# Smart City Application: Internet of Things (IoT) Technologies Based Smart Waste Collection Using Data Mining Approach and Ant Colony Optimization

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**Abstract**: *Globally today, Living in urban areas is more preferred than in living rural areas. This situation creates many problem for urban living. One of the big problem is waste management in urban areas. Optimizing waste collection has become very important phenomenon for being smart city. In this study, we aimed to optimize waste collection for reduce both cost of collection and pollution effect of environment. We designed a garbage container integrated sensors for measuring fill level of container, temperature, and ratio of carbon dioxide inside the container. We transmitted all information to our waste management software based Internet of Things (IoT) technologies. According to the ant colony algorithm, most efficient waste collection route delivered to garbage truck drivers' cellular enabled smart tablet. We used data mining approach to forecast when garbage container can reach highest level, and the planning of garbage container placement. We applied this smart waste collection management system in a town where is in Kayseri, Turkey. In first step, we applied for 200 Items (garbage containers) in the town that has 548.028 population and urban living ratio is 100%. Before smart waste management system 200 garbage containers was collecting by garbage trucks in a static route. After we had applied smart waste management system, containers were collected by garbage truck in dynamic route. Smart waste management system significantly decreased the trucks' oil cost, carbon emissions, traffic, truck wear, noise pollution, environmental pollution, and work hours. The system presented approximately 30% with in direct cost savings in waste collection.*

**Keywords**: *Ant colony optimization, data mining, IoT smart device, smart city, smart waste management*

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## 1. Introduction

In 1950, world's population of 30% was living in urban areas. According to the projection of United Nations, by 2050, world's population 66% will be living in urban areas [15]. While urban living is more preferred, many urban life problems comes such as policing, public education, waste collection, street maintenance, and environmental pollution etc. Waste management is very crucial for public health, environmental pollution, and cost of waste collection. Volume of waste is predicted to grow approximately 50 per cent of over next decade [8]. Thus, optimizing waste collection is very significant phenomenon for being smart city. Smart waste management systems are needed for optimum waste collection. There are many studies for smart waste management systems. Radio-Frequency Identification (RFID) based waste management system was used by Glouche and Couderc [7]. According to this RFID based waste management system, the items which can be describe next generation garbage containers were tagged with RFID tag. A plastic bottle was tagged as a plastic waste, and a glass was tagged as a glass waste. When a user comes with a plastic waste near the garbage container, only the plastic waste container's lid opens. RFID based real time smart waste management system was improved by Chowdhurys' study [2].

In this study we focused on solution of today's waste collection problems. One of problem is that garbage trucks have static route plan for collection. We get information of the garbage container waste level in real time, according to this information most efficient waste collection route delivered to garbage truck drivers' cellular enabled smart tablet. We used ant colony algorithm for finding the most efficient route. There are studies for vehicle routing. The various conditions of traffic at the day were first studied by Malandraki and Daskin [10]. Mazzeo and Loiseau [12] showed that till 50 nodes their ant colony algorithm performed very well. Bell and McMullen [1] multiple colony approach experiments showed that their approach was successful within 1% of known optimal solutions. This techniques opened new ways for larger problems. Moreover, Donati *et al*. [5] showed that their multi ant colony system was applied and shortest path algorithm to calculate time dependent paths. On the other hand the ant colony algorithm was applied for other problems too such as the job shop scheduling [3], the graph coloring problem [4], and the quadratic assignment [11].

## 2. Material and Method

In this study we improved the smart waste management application of the model to a real case is presented. This system was applied in a town where is in Kayseri, Turkey and has 548.028 population and urban living ratio is 100%. Firstly, the system was used for 200 garbage containers in the town.

### 2.1. Smart Waste Management System Units

In this study, our presented smart waste management system consist of 2 main units.

#### 2.1.1. Hardware Units

We placed integrated sensors box on the lids of garbage container as shown in Figure 1. The integrated sensor boxes has 3 different sensors which measure the fill level, temperature, and ratio of carbon dioxide inside the container.

Figure 1. The placement of integrated sensor box inside the garbage containers.

The integrated sensors box is an Internet of Things (IoT) device as shown in Figure 2. It enables IoT solution. We used cellular module for machine-to-machine communicate as shown in Figure 3. The cellular module gives our smart box the ability to communicate over mobile networks.

Figure 2. The integrated sensors box.

Figure 3. The integrated sensors box of micro controller and IoT cellular module.

#### 2.1.2. Software Unit

Object oriented web based programming language, and database programming were used for developing the software. Web services and IoT cellular module's programming language was used for machine-to-machine communication.

C# programming language via Microsoft Visual Studio 12.0 and Microsoft DirectX 11.0 were used for programming the smart waste management central user interface as shown in Figure 4. Moreover, garbage trucks' tablet application was developed by android system.

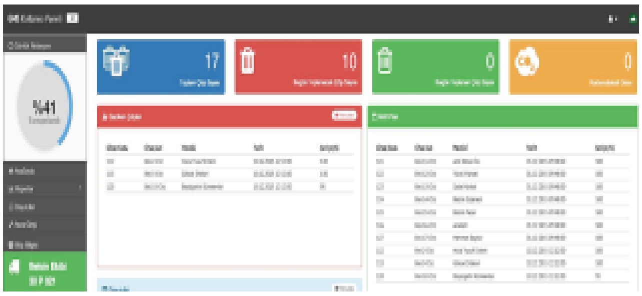

Figure 4. The smart waste management central user interface.

### 2.2. The Principle of System Operation

In this study our presented smart waste management system is a full solution for waste collection. Software logs, and reports can be accessed using system web service by operation centre users. On the other hand, garbage truck drivers see their dynamic and optimal routes via truck smart tablet application that gives chance drivers to report problems and solutions real time. As shown in Figure 4, system is based on machine-to-machine technology. Integrated sensors box which on the lids of garbage container sends real time event of temperature value, carbon dioxide ratio, and fill level to smart waste management software cloud. This information and also distance between garbage container and garbage truck information use for dynamic routes. Smart waste management software compute a garbage container of all this information to make a decision for collecting node's waste or not using clustering with decision trees construction and ant colony optimization.


Figure 5. The principle of system operation.

#### 2.2.1. Clustering Garbage Containers

Clustering is an investigative data analysis event. Decision tree algorithms are multivariate classifiers. They are powerful tools for prediction and commonly used in data mining [14]. Decision tree has rules that are understandable by software [9].

Many of studies aim to find the actual structure of information by organizing data objects into similarity clusters. This is typically unsupervised algorithm because no categories are known and data objects are non-labeled.

Basically, data mining algorithms can splits off into two main algorithms: supervised and unsupervised data mining algorithms.

Supervised algorithm uses known data set to estimation. The training data set contains input and output values. Hence, this algorithm can predict the outcome for new data set. This is mostly called classification.

In this study, we used classification method according to garbage container location, capacity, average fill level, average temperature, and average ratio of carbon dioxide. We performed the feature with 10-fold cross validation. In our real case for the town, garbage containers were compared of different classifiers according to 4 rules as Repeated Incremental Pruning to Produce Error Reduction (RIPPER or JRip), Partial Decision Tree (PART), Zero Rule (ZeroR), and One Rule (OneR) and 3 trees as J48 algorithm, random tree, random forest [13]. The classifier J48 have been performed better than other classifier. According to classifier J48 correctly classified instances value was up to 83%. We used simple k-means method for clustering garbage containers as shown Figure 6. This method can overcome many of deficiencies. 15 clusters were used for 200 garbage containers according to k-means method.

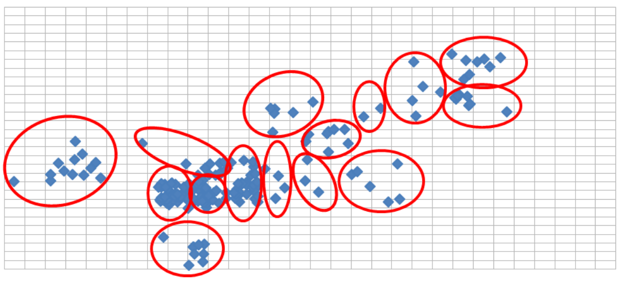


Figure 6. 15 clusters for 200 garbage containers.

#### 2.2.2. Ant Colony Optimization

We used an Ant Colony Optimization (ACO) to garbage container routing problem in our application. The behaviour of ants in real life is simulated in this algorithm. The algorithm based on how ant's selection routes to a food source from their nest. Ants communicate by traces of chemicals called pheromones, which lay on the road and will guide through these, the most promising routes are being left with higher pheromone trail to the other [6, 16].

The algorithm steps as follows:

- Parameter initialization.
- Read instance of the problem.
- Set initial pheromone.
- Repeat.
- Generate ants.
- For k from 1 through the number of ants make.
- Build a solution for ant k.
- Select the best solution.
- Update pheromone trails.
- To reach the number of iterations.

In this study, garbage container temperature value, carbon dioxide ratio, fill level, clusters were our keys.

The pheromone trail intensity updating is performed by the following equation:

$$\tau_{ij}(t+n) = p.\tau_{ij}(t) + \Delta\tau_{ij} \quad (1)$$

And:

$$\Delta\tau_{ij}^{k} = \begin{cases} \frac{Q}{L_k} & \text{if the kth ant uses edge (i,j)in its tour (between time t and t+n)} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Where: $\tau ij(t+n)$: amount of pheromone iteration between time $t$ and $t+n$.

- $\rho$: the pheromone evaporation
- $\tau ij$ $(t)$: amount of pheromone present
- $\Delta\tau$: increased pheromone

$L_k$ is the length of the tour for kth ant and $Q$ is a constant. The probability an ant k chooses to go from city $i$ to city $j$ $N_k$. Route is obtained using the following equation:

$$\rho_{ij}^{k}(t) = \begin{cases} \frac{(\tau_{ij(t)})^{\alpha}(n_{ij})^{\beta}}{\sum_{\in N_i^k}(\tau_{ij(t)})^{\alpha}(n_{ij})^{\beta}} (ifj \in N_i^k) \end{cases} \quad (3)$$

Otherwise, the result "0". Where:

- $\tau ij$: the pheromone concentration of point $i$, and point $j$.
- $nij$: inverse arc distance between the point $i$, and point $j$.
- $\alpha$: importance of the pheromone (control parameter).
- $\beta$: importance of visibility (control parameter).
- $\rho$: rate of evaporation of pheromone.
- $\tau$: initial concentration of the pheromone.

In our real case there were 200 garbage containers and 15 clusters, a best solution could contain different garbage trucks each with a different route to and from the waste management centre location. Using ant colonies the first truck's route is always evident with pheromone from ant colony 1, and these are not used to detect the route for the second garbage truck. Instead, the route for the second colony will only depend on the pheromone made by ant colony 2 and go on.

## 3. Result and Discussion

In this study, we aimed to apply smart waste management system in real case for establishing smart cities. Hence, we set up smart waste management system to the town successfully without any problem. We got very valuable results and feedback from the system.

Until now, waste collecting system had been based on fixed routes and schedules that require a lot of manual planning. Garbage containers were collected on a fixed schedule whether they were full level or not. Without the placing integrated sensors box on the lids of garbage container was unoptimized situation as shown in Figure 7. This situation made unnecessary and high costs, environmental pollution, and extra carbon emissions.

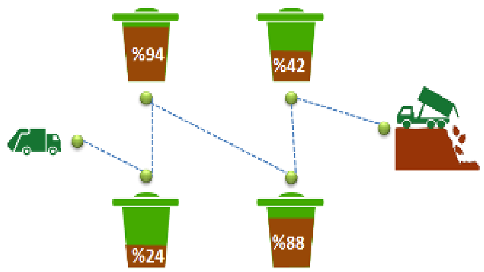


Figure 7. Unoptimized static route for waste collection.

After the smart waste management system application, the system automatically creates demand-based schedules and optimized dynamic routes as shown in Figure 8. Decision tree structure makes a decision whether going garbage container or not.

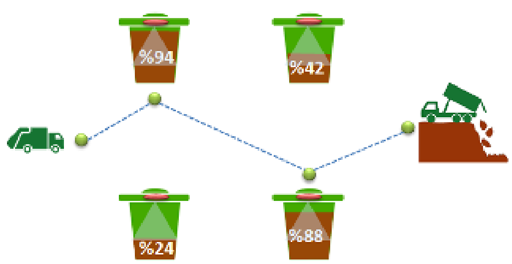


Figure 8. Optimized dynamic route for waste collection.

Thus, waste collection efficiency is increased by the smart system through route optimization using data mining approach and ant colony algorithm.

The information of the 15 problems that are our clusters is shown in Table 1, which contains of the problem size n, the garbage container capacity Q, and the best computational results using the ant colony optimization.

Table 1. Computational results using ant colony optimization.

| no | n | Q | Best Result |
|---|---|---|---|
| 1 | 50 | 150 | 521.61 |
| 2 | 75 | 130 | 795.32 |
| 3 | 50 | 150 | 521.61 |
| 4 | 100 | 200 | 772.18 |
| 5 | 100 | 200 | 783.18 |
| 6 | 120 | 200 | 790,45 |
| 7 | 50 | 150 | 522.62 |
| 8 | 120 | 200 | 982.12 |
| 9 | 75 | 130 | 791.75 |
| 10 | 75 | 130 | 772.73 |
| 11 | 120 | 200 | 1014.32 |
| 12 | 120 | 200 | 1003.12 |
| 13 | 50 | 150 | 522.42 |
| 14 | 100 | 200 | 788.24 |
| 15 | 50 | 150 | 521.32 |

We waited 6 months after the establishing smart waste management system for the first result of collection efficiency. According to the information of municipality of the town as shown in Figure 9, smart waste management system significantly decreased trucks' oil cost, carbon emissions, traffic, truck wear, noise pollution, environmental pollution, and work hours. The system presented approximately 30% with in direct cost savings in waste collection.

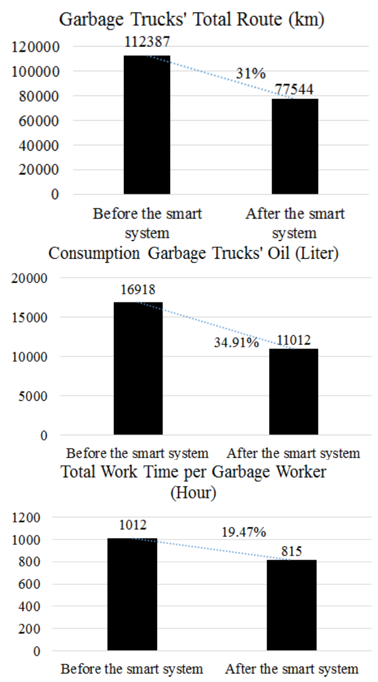


Figure 9. Smart waste collection efficiency.

In real case, garbage trucks' total route, consumption garbage trucks' oil, and total work time per garbage worker were decreased 31%, 34.91%, and 19.47% respectively by using smart waste management system as shown in Figure 9.

## 4. Conclusions

We have given a solution for establishing smart cities with real case application. According to Figure 9, there are many advantages for using smart waste management system. Moreover, this study shows that smart city applications are needed by municipalities. Therefore this study is a good real case example for further studies.

In this study, our presented smart waste management system can be improved by using some other knowledge such as a garbage container area population, using future garbage container fill level estimation, and content types so on.

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