International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Application of Arc Routing Problem for Municipal Solid Waste Collection in Kolhapur City, India

Nilesh A Aynodkar†* and S. M. Bhosale†

†Department of Technology, Shivaji University, Kolhapur, India-416004

Accepted 02 June 2015, Available online 12 June 2015, **Vol.5, No.3 (June 2015)**

Abstract

Solid waste management in most cities in India has become more demanding and in which Kolhapur is not an exception. It has therefore become necessary to design a model which can be used by Municipal Corporation and government alike to use an optimum distance to collect more waste in an area. Therefore why this work will be done to come out with a solution that can be used to minimize the tour in a collection area and also give some sort optimal routes for collection.

Keywords: *Ant colony optimization, arc routing problem, pheromone trail, heuristic value.*

1. Introduction

Kolhapur Municipal Corporation serves the area of 66.28 sq. km. There are total 11 sanitation wards in the Kolhapur city. Total population of Kolhapur as per 2011 census is 3,876,001. As per the Environmental status report 2012-2013 of Kolhapur Municipal Corporation, this city generates 165 MT solid wastes per day. So there is a need of optimized collection routing model to improve the collection of municipal solid waste. At present Kolhapur Municipal Corporation needs 25 crores more fund to improve the solid waste management system in the city. Collection of solid waste by optimized root through the application of arc rooting problem will reduce the some kind of load on solid waste management system. Kolhapur city is growing very fast with its population as well as industries. This increase is leading to production of large quantity of solid waste and that has to be managed properly. To understand and suggest management strategies the study of management of MSW of Kolhapur city is undertaken.

The collection, transport, processing and disposal of solid wastes require a large investment but receive small attention. Solid waste management is becoming a major problem of public health and environmental concern in urban areas of developing countries. The solid waste generated from the industrial area are heterogeneous in characteristics. The disposal of municipal solid waste is one of the more serious and challenging urban issues facing local governments in India, and indeed most technologically developed countries. Municipal solid waste comprises everyday items, such as product packing's, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, batteries, and other consumer related product forms. The composition depends upon number of factors such as lifestyles of population, their relative standards of living, general consumer pattern and the level of technological advancement of particular countries. Generation, composition and impact of municipal solid waste is difficult to predict and can have an unclear overall effect. The situation in India particularly in the capital cities is severe. In general solid waste management is given a very low priority and as a result, very limited funds are provided for solid waste management by the government. Today solid waste management is a top priority issue all over the world. Urbanization is occurring rapidly and the living standards are improving

2. Ant colony optimization

Ant colony optimization is a major part of the larger field of swarm intelligence in which scientists study the behavior patterns of bees, termites, ants and other social insects in order to simulate processes.

The ability of insect swarms to thrive in nature and solve complex survival tasks appeals to scientists developing computer algorithms needed to solve similarly complex problems. Artificial intelligence algorithms such as ant colony optimization are applied to large combinatorial optimization problems and are used to develop solution for such problems.

Ant colony optimization is a meta-heuristic technique that uses artificial ants to find solutions to combinatorial optimization problems. ACO is based on the behavior of real ants and possesses enhanced

*Corresponding author: **Nilesh A Aynodkar**

abilities such as memory of past actions and knowledge about the distance to other locations. In nature an ant alone can't hunt for food effectively. But as group ants can solve complex problem and can find minimum distance towards their food. Thus is to find food for their colony. Ants communicate by secreting chemical substance called pheromone. As ant moves forward it deposits constant amount of pheromone that guide other ants to follow. Each ant moves in random fashion but as ant encounters the pheromone trail, it must take decision whether to follow it or not. As ant follows the pheromone trail, it increases the amount of pheromone in existing trail. Increase in pheromone increases probability of the next ant selecting the path. So more the ants travel that path , it becomes more attractive for next ants to travel. Furthermore, ants choose shortest route to travel it will reach nest soon. So it will mark its route twice. Over time, as more ants are able to complete the shorter route, pheromone accumulates faster on shorter paths and longer paths are less reinforced. The evaporation of pheromone also makes less desirable routes more difficult to detect and further decreases their use. However, the continued random selection of paths by individual ants helps the colony discover alternate routes and insures successful navigation around obstacles that interrupt a route. Trail selection by ants is a pseudo-random proportional process and is a key element of the simulation algorithm of ant colony optimization.

3. Ant colony optimization for arc routing problem

Ant colony optimization (ACO) relates to the group of metaheuristic methods. This idea was first put forth in early 90s. The basic idea of ACO is to simulate the real behavior of ants in nature. The working ant colony gives indirect communication with the help of pheromone which ants excrete. The attractiveness of a given path depends upon the quantity of pheromone that ants excrete. The use of more attractive route ensures that the ant exudes more pheromones on its way back and so that path is more also attractive for other ants.

For practical application of ACO, it was necessary to project the artificial ants. It is important to set their initial properties. These properties help the ants to find shortest route. Artificial ants don't move continuously. They move in jumps. So after time unit, they will always in another node. The travelled path is saved in ant's memory. In the next tour ant decide by pheromone intensity. Because of pheromone evaporation, intensity on shorter path will be more.

3.1 Design and solution

Movement of artificial ant depends on amount of pheromone on edges. The probability *Pij* of movement of artificial ant from node i to node k is given by the formula (1).

$$Pij = \frac{(\tau ij)^{\alpha}\ X\ (\eta ij)^{\beta}}{\mathcal{E}(\tau ij)^{\alpha}\ X\ (\eta ij)^{\beta}} \quad (1)$$

Where,
τ_{ij}=Intensity of trail on edge between customer *i* and customer *j* at time *t*
η_{ij}=Visibility of edge between customer *i* and customer *j*.
η_{ij} is usually assumed as the inverse of the distance between customer *i* and customer *j.* Construct the initial graph G= (N, A) where set A fully connects components N. and is identical to the problem graph, that is the set of states of the problem corresponds to the set of all possible partial tours.

An initial solution is first obtained using the nearest neighbor heuristic: start from depot and then select the not yet visited closest feasible customer as the next customer to be visited. Each ant has its memory list called tabu list. Tabu list forces ants to make legal tour. It saves the nodes already visited. After all cities are visited, the tabu list of each ant will be full. The shortest path found is computed and saved. Then, tabu lists are emptied. This process is iterated for a user-defined number of cycles.

3.3 Initial pheromone trails

In most of the ant colony based algorithms to arc routing problem or VRP, initial pheromone trails τ_0 is set equal to the inverse of the route distances found for the particular problem. However, it was found that $\tau_0 = \frac{1}{n}$.

3.4 Route construction process

It is assumed that number of ants equal to number of customer. At start each ant positioned at each node point. Then, each ant constructs its own tour by successively selecting a not yet visited feasible node. The choice of the next customer to visit is based on proportional fitness (Roulette Wheel) in conjunction with the information of both the pheromone trails and the visibility of that choice.

3.5 Pheromone update

Artificial ant is using the same reverse path as the path to the food resource based on his internal memory, but in opposite order and without cycles, which are eliminated. After elimination of the cycles, the ant puts the pheromone on the edges of reverse path according to formula (2).

□□$_{ij}$ □ □□□$_{ij}^{k}$ (2)

where □□$_{ij}^{k}$ is the added pheromone to the arcs in the tour ant *k* has visited.

4. Case study

In this work we have taken Rajarampuri area in Kolhapur as a case study. Where we applied Ant colony optimization to find out shortest rout for municipal solid waste collection.

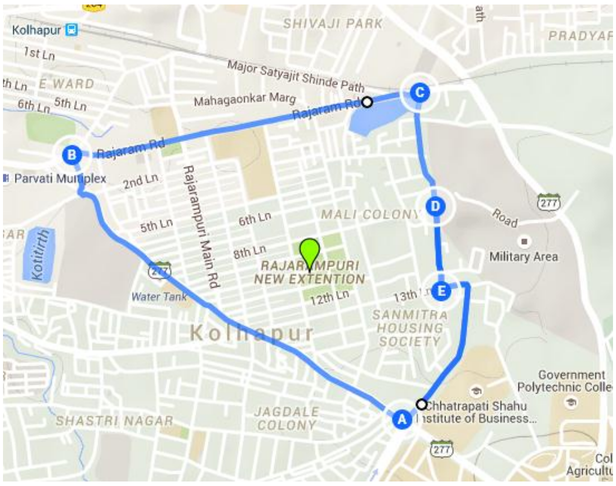

Figure 1: Maps showing Rajarampuri, Kolhapur with solid waste collection points

After finding location of collection point we measure distances between collection points. There are total five collection points. For measurement we refer data from Kolhapur Municipal Corporation and with the help of google maps.

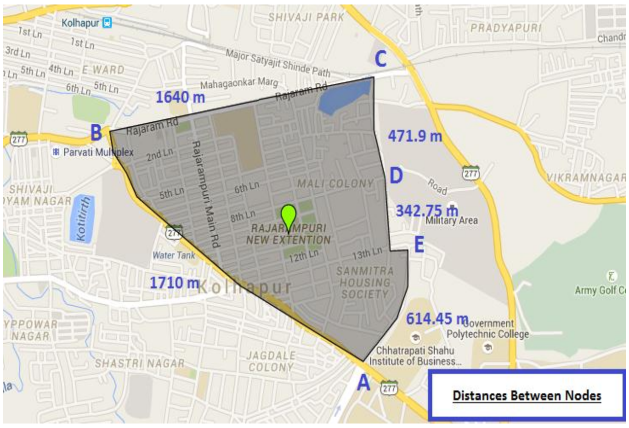

Figure 2: Distances between collection points

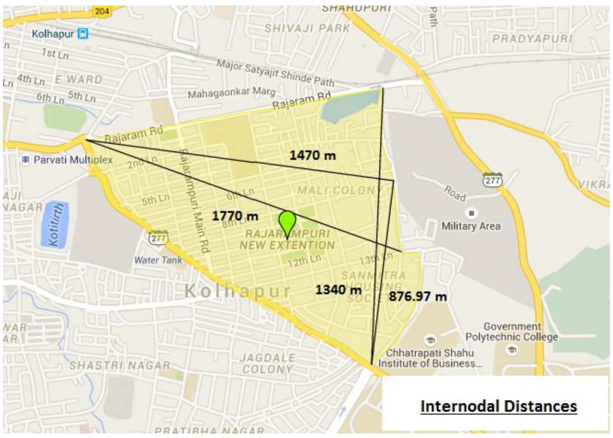

Figure 3: Inter distances between collection points

After measuring all distances between collection points, we convert our problem into travelling salesman problem.

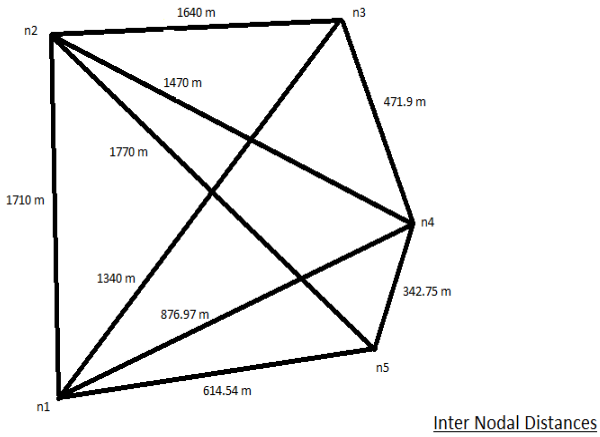

Figure 4: Connectivity diagram showing distances between collection points

Table No 1: Connective matrix

	A	B	C	D	F
A	0	1710	1340	876.97	614.54
B	1710	0	1640	1470	1770
C	1340	1640	0	471.9	814.06
D	876	1470	471.9	0	342.75
F	614	1770	814.06	342.75	0

5. Application of Ant colony optimization

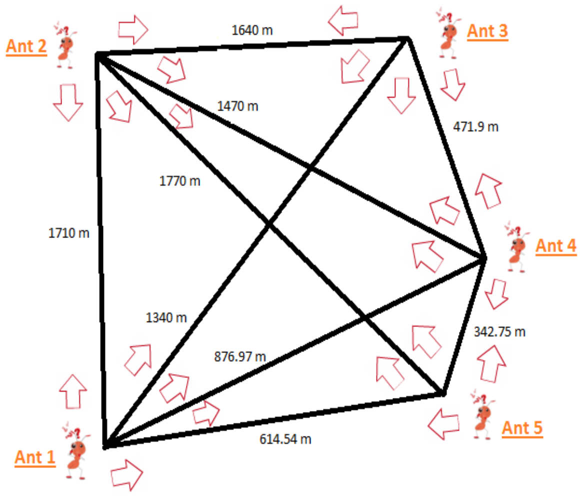

Figure 5: Probabilities of Ant's travel

5.1 Since there are five nodes (five collection points), choose size of colony as 5, each ant will start its tour from different collection point (node).

Let the heuristic value,

$$\eta ij = \frac{1}{dij}$$

Where d_{ij} is the distances between two collection points.

Table 2: Heuristic value

	N₁	**N₂**	**N₃**	**N₄**	**N₅**
N₁	0	0.584	0.746	1.15	1.62
N₂	0.584	0	0.609	0.680	0.564
N₃	0.746	0.609	0	2.12	1.22
N₄	1.15	0.680	2.12	0	2.92
N₅	1.62	0.564	1.22	2.92	0

5.2 At start there should be equal amount of pheromone trail on each edge. As size of colony is 5. Let be one volume of pheromone initially present. So amount of pheromone on edge is $\frac{1}{5} = 0.2$

Table 3: Initial pheromone value (τ_0)

	N₁	**N₂**	**N₃**	**N₄**	**N₅**
N₁	0	0.2	0.2	0.2	0.2
N₂	0.2	0	0.2	0.2	0.2
N₃	0.2	0.2	0	0.2	0.2
N₄	0.2	0.2	0.2	0	0.2
N₅	0.2	0.2	0.2	0.2	0

5.3 First iteration

We apply formula no 1 on each edge.

As the first ant starts its tour from first collection point n_1, there are four neighboring collection points to be considered by the first ant.

The probability of choosing any edge leading to another collection point is calculated above. These probabilities are tabulated below.

N₂	N₃	N₄	N₅
0.0704	0.114	0.273	0.541

Using proportional selection (Roulette Wheel), the ant chooses next collection point (node) say n_5.

The ant will update its memory and put node n_1 and n_5 in its tabu list.

When arrives at n_5, there are three nodes left to visit. The probability of choosing these nodes is tabulated below.

N2	N3	N4
0.030	0.14	0.82

Using proportional selection (Roulette Wheel), the ant chooses next collection point (node) say n_4.

The ant will update its memory and put node n_1, n_5 & n_4 in its tabu list.

When arrives at n_4, there are two nodes left to visit. The probability of choosing these nodes is tabulated below.

N₂	N₃
0.093	0.90

Using proportional selection (Roulette Wheel), the ant chooses next collection point (node) say n_3.

When ant arrives at node n_3, there is only one node to visit n_2.

The path that was built by ant 1 is n_1□□n_5 □□n_4 □□n_3 □□n_2.

The length of this path = $n_1n_5 + n_5n_4 + n_4n_3 + n_3n_2$

= 0.614+0.342+0.471+1.64

= 3.067 km.

When all ants finish their tour, they will back track and update the pheromone along their path by putting additional pheromone (□□), which is proportional to the gain obtained by the ant.

The new pheromone value is given by

□ **new** □ **(1 □ □)**□ **old** □□□□ (3)

where □ is the evaporation constant and it is taken as □ = 0.5 .

Similarly this procedure is applied for remaining four ants. Thus result given by ants is tabulated below.

Table 4: Results by first iteration

Ant	Path	Length of the path	□□□□□□□$\frac{7.08}{l}$
Ant 1	n_1□□n_5 □□n_4 □□n_3 □□n_2	3.067	2.3
Ant 2	n_2□□n_4 □□n_5 □□n_1 □□n_3	3.76	1.88
Ant 3	n_3□□n_4 □□n_5 □□n_1 □□n_2	3.13	2.26
Ant 4	n_4□□n_5 □□n_1 □□n_2 □□n_3	4.306	1.64
Ant 5	n_5□□n_4 □□n_3 □□n_2 □□n_1	4.163	1.70

Pheromone update is done for all edges. Thus results we got are tabulated below.

Table 5: Pheromone update after first iteration

	N₁	**N₂**	**N₃**	**N₄**	**N₅**
N₁	0	5.7	1.98	No update	8.18
N₂	5.7	0	5.74	0.98	No update
N₃	1.98	5.74	0	6.36	No update
N₄	No update	0.98	6.36	0	9.88
N₅	8.18	No update	No update	9.88	0

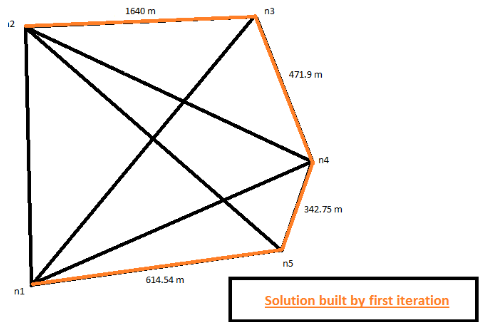

Figure 6: Best solution built by the first iteration

The same procedure is repeated as done in the first iteration. However, the initial pheromone values on all the edges have changed, thus the probability of selecting a certain edge will also change. The higher the pheromone on the edge, the more attractive it is for an ant to choose. After going through the whole procedure again, the table below summarizes the solutions built by the ants.

Table 6: Results by 2nd iteration

Ant	Path	Length of the path	□□□□□□□ $\frac{7.08}{l}$
Ant 1	n_1□□n_5□□n_4 □□n_3□□n_2	3.06	2.31
Ant 2	n_2□□n_3□□n_4 □□n_5□□n_1	3.06	2.31
Ant 3	n_3□□n_4□□n_5 □□n_1□□n_2	3.13	2.26
Ant 4	n_4□□n_5□□n_1 □□n_2□□n_3	4.3	1.64
Ant 5	n_5□□n_4□□n_3 □□n_2□□n_1	4.16	1.70

Pheromone update is done similar as done in iteration 1. The result given by pheromone update at the end of iteration 2 is tabulated below.

Table 7: Pheromone update after 2nd iteration

	N_1	N_2	N_3	N_4	N_5
N_1	0	5.70	No update	No update	8.62
N_2	5.70	0	8.06	No update	No update
N_3	No update	8.06	0	8.68	No update
N_4	No update	No update	8.68	0	10.32
N_5	8.62	No update	No update	10.32	0

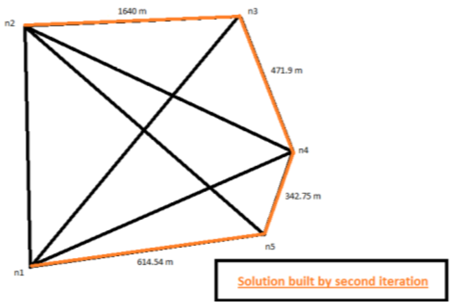

Figure 7: Best solution built by second iteration

The solution shown on connectivity diagram is implemented on Rajarampuri location maps. As implementation of results given by ants gives us optimized route for solid waste collection in Rajarampuri.

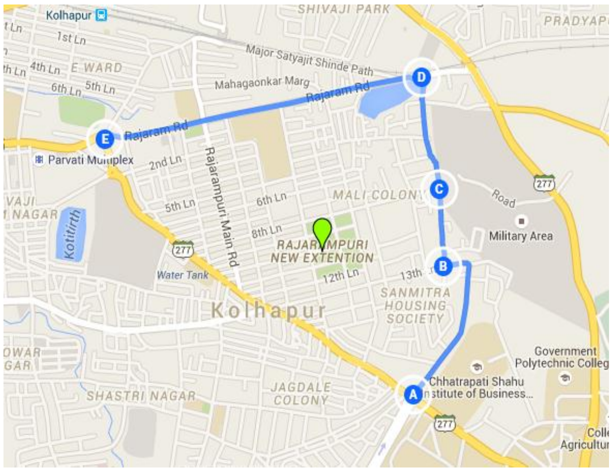

Figure 8: Optimized route for Rajarampuri, Kolhapur

Conclusion

The study was aimed at finding the minimum tour that can be used to collect solid waste at Rajarampuri. After formulating the problem as vehicle routing problem, **ant colony optimization** was implemented on each node to find the minimum tour.

We have model the routing of cluster points as CCVRP and determine optimal routing by Ant Colony optimization. We have also been able to determine optimum routing distance for Municipal solid waste collection in Rajarampuri, Kolhapur with a total routing distance in the area as (614.54+342.75+471.9+1640) m = 3069.19 m = 3.06 km.

References

Marco Dorigo, Luca Maria Gambardella (1997), Ant colonies for the travelling salesman problem,*IRIDIA*,p.p. 1-10.

Environmental Status Report (2012-2013) Kolhapur Municipal Corporation, Kolhapur.

Ministry of urban development, Government of India,(2000) Manual on municipal solid waste management.

R. Nithya, A. Velumani, S. R. R. Senthil Kumar, (2012)Optimal Location and Proximity Distance of Municipal Solid Waste Collection Bin Using GIS: a Case Study of Coimbatore City, *Weas transactions on environment and development,*8,p.p.107-119.

A. M. Vasumathi and S. Nagan,(2009) Geographic Information System: A Promising Tool for Collection and Transportation Route Optimization of Municipal Solid Waste Management, *International Journal of Earth Science and Engineering,*02,p.p. 569-575.

Ashtashil Vrushketu Bhambulkar,(2011) Municipal solid waste collection routes optimized with arc GIS network analyst, *International journal of advanced engineering sciences and technologies,*11 , p.p. 202-207.

Shaleen S & Suneel P.(2001)Solid waste management in India: status and future directions, *TERI Information Monitor on Environmental Science*, p.p.1-4.

Belenguer J. M., E. Benavent, Lacomme P. and Prins C,(2003) Heuristics and lower bounds for the mixed capacitated arc routing problem.*Univ. Tecnologie de Troyes, France*.

Rajendra Kumar Kaushal,(2012) Municipal Solid Waste Management in India-Current State and Future Challenges: A Review, *International Journal of Engineering Science and Technology (IJEST),*4,p.p. 1473-1489.

D. Otoo , S. K. Amponsah , C. Sebil,(2014) Capacitated clustering and collection of solid waste in kwadaso estate , Kumasi , *Journal of Asian Scientific Research,* p.p. 460-472.