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Minimization of Transportation Cost in Courier Service Industry

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ABSTRACT — This paper is focused on methodology to reduce the transportation cost for a courier industry. Transportation cost is one of the major concerns in courier industry. Most of their operations depend on the vehicles, hence maintaining transportation cost as much as minimum will increase the profit margin. Each company has got customers with each demanding for both delivery /pickup with their vehicles having variable capacities. The problem concerning in this paper is to find a set of tours of the vehicles with minimum total travelling lengths, so that minimum transportation cost can be obtained. In each tour, a vehicle begins at the depot with certain amount of parcels/documents for delivery, then visits a subset of the customers in order to deliver on board parcels /documents. After completing all its delivery demand the vehicle will return back and start picking up the parcels/documents from the same customer point and returns to the depot. Irrespective of the time during the tour, a vehicle must always satisfy the capacity constraint of the vehicle. K-Means clustering is used as a standard clustering technique and that has been further refined by nearest neighbourhood heuristic. For both these clustering, routing has been done using LINGO solver. Transportation cost has been calculated for the corresponding routing distance given by the solver.

KEYWORDS— Transportation cost, K-Means Clustering, Nearest Neighbourhood

I. INTRODUCTION

In the current globalized and distributed economic environment, companies are more interconnected and rely more on transportation for their business. The competition among logistics companies has become more and more intensive. Customers of logistics companies have high expectation of service quality which often requires on-time delivery within a small delivery time window and with short notice. Courier delivers messages, packages, and mail. Couriers are distinguished from ordinary mail services by features such as speed, security, tracking, signature, specialization and individualization of express services, and swift delivery times, which are optional for most everyday mail services. It is costlier than normal mail services. Obsolescence nature of courier is very less when compared all other technological trends at all-time people use courier to send their goods from one place to other place using courier service. Logistics is the core competency of courier services. The firm will focuses on the scope to manage the transportation effectively at low cost which will fetch them a good profit. For this work Courier Service Providers (CSPs) operated in India has been considered .

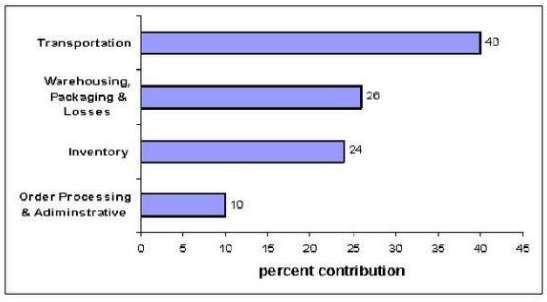

Figure. 1. Elements of Logistics cost in India
Source:sanyal(2006a) IIM A

Notations:

N - Customer points.
D_{ij} - Shortest distance between customer i and j.
d_i ,p_i - delivery& pickup request of node i
d_{iv}, p_{iv} - quantity of load to be deliver/ pick by vehicle v when departing from node i
v€V- Maximum number of vehicles
X_{ijv} - if vehicle v travels from i to j , else 0
C_a - Accumulated capacity of the vehicle
C_V - Actual capacity of the vehicle
MTL - Maximum Tour Length
p_i, d_i, C_v, p_{iv}, d_{iv} are non-negative integers.
NDSF-National Deep Submergence Facility

Figure 1 shows the split up of transportation cost on the total cost of the firm 40% of the total cost incurred by the transportation. This ultimately follows in the courier service industry too.

The courier delivery problem falls under the class of the vehicle routing problem (VRP), which was first introduced by Dantzig and Ramser in 1959. Being a fundamental problem in transportation, distribution, and logistics, VRP studies the scheduling a fleet of vehicles to satisfy a set of geographically dispersed demands at minimum cost. General review of the VRP can be found in a number of literatures, such as Toth and Vigo [1], Fisher [2], and Laporte and Osman [3]. Taillard et al. [4] suggest in their study that assigning more routes to a vehicle is a more practical solution in real life. Brandao and Mercer [5] improved the study by considering not multi-trip VRP, but also including the delivery time window and the capacity of the vehicles. Petch and Salhi[6] integrate the approaches proposed by Taillard et al. [4] and Brandao and Mercer [5]. Alonso et al. [7] extended the classical VRP to a periodic and multi-trip VRP with site-dependency and proposes a Tabu search based algorithm.A. Subramanian in [8] developed a parallel heuristic for the Vehicle Routing Problem with Simultaneous Pickup and Delivery. C K Y Lin in [9] develops a cooperative strategy for a vehicle routing problem with pickup and delivery times. The Lagrangian relaxation approach can be either an exact or a heuristic approach, depending on the ability of the algorithm to find good Lagrangian multipliers. Kohl and Madsen [10] applied Lagrangian relaxation to the customer assignment constraints of a VRP with a single time window per customer. The resulting model is decomposed into a set of simpler sub-problems: a shortest path problem with time windows and capacity constraints for each vehicle. Imai et al.[11] relaxed the truck capacity constraints for a PDP where trucks transport full container loads. The relaxed problem is decomposed into an assignment problem forming delivery-pickup location pairs. The pairs are then assigned to trucks by solving a generalized assignment problem. Tsung-Sheng et al in **[**12**]** formulated the city-courier routing and scheduling problem as a multi-objective multiple traveling salesman problems with strict time windows (MOMTSPSTW) that is NP-hard and then proposed a multi-objective Scatter Search framework that seeks to find the set of Pareto-optimal solutions to the problem.Michel Gendreau et al in**[**13**]** focused on a problem typically found in courier services for the same-day local pick-up and delivery of small sized items as opposed to dispatching systems where a vehicle is dedicated to a single customer, like those found in emergency services or truckload trucking applications, planned routes are associated with each vehicle to specify the order of visit of the previously assigned. Srisawat Supsomboonin**[**14**]** developed a mathematical model, Binary Integer programming, by using LINGO software solver. The objective was to find optimal routes of shortest distance in order to minimize logistics or transportation cost .Reza Tavakkoli Moghaddamin **[**15**]** presented a new mathematical model for a periodic vehicle routing problem (PVRP) considering several assumptions that minimizes vehicle travel costs. As it is a unified model, impose its computational complexity and are noTable to solve such a hard problem by any optimization software in a reasonably computational time, especially for large-sized problems. Thus, we propose a meta-heuristic method based on particle swarm optimization (PSO).

VRP is an important problem in the fields of transportation, distribution and logistics. Effective management of logistics incurs less transportation cost which can be done through vehicle routing problem. All the courier problem comes under Vehicle Routing Problem Delivery and Pickup (VRPDP).following sections of this paper consists in section 2 problem formulation has been discussed , In section 3 methodology used discussed followed with results and discussion in section 4.Conclusion has been given in section 5.

II. PROBLEM FORMULATION

Transportation cost is one of the major costs incurred during operations in courier service industry. Their profit margin depends purely on transportation cost hence they always strive to keep the cost at lower level. So that competitiveness among other courier service providers can be established .Consider the CSP which have 27 customers with a aid of 6 vehicles, each vehicle has its own capacity in terms of tones. CSP wants to utilize the maximum capacity of the vehicle(truck ,van etc.) while delivering and picking up the couriers to/from the customer points, and to reduce total distance travelled while completing the tour which increases the total transportation cost. Hence, this project work concentrates to reduce the transportation cost by reducing the travelling distance and utilizing the maximum capacity of the vehicle.

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

Subjected to

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

$$\sum_{i=0}^{N} X_{ijv} - \sum_{i=0}^{N} X_{jiv} = 0 \quad \text{for all } j = 0 \ldots N, \quad v = 1 \ldots V \tag{3}$$

$$\sum_{i=0}^{N} p_{iv} X_{ijv} \leq C_{V,} \text{for all } j = 1 \ldots N \tag{4}$$

$$\sum_{v=1}^{V} \sum_{i=0}^{N} \sum_{J=0}^{N} D_{ij} X_{ijv} \leq MTL \tag{5}$$

The objective function Equation 1 minimize the travelling distance between the customer points of vehicle. Equation 2 shows that each customer should be visited exactly once by vehicle, Equation 3 is route continuity equation. Equation 4 shows that quantity of pickup load at customer point should not exceed the vehicle capacity. Equation. 5 is the maximum tour length constraint i.e., objective value should not exceeds the MTL.

A. Case system data

In this work, data has been collected about the number of customers, locations, demands, number of vehicle used and maximum tour length shown in Table 1. Parcels/documents from various part of India will be collected and distributed to the respective places from the common depot. Let us consider the CSP with 27 main service points among those few are the cross docking points from which the parcels/documents get separated to the other interior service points, that mean the service through truck is offered only to the node of the route not to the arc, arc can be done by cross docking through small vehicle and other means of delivery/pickup vehicles. In existing methodology CSP actually not using any standard techniques to cluster and allot the vehicle to the cluster. it has been done on the basis of existence of cities present in a straight path, due to this company tend to send individual vehicle to the each straight line path shown in Figure 2, this enables the firm to incur high transportation cost and increase in number of vehicles.

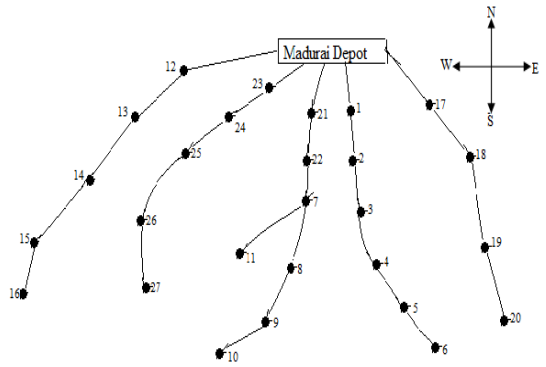

Figure 2. Current route map

TABLE I.

CUSTOMER POINTS DELIVERY AND PICK UP DETAILS

S.No	Customer points(C)	Average demand (kg)		Max Tour Length (km)	No of Vehicle used
		Delivery	Pick up		
1	C1	14	21	547	1
2	C2	219	190		
3	C3	4	2		
4	C4	681	702		
5	C5	73	55		
6	C6	3	5		
7	C7	223	242	212	1
8	C8	2	7		
9	C9	79	100		
10	C10	216	198		
11	C11	315	432	184	1
12	C12	9	3	334	1
13	C13	17	31		
14	C14	319	371		
15	C15	30	27		
16	C16	37	40		
17	C17	96	95	275	1
18	C18	23	41		
19	C19	362	390		
20	C20	370	500		
21	C21	66	254	302	1
22	C22	33	30		
23	C23	8	5		
24	C24	143	176		
25	C25	245	185		
26	C26	87	102		
27	C27	3	3		

TABLE II.

ANALYSIS OF EXISTING DATA

Route	Max Loading Capacity(Tones)	Accumulated Capacity(Tones)	Transportation cost(Rs)
1	3.5	1.2	7371
2	2.5	1	2226
3	.75	.30	1380
4	2.5	1	3507
5	6	1.5	3715
6	3.5	1.5	4077

Total Transportation Cost Per Day (Existing) - 22276Rs

Table II shows the transportation cost of the considered CSP which does not use standard clustering

technique and customized routing method for their fleet this makes the transportation cost high.

III. METHODOLOGY

The adopted methodology to address this issue to reduce the transportation cost is by clustering the customer service points on the basis of distance and nearest neighborhood in order to attain minimum distance travelled to serve all the customer points at minimum cost and also effectively reduce the number of transportation vehicles required.

A. K-Means clustering

K-Means clustering can be used to get a combination of cities with respective to the centroid. Cities gets cluster as a group based upon the centroid, customer points will have minimum distance with all the other cities present in the group. XY co-ordinates of customer service points has been given as input to K-Means clustering method. For real time data usage corresponding longitude & latitude of cities can be taken from the internet and converted into a corresponding (X,Y) coordinates using NDSF software application.

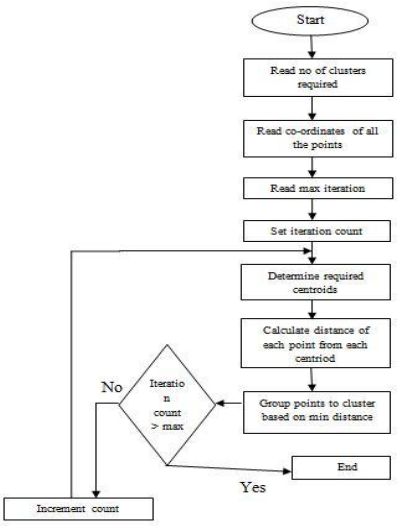

Figure 3. K-Means algorithm for clustering

Figure 3 shows the flow chart of the K-Means Method the clustering can made for 2 cluster, 3 cluster, 4 cluster, 5 cluster (K=2,3,4,5) reason for going up to 5 , In existing scenario courier company uses 6 vehicles to serve all their customer, hence to reduce the number of vehicles clustering limited as 5. Each cluster can have few or many customers in the group, these each cluster mean that one vehicle can send to the cluster to satisfy the customer demand with minimum distance, obeying maximum tour length and should not exceed vehicle capacity. For each cluster travelling distance has been calculated ,if the obtained value lesser than the Maximum tour length and obey all other constraints then that can be consider for the best solution if not next clustered cities will be consider. In this paper we have tried different K values and finally got a cluster of cities which has given minimum objective value than other combinations.

B. Nearest Neighborhood method

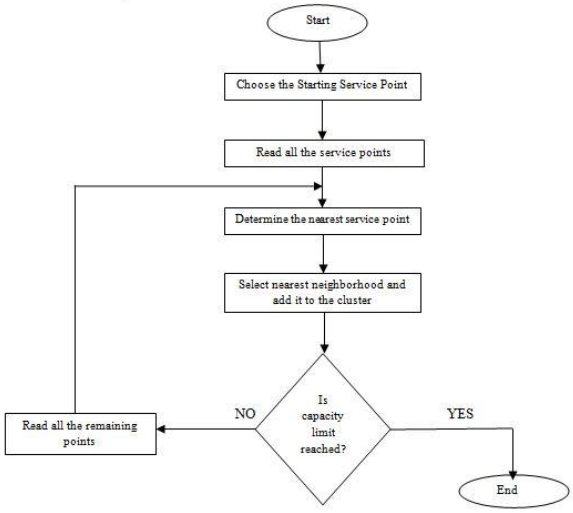

Figure 4. Flowchart for Nearest neighborhood method

IV. RESULTS

Case 1

TABLE III.

INPUT DATA (K-MEANS)

Cities	X	Y
C1	-2.1275	-24.2989
C2	-2.1275	-45.3313
C3	-14.9257	-85.1293
C4	2.2592	-122.7334
C5	-9.541	-158.8666
C6	-19.6754	-144.8356
C7	-18.5777	-37.2060
C8	-20.7710	-60.7971
C9	-20.5846	-50.7214
C10	-27.3511	-82.9172
C11	-35.0278	-51.9491
C12	-25.1577	-18.7689
C13	-53.6715	-44.6356
C14	-62.4447	-51.9497
C15	-62.4447	-84.0232
C16	-77.7213	-83.2822
C17	-8.1154	1.5042
C18	-35.0278	5.5612
C19	-40.5112	16.5268
C20	-81.0081	-9.9209
C21	-89.8761	-20.9809
C22	-33.1965	-22.4519
C23	-70.1214	-24.9989
C24	51.7192	-41.5526
C25	77.9297	-59.6911
C26	-6.0317	-3.8710
C27	-15.2786	-12.1320

The obtained X,Y coordinate shown in Table III has implemented in to MATLAB , 4 clustering of customer service points has been given it has clustered the cities based on the minimum distance results shown in the Figure 5 each cluster can be modeled as distance matrix so that routing can be done through LINGO 8 solver.

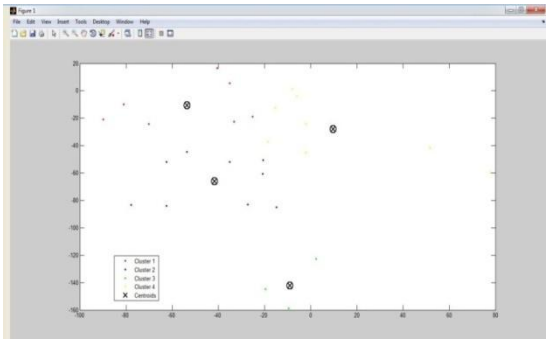

Figure 5. K-Means clustered customer service points

TABLE IV.

COMBINATION OF CLUSTERED CITIES (K-MEANS)

Cluster 1	Cluster 2	Cluster 3	Cluster 4
C10	C1	C3	C6
C23	C2	C4	C11
C24	C7	C5	C27
C25	C9		C12
C26	C8		C13
C14	C18		C15
C16	C19		C20
C17			C21
			C22

Table IV shows the clustered cities of K-Means method. K-Means used for the clustering and customized routing done using LINGO solver. Though it has given the minimized value of the previous transportation cost, but it fails to satisfy the maximum tour length (520km). MTL is the requirements followed in CSP in order to deliver/pickup the demands at correct time. The tour which exceeds the MTL will surely fetches more time to service the entire customer points which ultimately leads to customer dissatisfaction.

Case 2

In K-Means method clustered cities does not obey the Maximum tour length constraint. Hence it has been further refined by clustering the cities based on the neighborhood. The flow chart has shown in the Figure 4. Clustered combination for nearest method shown in Table V.

TABLE V.

COMBINATION OF CLUSTERED CITIES(NEAREST NEIGHBOURHOOD METHOD)

Cluster 1	Cluster 2	Cluster 3	Cluster 4
C1	C21	C12	C17
C2	C22	C13	C18
C3	C7	C14	C19
C4	C8	C16	C20
C5	C23	C15	
C9	C24		
C10	C 25		
C6	C26		
	C27		
	C11		

A. Routing of Vehicle

Routing of vehicle is major concern in this work. Allotting right vehicle to the right clusters produced by both methods. Routing should be in a such a way that it should produce a result with minimum distance to serve all the points in the cluster Vehicle will travels the following route, initially starts it tour from the depot completes its demand of delivering courier to the customers and finally stops at point where all the accumulated parcels/documents becomes zero. Then that last point will be treated as a depot, from their vehicle will starts to pick up demand service of the same customers both these operations follows the routing given by the LINGO solver. By this approach we can get a minimum distance to serve all the points and there will be reduction in number of vehicles used. This is the process for all the clusters. This is called Vehicle Routing Problem Delivery and Pickup.

Case 1

TABLE VI.

TRANSPORTATION COST(K-MEANS CLUSTERING METHOD)

Cluster	Routing distance (km)	No of vehicles used	Vehicle capacity (tones)	Transportation cost(Rs)
1	389.200	1	3.5	5254.2
2	220.800	1	2.5	3249.6
3	188	1	2.5	2256
4	636.200	1	6	8588.7

Total transportation cost per day -19348 Rs

Table VI shown the transportation cost for the K-Means Method here for the 4th cluster routing distance in 636.200 which does not obey the MTL (520). Hence this has been further refined using nearest neighborhood method.

Case 2

Routing of the cities obtained in Nearest neighborhood Method and the transportation cost for the corresponding Travelling distance is shown in Table VII and Table VIII respectively.

TABLE VII.

ROUTING OF VEHICLES

Cluster	Routing of vehicle (Delivery & pick up)	LINGO objective value
1	Depot- C1-C2-C9-C10-C3-C4- C5 –C6	497.3
2	Depot- C21-C22-C23-C7-C8-C11-C24-C25-C26-C27	393.3
3	Depot- C12-C13- C14- c16- C15	269.4
4	Depot- C17-C18-C19-C20	331.1

TABLE VIII.

TRANSPORTATION COST(NEAREST NEIGHBORHOOD METHOD)

Cluster	Routing distance(Km)	No of vehicle used	Vehicle capacity(tones)	Cost per km	Transportation cost per day(Rs)
1	497.300	1	6	13.5	6713.6
2	393.3	1	3.5	12	4717.2
3	269.4	1	2.5	12	3232.8
4	331.1	1	2.5	12	3476.55

Total transportation cost per day -18636 Rs

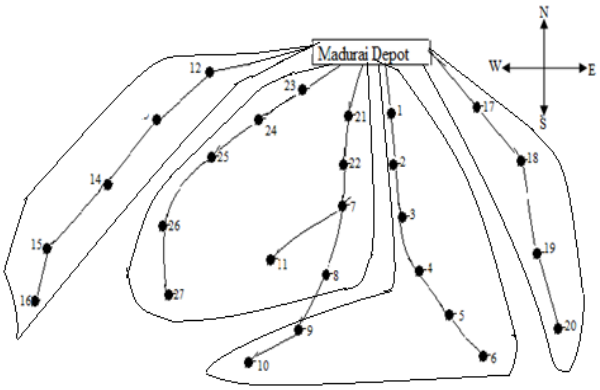

Figure 6. Proposed Route map

Figure 6 shows the Proposed Route Map of the cities considered incurs the reduced transportation cost than the earlier one is shown in Table IX.

TABLE IX.

SUMMARY OF RESULTS

S.NO	Combination of cities	Total transportation cost (Rs)	Number of vehicles used	Cost savings per day (Rs)	Cost savings per month(Rs)
1	Existing transportation cost	22276	6	-	-
2	Using K-means clustering combination	19348	4	2928	87840
3	Using Nearest neighborhood method	18636	4	3640	1,09,200

V. CONCLUSION

The work aims to provide a combined approach for both reductions in the service distance travelled and also the number of vehicles employed for the task. A real time sample test system was developed and the task was performed using k-means clustering and Nearest neighborhood method. From the results and discussions it is concluded that, travelling distance between the customer points has been minimized and number of vehicles used to serve also reduced thereby transportation cost reduced considerably . Cost savings of Rs 2928 for K-means clustering, Rs 3640 for Nearest neighborhood method. Number of vehicles reduced from 6 to 4. Thus, the obtained result substantiates the effectiveness of the application of the proposed method. This work can also be refined further for different applications.

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