ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(37), DOI: 10.17485/ijst/2016/v9i37/99047, October 2016* ISSN (Online) : 0974-5645

A Geo-Information System for Optimum Municipal Solid Waste Management (A Case Study of Kanchipuram Municipality, Tamil Nadu, India)

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Abstract

Objectives: The municipal solid waste management is a challenging task for local authorities. To manage this, a study was conducted in Kanchipuram municipality, Tamil Nadu, India. **Methods/Statistical Analysis:** Spatial database was prepared for the study area by using high-resolution satellite imagery. Non-spatial information like street name, road name, a nearby landmark, bin number and bin type were added in Geographical Information System (GIS). In this study modern technique like Global Positioning System (GPS), a communication system (GPRS and GSM), GIS and computer programming are integrated to assist the solid waste management. **Findings:** This integration may serve to overcome the conventional conflict in solid waste management within the municipal region. The proposed system consists multiple spatial information in the prepared digital database, like bin location (with reference to its latitude and longitude); ward details, onboard monitoring of bin strategy. Based on a study of smart bin usage in developed countries, new type smart bins with sensor arrangements are suggested. The solid waste strategy of each bin in each ward could be collected by monitoring authority through the GPRS and GSM technique which is fixed in the proposed bin. This developed system consists of the bin priority, strategy, and track location. This will serve for taking a decision by applying queries to the created database and also to enhance the solid waste management technique in Kanchipuram municipality. **Application:** This work proves incorporation of recent technique in municipal solid waste management will save both time and money.

Keywords: GIS, GPS, GSM, Sensors, Solid Waste Management

1. Introduction

Municipal Solid waste has been one of the most significant threats to the environment. Solid waste management is feasible to make easy by adopting the latest technologies to overcome the present conflict. In Kanchipuram municipality information associated with waste generation, location and urgent service requirement are helpful to local authorities for proper management. A multi-methodological method is necessary to improve the regional solid waste management structure[1] for proper solid waste management in developing countries. Rapid urbanization is translated into an increase in population as well as the tremendous increase in solid waste generation. The increase in solid waste leads to serious environmental threat in case if it is not properly managed. Solid waste generation estimation was identified by using unique technique[2]. This proposed technique is useful to generate the information related to solid waste management in Kanchipuram municipality not only for easier management as well as improve environmental hygiene. GIS with spatial modelling techniques has provided

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more benefits in environmental and economic savings by means of a reduction in travel time, pollution, fuel consumption, and distance travelled[3]. GPS is nowadays used in all the fields like vehicle monitoring, navigational purposes, location identifying purposes, etc. In this study, GPS is used by monitoring authorities to monitor the truck location and to suggest the driver. The vehicle delay time is identified by using the Global Positioning System (GPS)[4]. In developing countries the municipal services exert its pressure in a different context, to ensure the public health protection by proper waste collection for the highly populated urbanized area[5]. Priority of solid waste collection needs to be based on the daily analysis result. The features in city maps, the solid waste collecting point, its transportation vehicle, route, etc., are involved in Geo-rectified spatial database for municipal solid waste management[6].

2. Study Area

The study area covers 51 wards and 707 streets in the municipal boundary with an aerial extent of 36.14 km^2. Population in Kanchipuram municipality is 1.64 lakhs (Census 2011). As per government data, the per capita waste generation is 450 grams. Kanchipuram is located at a distance of 75 km from Chennai, the capital of Tamil Nadu, India. The prepared base map is shown in Figure 1 revealing the municipal boundary of the study area.

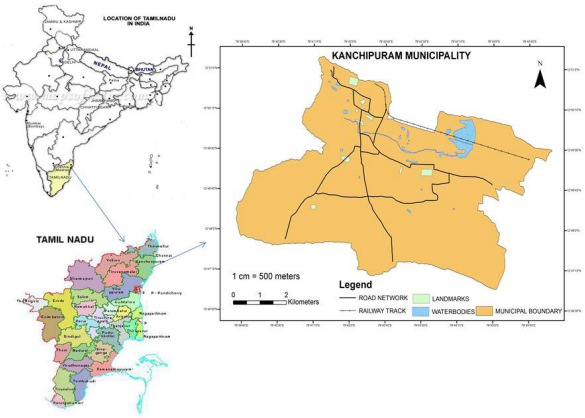

Figure 1. Kanchipuram Municipal Boundary.

3. Digital Spatial Map Preparation

By using the Arc GIS software spatial map has been prepared for the Kanchipuram municipal boundary. For base map preparation municipal boundary map (1:50000 scale) is collected from Kanchipuram municipality and Geo-rectified by adding the collected GPS points with respect to a different location in the study area. The high-resolution satellite imagery was used to prepare the spatial database of the study area. For this, each ward boundary with the street network connection within the ward is digitized using the relevant Arc catalogue tool. These street networks are linked to the road network in Kanchipuram municipality. In this base map, the present bin location in town is incorporated by importing its GPS coordinates after completion of the field study of each bin location. For various application, GIS has been effectively used, such as forestry, transportation, geology, health sciences, environmental modelling and other engineering works[7].

This prepared base map is used to overlay other features in Kanchipuram town like vehicle route, landmark, vehicle position monitoring, water bodies, etc. In Kanchipuram municipality hand rickshaws, mini trucks, compactor trucks, hook loader and dumper placer vehicles are used for collecting the wastes from the bin. Based on the width of the road and type of solid waste collection bin the vehicle type is used[8]. The study area has different categories of bins, but for this study compactor type bin presence in the municipality is analysed because this type of bin is used in the majority. This information is useful to replace the proposed designed bin in that position for effective solid waste management in the municipality. The analysis will be based on analysing all the factors like point feature (bin position), a line feature (Street, road network), polygon feature (water bodies, landmarks) etc., are created in the base map.

For using maps in GIS, it is possible to integrate the common database by means of the query and other analysis visually[9]. By applying queries the required information in the prepared base map can be obtained froma number of bins in a particular ward, the shortest distance to collect the solid waste, the presence of water bodies in a particular area, temporary storage location, bin to bin distance, etc. The prepared base map is possible to edit, analyse, modify, update the created point, line, and polygon features in GIS platform so that data managing and updating is easy in this technique.

4. Integration of GPS Data in Spatial Database

In this system, GPS is used for two purposes one is to identify the bin location with reference to its latitude and longitude and another is to track the waste collecting vehicle movement. Handheld GPS receiver was used to collect the coordinates of the point features in the municipal limit. GIS technique is used to prepare the digital base map with different themes such as bin, road network, street network, ward boundary, landmarks, etc. The collected data are exported to Arc GIS software for incorporating in the base map for further analysis. Collected GPS coordinates of each feature are categorized into different types such as bin, landmark, etc., and are incorporated in developed map by using Arc GIS software. The incorporated data are used to prepare different themes; each theme is used for the different categories like type of bin, nearby landmark and so on.

The bin location, theme plays an important role to find the shortest origin and destination path. Through improved siting of transfer station, several authors have investigated solid waste vehicle route optimisation based on both solid waste collections in the rural and urban environment for transport minimisation[10]. The layout of developed spatial map with bin location is shown in Figure 2. It depicts the details about the overlaid features in the base map.

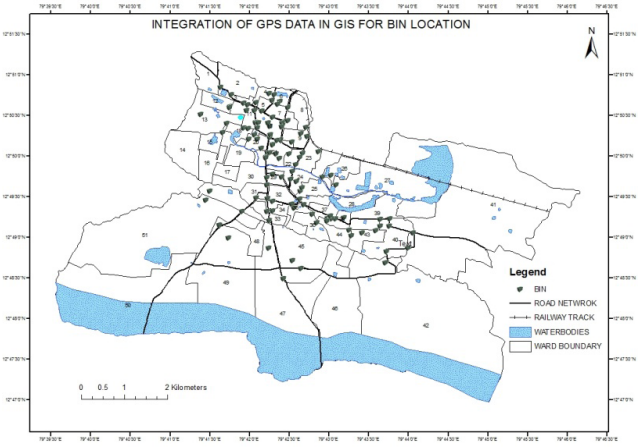

Figure 2. Bin Location.

This developed database is useful for easy management, such as the spatial location of each bin on the municipal boundary with other features. In the last few decades by using GIS and its multi-criteria techniques, numerous studies have been carried out for landfill site selection to make the environmentally friendly and economically sound selection[11].

The collected GPS data are converted into a shapefile format for further analysis in a GIS platform. After integration, prepared themes are cross-checked by exporting it into Google Earth software for the positional accuracy in the format of .Kml file. Google Earth software representation is shown in Figure 3; it shows the details of the bin with its information like its number, latitude, and longitude position, ward number and type of bin. This universal format can be accessed by the public in the study area to know the strategy of bin nearby to their household or other places in the city; it is easy to inform the authorities of any compliance or another necessary requirement to the peoples.

Figure 3. Bin Location in Google Earth.

5. Bin Design

In the study area, there are three types of bins are used for the solid waste management system. The three type's bins are classified as compactor, dumper placer, and hook loader. Existing bins in municipalities all are conventional type solid waste collecting bins. In developed countries smart, solid waste collecting bins is available in different models with functions. This study suggests adopting such a type of bin with specially designed for easy management in Kanchipuram municipality. Based on the calculation result of the optimal number of solid waste collection bins and its allocation obtained from solid waste generation a new method is proposed to manage[12]. The proposed

bin design consists of the five sensors, which are fixed at each level in the bin to detect the solid waste filled level in the bin. For increasing capacity in waste management simulation modelling is adopted for collecting solid waste[13].

These sensors are connected to a circuit which is connected to a GSM modem which will send the binning strategy to the monitoring authorities. By using GPRS technology, it can be done by sending and receiving real-time data. By utilizing GPRS, it is possible to send data at a rate up to 160 Kbps[14]. The emitter and sensor arrangements are shown in Figure 4.

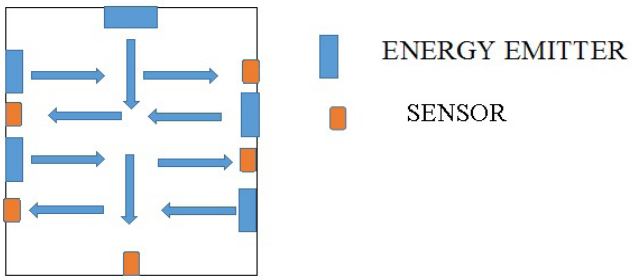

Figure 4. Energy Emitter and Sensor Model in proposed bin.

Municipal management is being required to improve their performance for the efficient waste management services. This improved performance will have to be provided with minimum cost[15]. The monitoring authorities can receive the information about the bin location in a digital map with its waste quantity strategy based upon the sensor information in the bin. The bin solid waste filled information like fully filled, half-filled or quarter filled information's are necessary not only to fulfil the present management but also for the future new bin requirement identification of the particular location. The proposed method will overcome the old conventional solid waste management practices like physical maintenance in each location to know the routine maintenance work is done or not.

This is one of the most important information for taking cleaning action. It not only shows the solid waste level but also warns in case the bin is filled earlier than the regular collection time or other decision-making activity. By using GIS technology effective decision making is possible in the field of implementation of vehicle routing techniques[16]. This action is used for achieving proper solid waste collection, identifying the omitted waste collecting bins, a quick response where ever bins are filled and overall it improves a healthier environment for the people in the Kanchipuram municipality because of the effective solid waste management practices. The bin is numbered so that the other information about the bin is added in the attribute table on a GIS platform like its spatial position, type of bin, ward number, etc. This is the precise information to the monitoring authorities to track any compliance in solid waste management especially the bin location in the municipal limit. Manual records can be the rule and the digital database has been created for easier management, quick process and to improve the solid waste management role in the city.

6. GIS Analysis

In conventional system, daily waste generation in each ward is collected periodically, but it is won't carry out whenever urgent action required, like if bin filled earlier than usual collection time. The following five operations such as digitizing, overlay, network analysis, query and buffering are used as a major operation in GIS spatial analysis[17]. On GIS platform, it is possible to carry out daily analysis for waste generation based on the received information from each bin which is fixed with GSM technique. Whenever the bin is filled which requires immediate attention the message is sent to the monitoring authorities by displaying on the base map of the town with bin information like bin number, position, nearest landmark etc. By connecting the road network with the street network a complete network database has been prepared it will show the shortest path for collecting the solid waste from the vehicle position. Preferred routing of the vehicle for solid waste collection depends on the travelled distance and time taken based on the earlier work[18].

The number of bin needs urgent attention decides the capacity of the vehicle requires for that operation. Apart from the imperative need, routine maintenance of solid waste transportation is also possible to get assists from GIS analysis like an immediate need, moderate need, and no need mode. Recent techniques automatically generate a route and it shows each turn-by-turn direction from one origin to destination[19]. In the case of no need mode analysis result based upon the sensor message from the

bin that particular bin route may be avoided for one day, but that bin must be considered for the next day for solid waste collection. The organized road network of the study area is shown in Figure 5 by using the network dataset tool in Arc GIS. The road network is formed as a dataset. By means of reallocation of solid waste collection bins and vehicle route optimization based on time travelled and distance the efficiency of waste collection and transport is improved in the municipality of Nike, Athens, Greece by using Arc GIS Network Analyst model[20]. The network analysis results show the shortest paths from the collecting bin spot to the dump yard location it not only saves time, but it also saves fuel consumption on that trip. GIS has been once again proved to be an effective tool which provides the alternative methods for minimizing their operational costs[21].

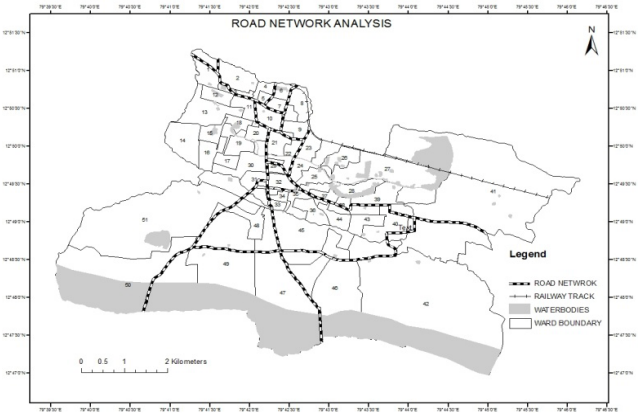

Figure 5. Road network analysis in study area.

7. QUERYING GIS DATA

Querying in GIS is used to efficiently search the required item in a large database. It is possible to raise multiple queries in a GIS platform by using the query tool. It will be useful for decision making. A query can be implemented in both raster and vector data set. In this project, different types of queries are used such as Boolean algebra (or, not, and), Structured Query Language (SQL) and arithmetical operators (=, -, /, *) to define the required data for solid waste management work in a GIS database. The developed database in Figure 6 shows the ward number and ward area. In this database, the above mentioned different types of the query can be applied to extract the required information in it. It is possible to select and export the specified data (ward number, shape, length, shape, area, etc.) based on the defined requirement.

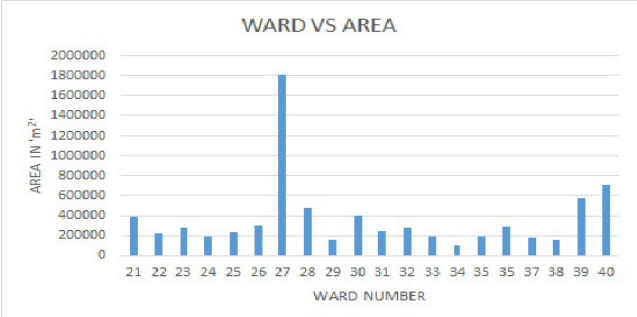

Figure 6. Query in attribute table.

By using the SQL query in the attribute database required information is collected and arranged (like bin types are arranged in order, ward numbers are arranged, the number of bins in a particular ward and types of the bin in a particular ward are identified). Ward areas versus ward number graph have been plotted by using the export option in ArcMap. The management of solid waste generation is not just complex because of increasing its quantity, but also the improper management system is cause for it[22]. The graph which is shown in Figure 7 shows the ward number is taken as a common identifier; it represents the ward area in Kanchipuram with its household information. Similarly, ward number can be used as a common identifier for joining other tables in GIS platform. This type of operation will be useful in future to update any new data will be going to be added to an existing dataset based on the ward number or any other common identifier in the attribute table, so that updating the existing database is made easy by this work.

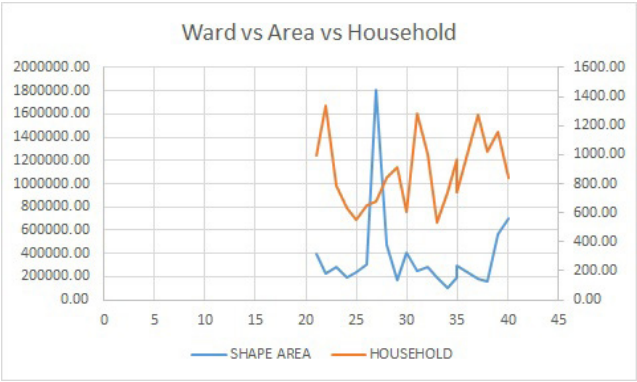

Figure 7. Displaying Ward vs Area vs Household.

Boolean operators, such as OR, NOT, AND are

accompanied by logical operators such as =, >, < to form the query statement. This type of query is used to find specific information such as [ward number] = 1-51 AND [population] >=2000. This result shows the wards which are present in the study area where the population is greater than or equal to 2000 it will be useful to take decision for solid waste management work in that particular selection and provision of facility in the ward based on population database, by using similar query different user define data can be retrieved in this dataset. In developed database, spatial query is applied directly in displaying a map to retrieve the information by using a cursor. This information about the vector will be displayed immediately when the cursor clicked on it like a type of the feature, id, length or area. This type of query is not difficult to use by using the identify tool by clicking on the feature for collecting instant information about the feature.

Determining the impact of a particular feature to its surroundings is important in solid waste management work to know the solid waste environmental threat issue around the waste. For taking remedial measures as well as for appropriate organization to ensure sustained sound urban solid waste management practices are required with vital information[23]. In this type of query, it is possible to retrieve the information based on proximity analysis of a particular feature like creating a buffer of the 100m location of the feature around bin or around the water body etc. The buffer result representation of 100m surrounding to thebin is shown in Figure 8.

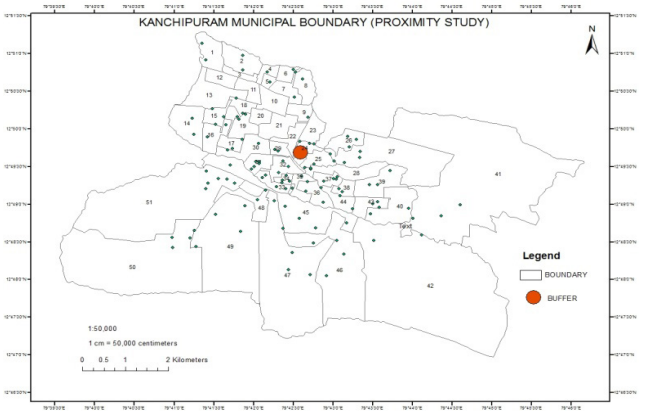

Figure 8. Identifying the proximity of features around 100m surrounding.

The line in polygon query is used to extract the line feature such as streets and road present in a particular ward this will be useful to extract the information to determine the type of the road and street length and other relevant non-spatial information in it. Figure 9 shows the ward boundary of ward number 21 to 40 within the municipal limit of Kanchipuram. Micro level study of the specified wards within the municipal limit is possible by doing such type of specific extraction of a feature in the entire database.

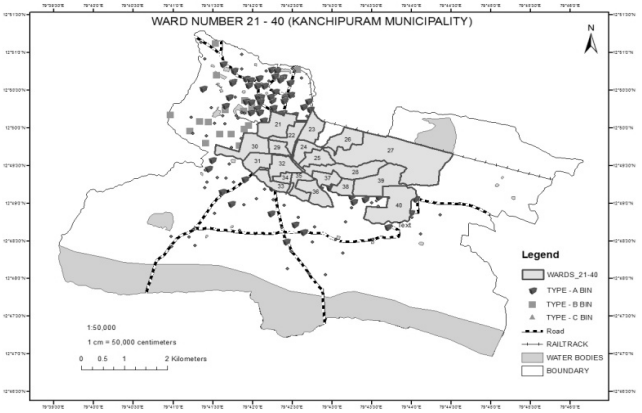

Figure 9. Ward boundary 21 – 40 extraction.

Polygon in polygon query is implemented to retrieve the information of a polygon present in a polygon feature. By applying this query presence of water bodies with its information such as the spatial extent of it are extracted. This extracted information is used to identify the presence of a water body in each ward and used to identify the location of the bin in that area. In case bins are not there means there may be a possibility of dumping the solid waste nearby of the water body so that there is a possibility of water contamination in that water body due to the solid waste, the provision of the bin nearby to it will prevent such type of environmental pollution in that area. The larger amount of data with its modification proficiency is more in GIS[24]. Similarly, the extraction of specific ward boundary (1-5) polygon feature in overlaid municipal boundary polygon feature is shown in Figure 10 to validate the editing and manipulating in developed GIS platform.

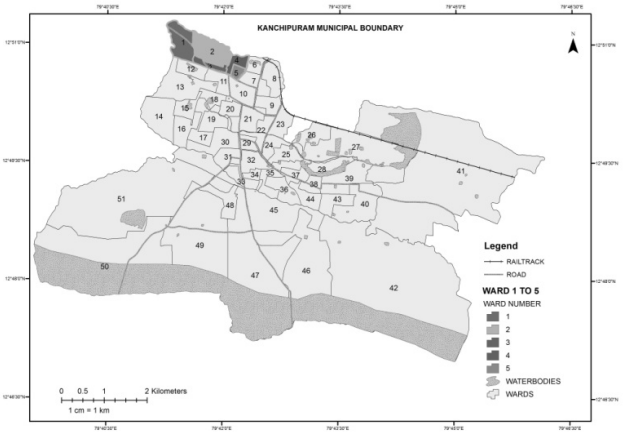

Figure 10. Ward boundary (1 – 5) Extraction.

8. Conclusion

The developed database is useful to take the proper decision at the right time. By adopting this work may make the solid waste management easy in Kanchipuram municipality. It will not only make the solid waste management easy but also it will prevent the serious environmental hazards in the municipality. The courteous communication of sensor which is fixed in the suggested bin commands the authorities in monitoring board. The GIS platform is useful for quick analysis and decision making. It is possible to update the current database in future for any updating requires. Proper guidance for drivers for solid waste collection regarding the route of travel and collecting bin number is generated by the computer system and the result will help for both costs wise and time-saving. The querying technique is applied to extract the required information in creating a large database and it will be used for this project at the micro level like within the specific boundary of each ward. The overall work will improve the ecological status of the city by doing the proper solid waste management service in the Kanchipuram municipality with the recent technique in this specified area.

9. Acknowledgments

The authors wish to his sincere thanks to SRM University, Kattankulathur, Chennai, Tamil Nadu, India for providing research opportunities. The authors wish his sincere thanks to SCSVMV University, Enathur, Kanchipuram, TamilNadu, India for valuable support. The authors also wish to record a deep sense of gratitude to Tamil Nadu Agricultural University, Thanjavur, Tamil Nadu, India.

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