

# Application of Ant Colony Optimization for the Municipal Solid Waste Collection in Kolhapur City

N. A. Aynodkar\*, S. M. Bhosale\*\*

\*Department of Technology, Shivaji University, Kolhapur 416004 (India)

\*\*Assistant Professor, Department of Technology, Shivaji University, Kolhapur 416004 (India)

**Abstract:** Solid waste management in most of the cities in India has become more challenging and in which Kolhapur city can't be neglected. It has therefore become necessary to design optimum route for municipal solid waste collection that can be used by Kolhapur Municipal Corporation. Therefore this work is done to calculate and design optimum route for municipal solid waste collection. Thus more waste can be collected by travelling short distance.

**Keywords:** Ant colony optimization, heuristic value, tabu search, pheromone

## 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 5, 49,283. Kolhapur Municipal Corporation, this city generates 165 MT solid wastes per day. At present Kolhapur Municipal Corporation needs 25 crores more fund to improve the solid waste management system in the city.[1]

In this work we have taken Rajarampuri as a case study area. It is a typical residential area in Kolhapur with number of stores and residential buildings. This area has plan with main road going down its length and street intersecting at right angle.

Therefore it is necessary to collect solid waste by using optimized route, which can improve collection efficiency. Application of Ant colony optimization for collection route design will reduce some kind of load on solid waste management system. Kolhapur city is growing very fast with its population as well as industries. This increase results in production of large quantity of solid waste and it has to be managed properly.

## 2. Ant System

Ant colony optimization is a major part of swarm intelligence in which researcher study natural behavior pattern of ants. When ant system was introduced, it was used to solve travelling salesman problem. Initially three different ant systems were introduced. [2] These are ant density, ant quantity and ant cycle. In ant density and ant quantity, the ants update their pheromone directly after a move from one city to adjacent city. While in ant system pheromone update is carried out after all ants has constructed their tour. [3] Ant cycles give better results than other two ant systems.

### 2.1 Route Construction

At start, each ant is located at randomly chosen city. At each step, ant k follows probabilistic action choice rule.

Probability with which ant k, currently at city i, chooses to go to city j at  $t^{\text{th}}$  iteration is given by formula 1.

$$p_{ij}^k(t) = \frac{[\tau_{ij}(t)]^\alpha [\eta_{ij}]^\beta}{\sum_{l \in N_{(i,k)}} [\tau_{il}(t)]^\alpha [\eta_{il}]^\beta} \quad (1)$$

Where

$$\eta_{ij} = \frac{1}{d_{ij}} \quad (2)$$

is an heuristic value,  $\alpha$  &  $\beta$  are two parameters which determines the influence of the pheromone trail and  $N_{(i,k)}$  is the feasible neighborhood of ant k, that is, ant k has not visited that cities yet. Where  $d_{ij}$  is the distance between two cities.

If  $\alpha = 0$  then possibility of selection of closest cities. If  $\beta = 0$  then only pheromone value is taken into consideration.

### 2.2 Pheromone Update

After completion all ant's tour, pheromone trails are updated. This is done by lowering the strength of pheromone of all edges by a constant factor and then each ant is allowed to add pheromone to the edges it has visited. Is is done by formula (3).

$$\tau_{ij}(t+1) = (1-\rho) * \tau_{ij}(t) + \sum_{k=1}^m \Delta \tau_{ij}^k(t) \quad (3)$$

If an particular edge is not used by any ant then its associated pheromone strength decreases exponentially.

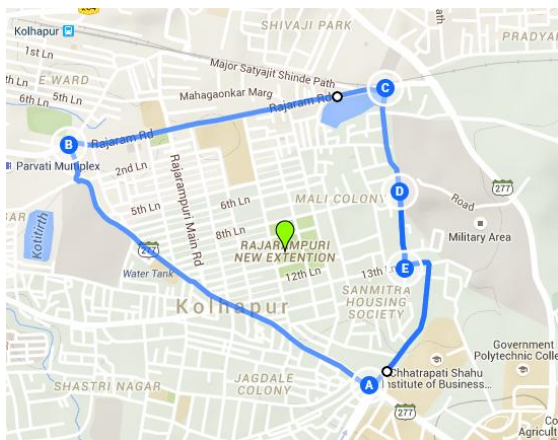
$$\Delta_{ij}^k(t) = \begin{cases} \frac{1}{L^k(t)} & \text{if arc}(i,j) \text{ is used by ant } k \\ 0 & \text{otherwise} \end{cases}$$

### 2.3 Tabu Search

Solutions having the same attributes with the previously searched solutions are put into tabu list and moving to these solutions is forbidden. Tabu list is nothing but memory of artificial ants of previously visited city.

### 3. Data Collection

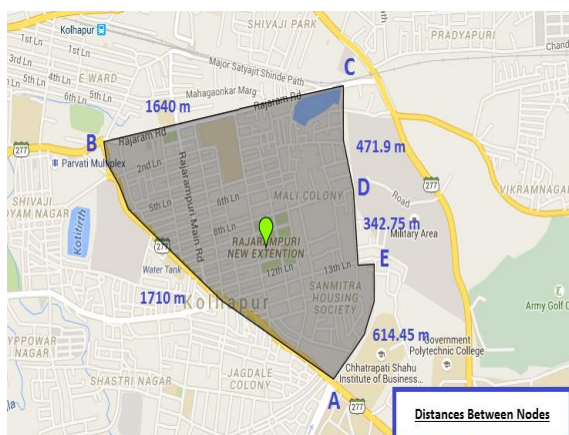
The site layout of Rajarampuri was obtained by office of Assistant Director, Town planning department, Kolhapur Municipal Corporation. Location map of Rajarampuri is obtained by using software called Google earth.



**Figure 1:** Map of Rajarampuri with location of collection point

#### 3.1 Distances between Collection Points

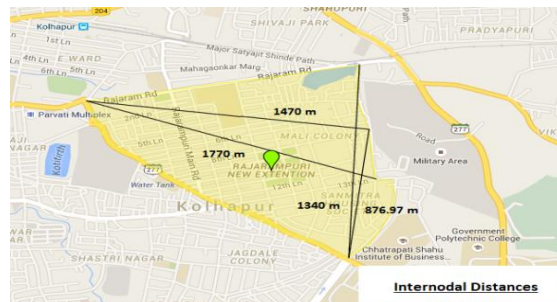
To measure the distances between two solid waste collection points (nodes), the survey is carried out. In the survey, Surveyor wheel is used to measure the distances. For more accuracy data from Kolhapur Municipal Corporation was referred.



**Figure 2:** Map showing distances between two collection points

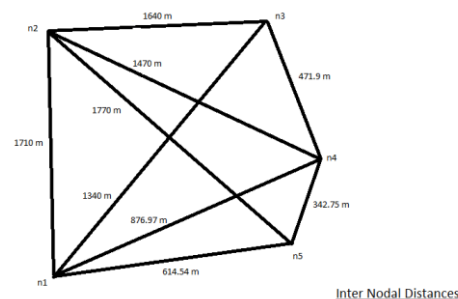
#### 3.2 Inter Nodal Distances

Inter nodal distances are required to form connectivity matrix.



**Figure 3:** Map showing inter nodal distances

### 4. Problem Formulation



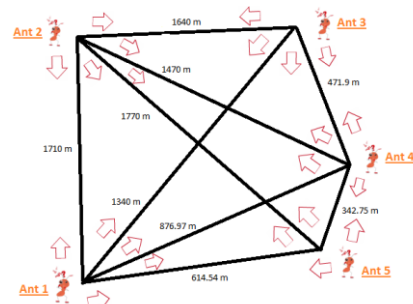
**Figure 4:** Connectivity diagram

After measurement of distances between collection points the whole problem is converted into travelling salesman problem. Thus it is easy to apply Ant system for particular problem. In above diagram  $n_1$ ,  $n_2$ ,  $n_3$ ,  $n_4$  &  $n_5$  are collection points A, B, C, D, E resp. that are shown on map.

**Table 1:** Connectivity matrix

	$N_1$	$N_2$	$N_3$	$N_4$	$N_5$
$N_1$	0	1710	1340	876.97	614.54
$N_2$	1710	0	1640	1470	1770
$N_3$	1340	1640	0	471.9	814.06
$N_4$	876	1470	471.9	0	342.75
$N_5$	614	1770	814.06	342.75	0

### 5. Application of Ant System



**Figure 4:** Route selection probabilities

Initially heuristic values are calculated by using formula (2). The table below shows heuristic values of all edges.

**Table 2:** Heuristic value

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>5</sub>
N <sub>1</sub>	0	0.584	0.746	1.15	1.62
N <sub>2</sub>	0.584	0	0.609	0.680	0.564
N <sub>3</sub>	0.746	0.609	0	2.12	1.22
N <sub>4</sub>	1.15	0.680	2.12	0	2.92
N <sub>5</sub>	1.62	0.564	1.22	2.92	0

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). Each edge in the problem is given an initial pheromone value

$$\tau = \frac{1}{n}$$

Where, n = size of colony.

In our problem size of colony is 5. Therefore initial pheromone value is 0.2

**Table 3:** Initial Pheromone Value

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>5</sub>
N <sub>1</sub>	0	0.2	0.2	0.2	0.2
N <sub>2</sub>	0.2	0	0.2	0.2	0.2
N <sub>3</sub>	0.2	0.2	0	0.2	0.2
N <sub>4</sub>	0.2	0.2	0.2	0	0.2
N <sub>5</sub>	0.2	0.2	0.2	0.2	0

### 5.1 First Iteration

As the first ant starts its tour from first collection point n<sub>1</sub>, 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.

N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>5</sub>
0.0704	0.114	0.273	0.541

Using proportional selection (Roulette Wheel), the ant chooses next collection point (node) say n<sub>5</sub>.

The ant will update its memory and put node n<sub>1</sub> and n<sub>5</sub> in its tabu list.

When arrives at n<sub>5</sub>, there are three nodes left to visit. The probability of choosing these nodes is tabulated below.

N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>
0.030	0.14	0.82

Using proportional selection (Roulette Wheel), the ant chooses next collection point (node) say n<sub>4</sub>.

The ant will update its memory and put node n<sub>1</sub>, n<sub>5</sub> & n<sub>4</sub> in its tabu list.

The probability of choosing any edge leading to another collection point is tabulated below.

N <sub>2</sub>	N <sub>3</sub>
0.093	0.90

Using proportional selection (Roulette Wheel), the ant chooses next collection point (node) say n<sub>3</sub>.

When ant arrives at node n<sub>3</sub>, there is only one node to visit n<sub>2</sub>.

The path that was built by ant 1 is n<sub>1</sub> → n<sub>5</sub> → n<sub>4</sub> → n<sub>3</sub> → n<sub>2</sub>

The length of this path = n<sub>1</sub>n<sub>5</sub> + n<sub>5</sub>n<sub>4</sub> + n<sub>4</sub>n<sub>3</sub> + n<sub>3</sub>n<sub>2</sub>  
 = 0.614+0.342+0.471+1.64  
 = 3.067 km

Similarly this procedure is applied for all remaining four ants.

The following table summarizes solution built by all ants. The last column in table below is the gain obtained by each ant. Since the longest distance between nodes is 1.77 km, the solution built by the ant must not exceed 4×1.77 = 7.08. Thus, the gain of each ant can be formulated as  $\frac{7.08}{L}$  with L as the length of the path of solution.

Ant	Path	Length of the path	$\Delta\tau = \frac{7.08}{l}$
Ant 1	n <sub>1</sub> → n <sub>5</sub> → n <sub>4</sub> → n <sub>3</sub> → n <sub>2</sub>	3.067	2.3
Ant 2	n <sub>2</sub> → n <sub>4</sub> → n <sub>5</sub> → n <sub>1</sub> → n <sub>3</sub>	3.76	1.88
Ant 3	n <sub>3</sub> → n <sub>4</sub> → n <sub>5</sub> → n <sub>1</sub> → n <sub>2</sub>	3.13	2.26
Ant 4	n <sub>4</sub> → n <sub>5</sub> → n <sub>1</sub> → n <sub>2</sub> → n <sub>3</sub>	4.306	1.64
Ant 5	n <sub>5</sub> → n <sub>4</sub> → n <sub>3</sub> → n <sub>2</sub> → n <sub>1</sub>	4.163	1.70

### 5.2 Pheromone Update

Pheromone update is done as per formula 3.

**Table 4:** Pheromone update after 1<sup>st</sup> iteration

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>5</sub>
N <sub>1</sub>	0	5.7	1.98	No update	8.18
N <sub>2</sub>	5.7	0	5.74	0.98	No update
N <sub>3</sub>	1.98	5.74	0	6.36	No update
N <sub>4</sub>	No update	0.98	6.36	0	9.88
N <sub>5</sub>	8.18	No update	No update	9.88	0

As higher the pheromone value, more probability of choosing that edge. By observing table no. 4, we get best solution as shown in figure below.

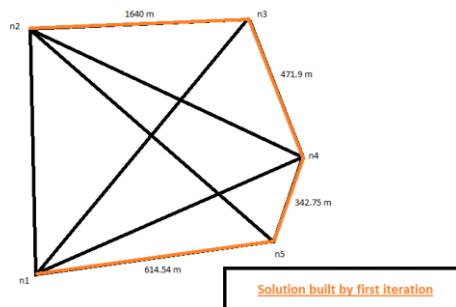


Figure 5: Best solution after 1<sup>st</sup> iteration

## 5.2 Second Iteration

The same procedure is followed as done in first iteration. However, the initial pheromone value on all edges have changed, thus probabilities of selecting edges will also change.

Table 5: Solution built by ants in second iteration

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

Pheromone update is done for all the edges and the new pheromone matrix at the end of iteration 2 is as shown below.

Table 6: Pheromone update after 2<sup>nd</sup> iteration

	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>	N <sub>5</sub>
N <sub>1</sub>	0	5.70	No update	No update	8.62
N <sub>2</sub>	5.70	0	8.06	No update	No update
N <sub>3</sub>	No update	8.06	0	8.68	No update
N <sub>4</sub>	No update	No update	8.68	0	10.32
N <sub>5</sub>	8.62	No update	No update	10.32	0

After second iteration, we get best solution as shown in figure below.

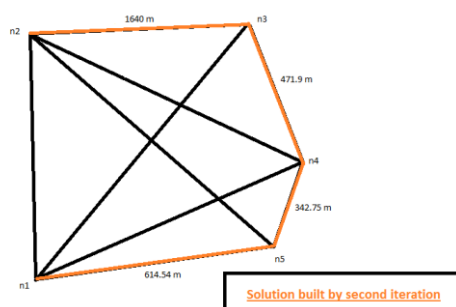


Figure 6: Best solution after 2<sup>nd</sup> iteration

We implement solution given by connectivity diagram on location map of Rajarampuri.

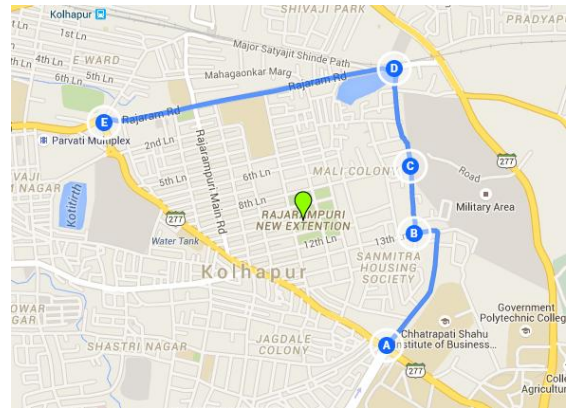


Figure 7: Optimized route

## 6. Conclusions

We have model the routing of cluster points as TSP (Travelling salesman problem) 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  $(614.54+342.75+471.9+1640) \text{ m} = 3069.19 \text{ m} = 3.06 \text{ km}$

## References

- [1] Kolhapur Municipal Corporation, Environmental status report 2013-2014.
- [2] Alberto Colomi, Marco Dorigo, Vittorio Maniezzo, Distributed optimization by ant colonies, in proceedings of the first European conference of artificial life (ECAL 91), Elsevier, 1991, 134-142.
- [3] Thomas Stautzleand Marco Dorigo, ACO for travelling salesman problem, IRIDIA, Universite libre de bruxelles, Belgium, 1999.
- [4] Mr. Amar V Katkar, Improvement of solid waste collection by using optimization technique, International Journal of Multidisciplinary Research, ISSN 2231 5780, Vol.2, Issue 4, April 2012, 298-307.
- [5] D. Otoo , S. K. Amponsah , C. Sebil, Capacitated clustering and collection of solid waste in kwadaso estate , Kumasi , Journal of Asian Scientific Research, 2014, 460-472.
- [6] Clarke, G. & Wright, Scheduling of Vehicles from a Central Depot to a Number of Delivery Points, Operations Research, Vol. 12, 1964, 568-581.
- [7] N. Suthikarnnarunai, A Sweep Algorithm for the Mix Fleet Vehicle Routing Problem , Proceedings of the International Multi Conference of Engineers and Computer Scientists, Vol II, March 2008.
- [8] Jeroen Beliën, Liesje De Boeck, Municipal Solid Waste Collection and Management Problems: A Literature Review, Transportation science, Articles in advance, 2012, 1-25