International Journal of New Technology and Research (IJNTR)
ISSN:2454-4116, Volume-3, Issue-10, October 2017 Pages 22-26

Use of Operations Research in Courier Delivery Services

Alisha Fernandes, Aksh Tulsyan, Ankit Nisar, Anisha Rawat, Aditya Kumar

***Abstract*— Courier delivery services are used worldwide by millions of people. The scope of this field is wide. The services provided by most companies in this field is more or less the same. What sets them apart is the optimisation of resources and how these companies reduce their transportation cost while providing good service. While finding the best route, companies often blind side other factors and only focus on the shortest route. This paper is focused on Vehicle Routing Problem and its variations. It also talks about the current Softwares being used in this field.**

***Index Terms*— Vehicle Routing Problem (VRP), Route optimisation.**

I. INTRODUCTION

In the current scenario, companies are interconnected much more with their customers and mainly use transportation as method for their business. These days there is high competition among logistics companies. This is mainly due to high expectation of customers on quality of service which includes on time delivery in short notice. Couriers are mainly used to deliver mails, parcels etc.

There are several problems courier companies face. Some of them include:

A. **Packages get damaged or lost**:Since the quantity of packages is higher hence companies can't focus on each and every parcel so in the transit a few packages might get damaged or even lost. The transportation is done generally on trucks where piles are sacked upon each other hence the chances of parcel getting damaged is very high.

B. **Large overheads cost**:Companies spend a lot on insurance and travelling and this gets reflected in the delivery prices of the package.

C. **Unreliable service**:Some companies often contact to local private couriers which might be unauthorized. Those local companies could be unreliable, unprofessional and might not handle the package with care.

D. **Poor knowledge and awareness from the customer's side**

Couriers differentiate themselves from other mail services by features like security, signature, fast delivery etc. Couriers are also costlier than other mail services. The core on which a courier company works is logistics. Any firm will try to manage effective transport in lesser cost.

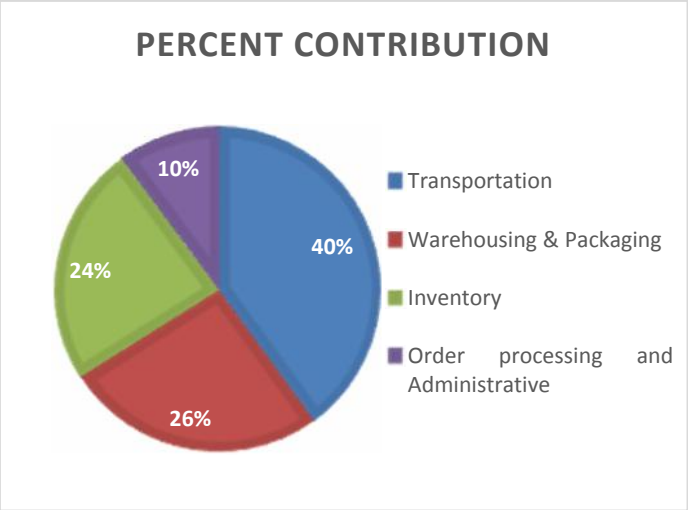


Fig1 : Elements of logistic cost in India

Source: Sanyal(2006a) IIM A

It is seen that 40% of cost of a courier service is in the transportation cost. Thus, it is important that a company minimizes its transport cost. This is where VRP comes in.

II. VEHICLE ROUTING PROBLEM

Vehicle Routing Problem (VRP) is the generalization of the travelling salesman problem, seeking to service a number of customers with a fleet of vehicles given a set of constraints usually being limited gas or limited time.
It was first in the "truck dispatching" problem in Dantzig and Ramser's paper in 1959 and much progress has been made since. The first approach to the problem was applied to petrol deliveries.

Goal:
"To plan a set of routes for some vehicles which are located in one or more depot(s) in order to serve some customers in less possible travel time, travel costs or travel distance."

Components of VRP:

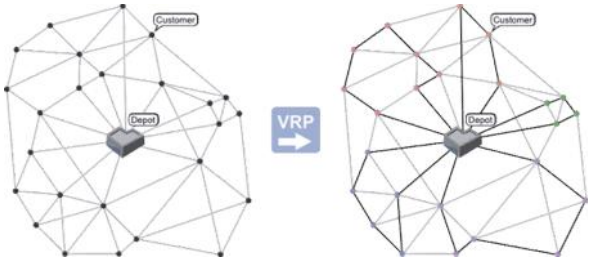
A. Depots – A Depot is the starting point and the finishing point of VRP. A VRP can have one or more depots.

B. Customers – The goal of VRP is to service the customers. Customers are spread around depot(s).

C. Vehicles – Their characteristics include capacity, cost, departure, maximum travelling time and number of vehicles.

D. Routes – Routes connect customers together. They can have different travel time and cost. Routes can be one or two way.

Alisha Fernandes, NMIMS Maharashtra
Aksh Tulsyan, NMIMS Maharashtra
Ankit Nisar, NMIMS Maharashtra
Anisha Rawat, NMIMS Maharashtra
Aditya Kumar, NMIMS Maharashtra



Assumptions:

A. Each customer must be served once and by one of the available vehicles.
B. Each tour starts from and ends at one depot.
C. Sum of customer demands of each tour must not exceed the vehicles' capacity.
D. Total travelling distance or time must not exceed their maximum limit.

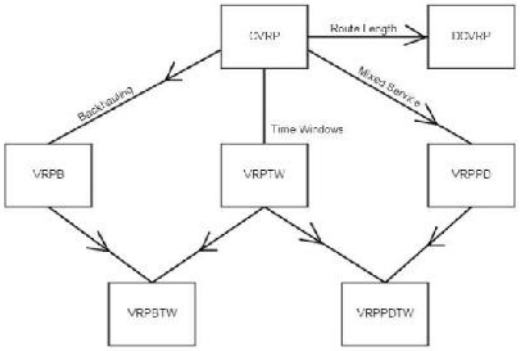
Some constraints of VRP are:

A. Capacity constraints
B. Max no. of locations that can be visited in one trip
C. Time constraints
D. Time window
E. Distance constraints
F. Precedence relations between certain relations

Variations of VRP:

A. Vehicle Routing Problem with Pickup and Delivery(VRPPD):
   a. In VRPPD, it is important to consider that the goods that customers return to the delivery vehicle must fit into it. This makes the planning problem more tough and can lead to bad use of the vehicles capacity, increase in travel distances or a need for more vehicles.
B. Vehicle Routing Problem with LIFO
C. Vehicle Routing Problem with Time Windows (VRPTW):
   a. In VRPTW, a number ofcustomers have to be served within predefined time windows at minimum cost (in terms of distance travelled), without violating the capacity and total trip time constraints for each vehicle.
D. Capacitated Vehicle Routing Problem: CVRP or CVRPTW:
   a. CVRP is a VRP in which a fixed fleet of delivery vehicles of same capacity must service known customer demands for a single commodity from a common depot at minimum transit cost i.e. CVRP is like VRP with the additional constraint that every vehicle must have uniform capacity of a single commodity.
E. Vehicle Routing Problem with Multiple Trips (VRPMT)
F. Open Vehicle Routing Problem (OVRP)
G. Distance Capacitated Vehicle Routing Problem (DCVRP)
H. Vehicle Routing Problem with Backhauls (VRPB):
   a. In VRPB VRP, customers can demand or return some commodities.
I. Vehicle Routing Problem with Backhauls with Time Windows (VRPBTW)

Below is a map of some of the VRP subtypes. There can be several constraints added to the basic CVRP.



Uses in the real world:

A. Dynamic Fleet Management
B. Vendor-Managed Distribution Systems
C. Couriers
D. Rescue and Repair Service Companies
E. Dial a Ride Systems
F. Emergency Services
G. Taxi Cab Services
H. Refuse Collection
I. Newspaper Distribution

Problem Formulation:

The formulation of the TSP (travelling salesman problem) by Dantzig, Fulkerson and Johnson was extended to create the two index vehicle flow formulations for the VRP.

$$\text{MINIMIZATION } Z = \sum_{v=1}^{V} \sum_{i=0}^{N} \sum_{j=0}^{N} D_{ij} X_{ijv} \qquad (1)$$

Subjected to:

$$\sum_{v=1}^{V} \sum_{i=0}^{N} X_{ijv} = 1 \text{ for all } j = 1 \ldots \ldots N \qquad (2)$$

$$\sum_{i=0}^{N} X_{ijv} - \sum_{i=0}^{N} X_{ijv} = 0 \text{ for all } j = 0 \ldots N \qquad v = 1 \ldots V \qquad (3)$$

$$\sum_{i=0}^{N} P_{iv} X_{ijv} \leq C_v \text{ for all } j = 1 \ldots N \qquad (4)$$

$$\sum_{v=1}^{V} \sum_{i=0}^{N} \sum_{j=0}^{N} D_{ij} X_{ijv} \leq MTL \qquad (5)$$

Equation 1 – Total travel cost of the routes is minimized

Equation 2 – Each customer should be visited only once by a vehicle

Equation 3 –Route continuity

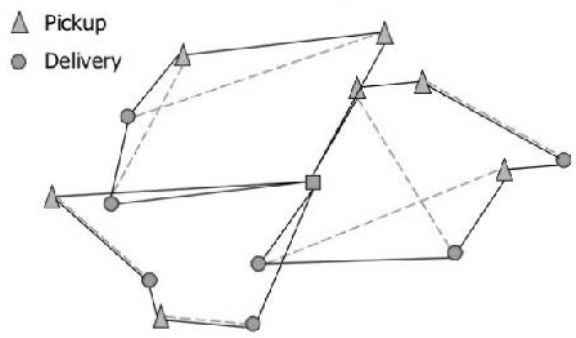
Equation 4 - Quantity of pickup load at customer point should not exceed the vehicle capacity

Equation 5 - Maximum tour length constraint [1].

Scenario Today:

Pickup and Delivery problem with Time Windows (VRPDTW):

Due to the advancing technology, today, most of the courier companies offer pick-up and delivery of the courier at the time requested by the customers. Thus, in this a number of vehicles have to serve a number of transportation requests. Each vehicle has a given capacity. Each transportation request specifies the size of the load to be transported, the location where it is to be picked up a pickup time window, and the location where it is to be delivered plus a delivery time window. Types of decisions involved are assigning, routing and scheduling.



The four types of Transport Requests are:

A. Customizing Requests as the name suggests has been used to address the special demand of the clients in order to create tailor made yet the most optimum transportation schedule.

B. Workbench Requests are those that involve changes to cross-client Customising and Repository Objects. The objects here are independent of the client. So, the requests are mostly used for transferring and transporting changed Repository objects and changed system settings from cross-clients. Therefore, it contains changes made to the repository objects of ABAP work bench.

C. Transport of Copies allows to transport any sub objects into object list to any other SAP system. This is similar to customising and workbench but with different behaviour. The best part is that it dies in the next target system.

D. Relocation it is used when development system of a complete package is to be changed on a permanent basis.

Ways of solving VRP:

A. **Manually:** Given all the constraints presented, this way is the least effective way. This method requires hours and hours to solve and even then, there are chances of errors.

B. **Pre-Set Solvers:** This method is a little faster. However, these solvers only satisfy 2-3 basic constraints. This method can only be applied in academic settings.

C. **Using Route optimisation software:**Route optimisation Softwares can solve the Vehicle Routing Problems within seconds. It eliminates all manual planning and generates the optimal route automatically.

Solution methodsfor VRP:

VRP is a difficult problem due to huge size of the feasibility set. Without any restriction, suppose there are *n* demand points with one vehicle. Then total number of feasible solutions is simply *n!* which grows very fast. For n=5, total number of solutions is 120 while for n=8, number of solutions is 40320 and for n=10 **total number of possible routes is 3,628,200**. VRP is a combinatorial-integer optimization type of problem.

Most methods for solving Vehicle Routing Problem (VRP) are heuristics and metaheuristics because no exact algorithm can be guaranteed to find optimal routes within reasonable delivery time when the number of cities is large. This is because of the **NP-Hardness** of the problem.

A. Exact Approaches: This method proposes to compute every possible solution till we reach the best one. This includes 'Branch and bound' and 'Branch and cut'.

B. Heuristics: This method produces good quality solutions within modest computing times. Heuristic methods perform a relatively limited exploration of the search space.

C. Constructive Methods: Gradually builds a feasible solution while keeping an eye on the cost.:

a) Nearest Neighbour Heuristic for CVRP
b) Nearest Addition Heuristic for CVRP
c) Sweep Heuristic for CVRP
d) Clark and Wright Heuristic for CVRP
e) Solomon's Sequential Insertion Heuristic I1 for CVRPTW
f) Coefficient Weighted Distance Time Heuristics for CVRPTW

D. 2-Phase Algorithm: There are 2 natural components-

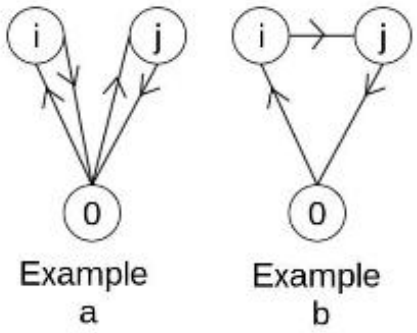
- Clustering of vehicles into feasible routes
- Actual route construction

With possible feedback loops between the 2 stages

E. Metaheuristics

The Savings Algorithm:

In 1964, Clarke and Wright published a **heuristic** algorithm for solving the CVRP which is based on the concept of savings.It frequently gives a relatively optimal solution and is cheap to compute as well as easy to understand. The savings concept expresses the savings in cost that can be obtained by joining two routes up and making them into one. This is shown in the figure below where 0 represents the depot and *i*and *j* are customers [Lysgaard, 1997].



In example a, customers *i*and *j* served by separate routes. However, alternatively we could visit *i*and *j* in the same route as shown in example b. As the costs of transportation are given we can calculate the difference in cost between a and b and calculate the savings made in total cost.

If we write the transportation cost between two points c_{ij} then the total cost in example a and b can be written as follows

$$D_a = c_{0i} + c_{i0} + c_{0j} + c_{j0}$$
$$D_b = c_{0i} + c_{ij} + c_{j0}$$

Then combing these we can calculate what our savings, S_{ij} would be if we went directly from *i*and *j* instead of via the depot.

$$S_{ij} = D_a - D_b = c_{0i} + c_{i0} + c_{0j} + c_{j0} - (c_{0i} + c_{ij} + c_{j0})$$
$$= c_{i0} + c_{0j} + c_{ij}$$

This information can be used in 2 different ways to create a savings algorithm – using a sequential or a parallel algorithm. The first builds only one route at a time and the second permits more than one to be built at once.

Free Softwares for solving VRP

A. jsprit
B. Open-VRP
C. OptaPlanner
D. SYMPHONY
E. FAST
F. VRP Speadsheet solver

Latest trends in courier delivery:

A. **Crowdsourcing**: Crowdsourcing is when an organization outsources a particular job or activity to the open public or to a large peergroup. This job or activity was earlier performed by theemployees of the organization itself. One of the mostimportant condition for crowdsourcing is a large network ofpotential people who are enthusiastic about the workallotted to them. Now in the case of courier companies, theyare considering the possibility of using public to get theparcels delivered in return of a reward or payment. A fewadvantages of crowdsourcing included improved costs i.e.less cost incurred by the organisation, increased speed of delivery, flexibility of delivery of packages and diversity. However, it might get difficult to organize the public and theproduct quality may suffer.

B. **Delivery drone**:This refers to delivering packages through an unmannedaerial vehicle (UAV). E.g.- Amazon Prime Air delivers packages5lbs in 30 minutes or less. This type of technology is moreenvironmental friendly which is the need of the hour. However, it is economically not feasible. It may not besuitable for small organizations. Also, people may not trustdrone since it operates without human monitoring.Also these days almost all the courier delivering services areusing improved connectivity through smartphone applications, GPS tracking etc.

C. **Package tracking:**Package tracking refers to shipping containers or parcel toone place to another at different point of time by sorting,warehousing, and delivering the package. The tracking of packages is done generally in 3 ways:Reporting the arrival and departure time of the package.Vehicle tracking system- it enables the person to locatethe vehicle which is carrying his/her package.Tracking through internet, mobile applications,GPS.

Case Study (UPS):

The United Parcel Service, UPS, is a courier delivery service agency that delivers an average of 18.3 million packages every day. UPS has 104,926 cars, vans, tractors, and motorcycles etc. making multiple stops in a day. Like most courier companies, UPS began with the assumption that the best route was the one that was the most direct. But when they considered accident risks, travel time, and fuel use, it became clear to them that left-hand turns across traffic were a problem. Taking a left turn (in countries with right hand traffic) has a higher risk of accident, and waiting for a break in oncoming traffic wastes a lot time and increases fuel consumption.

UPS now focuses on optimising the journey instead of taking the shortest route. Although this might increase the distance of the route, it reduces the chance of an accident and cuts delays caused by waiting for a gap in the traffic. This also reduces fuel usage thus helping the environment.

UPS use Route Optimisation Software to eliminate left hand turns. As a result, they use 10 million gallons less fuel, emit 20000 tonnes less CO2 and deliver**350000 more packages each year**. The efficiency of the software has helped UPS reduce its number of trucks by 1100 bringing down the

company's total distance travelled by 28.5m miles despite the longer routes.

UPS senior vice president Bob Stoffel told *Fortune*, "We'll never have a person turn left to deliver on that side. We'll have someone go down the right-hand side and someone coming back down the right-hand side to avoid those left-hand turns. And that's where you get stuck in traffic trying to come back across."

The company still authorizes a left turn about 10% of the time if it's the most efficient way to go., maybe in a residential area or if a right turn takes the driver too far out of the way.

III. Conclusion

Courier services may look simple from the outside but they have a very complicated process happening within. In today's world, with the advancement of technology, the customers can track their products at any time they want. The courier companies are now more liable to deliver the products on time without delaying the process. While doing so, they have to ensure that their overheads don't become too expensive. Many factors like traffic, fuel consumption, weather etc.have to be taken into consideration in VRP. The Softwares used today can give proper details about which is the optimum path so that the companies can cut their cost. VRP has several constraints including time constraints, capacity constraints etc. VRP generalises the travelling salesman problem. Determining the solution to VRP is NP-hard, so the size of problems that can be solved, optimally, using mathematical programming is limited. Therefore, commercial solvers tend to use heuristics. There are various Softwares available for Route optimisation. These Softwares can solve problems within seconds. This shows how far technology has come. Even with the advances of dynamic routing there are certain challenges that remain for e.g., the driver. At least until we get autonomous vehicles, we'll be relying on drivers to adhere to the policies that we've set," said Kavanagh of WEX. "With all the technology, this is where things like gamification comes into play. The ever-changing business needs is another challenge." So what lies ahead? Smart city programs could use routing data to assist in traffic management. Autonomous driving will advance routing and maybe bring more optimisation and efficiency in courier delivery services.

References

[1] Minimization of Transportation Cost in Courier Service Industry by Muthu karthikeyan, Dr. M. Elango; International Journal of Innovative Research in Science, Engineering and TechnologyVolume 3, Special Issue 3, March2014. https://www.rroij.com/open-access/minimization-of-transportation-cost-incourier-service-industry.pdf
[2] http://neo.lcc.uma.es/vrp/
[3] http://www.orcomplete.com/computer/sertalpbilal/solving-vehicle-routing-problem
[4] Resources Requirement and Routing in Courier Service by C.K.Y. Lin; Department of Management Sciences, City University of Hong Kong Hong Kong, P.R.O.C.https://www.intechopen.com/books/vehicle_routing_problem/resources_requirement_and_routing_in_courier_service
[5] Vehicle Routing: Problems, Methods and Applications (Second Edition) by Paolo Toth and Daniele Vigo.
[6] https://sappond.wordpress.com/2011/10/12/what-are-the-types-of-transport-requests/
[7] https://www.capterra.com/courier-software/
[8] http://edition.cnn.com/2017/02/16/world/ups-trucks-no-left-turns/index.html