresponding cluster is procured and stored. The p-center problem can be formulated as

**2.6 Objective function:**

$$Minimize z = \sum_{i=1}^N CS_i \times X_{ii} + C_t \times D_t$$

**2.7 Constraints:**

1.  $X_{ij} = X_{ii} \quad ,i=2,3,\dots,N; j=1,2,\dots,N$
2.  $\sum_{i=1}^N X_{ij} = 1 \quad ,j=1,2,\dots,N$
3.  $D_t = \sum_{i=1}^N \sum_{j=1}^N D_{ij} \times X_{ij}$

Here, the objective function consists of two terms. The first one calculates the total cost involved in the setting up of the p-centers. The second term calculates the cost incurred in transporting the milk from the individual nodes to the assigned p-centers. The first constraint shows us that if a node is assigned to be a p-center, that node will be assigned to itself. i.e. the demand from that node will be accumulated in the node itself. The third constraint calculates the total distance covered by each vehicle which travels from each node and collect the milk to the p-center.

**3. RESULTS AND CONCLUSIONS**

The HVRPTW and p-center were run with test data taken from a dairy industry. The p-center problem was done for 24 nodes and the results were better than in the case of current working model used in the dairy. If the value of CS is given as a constant, then with the decrease in the value of CS, the number of p-center allocated increases and the distance to be covered decreases. When the value of CS is kept variable, then there is a tendency for the node with the least value of CS to be assigned as the p-center. If we split the problem into a two-tier supply chain and apply these two methods, we can obtain better results. i.e. we first apply p-center approach to all the nodes and find out the optimal number of p-centers. Now, apply HVRPTW on these selected p-centers to get an optimal solution. By using this technique, cost minimization can be done and the cost hence saved can be divided between the dairy and farmers and the farmers can be given the advantage. By using this approach, job can be offered for many people in the p-centers. Thus we can reduce the unemployment. Also by optimizing the vehicle transportation, we can reduce the pollution. Another advantage of optimization of transportation is that the usage of fuel can be minimized which, in today’s world, is a major problem as fossil fuels are non-renewable.

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