Solid Waste and Waste Bin Management By Using RS & GIS: A Review

Sumedh D. Kashid, Dhananjay B. Nalawade, Ajay D. Nagne, Rajesh K. Dhumal, K.V.Kale

Abstract— Due to rapid increase in population and its urbanization problem of solid waste becomes a critical issue. Its direct impact on human health and environment makes it crucial one. In solid waste management proper allocation of waste bins and their collection plays an important role. Due to unavailability of bins at proximity distance waste is dumped at open spaces which create lot of environmental and health issues. These problems arise due to improper management of waste bins. This paper proposes a discussion about role of Remote Sensing and Geographic Information System in solid waste management and its use in waste bin allocation, waste bin allocation strategies and GIS for the optimization of waste collection and transport.

Index Terms— Geographic Information System (GIS), Municipal Solid Waste (MSW), Optimal location, Remote Sensing (RS), Solid waste, Solid Waste Management (SWM), Waste Bin.

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1 INTRODUCTION

TODAY the world's largest problem is of solid waste management. Waste management is the process of storage, collection, transport, recycling and disposal of waste materials. The term waste relates to materials produced by human activity. Due to its direct impact on human health and environment it is necessary to manage it properly. Waste management can contain solid, liquid, gaseous or radioactive substances. Waste management treatment differs for developed and developing nations, for urban and rural areas, and for residential and industrial producers.

Municipal solid waste is defined to include refuse from households, solid waste from industries, commercial and hospitals, market waste and street sweepings. The first goal of Municipal Solid Waste Management (MSWM) is to protect the health of people, particularly that of people having low-income. Secondary goals include promotion of environmental quality and sustainability and employment generation. GIS and remote sensing have not been effectively used in most Indian cities. There were no studies aimed at integrating these technologies into a planning process to improve the efficiency of municipal solid waste management [1].

In developing nations like Sri Lanka, urban solid waste is critical problem and it becomes severe due to absence of proper solid waste management systems in the country. Due to the unjustifiable command area of the existing dustbins located along the road, those bins are not used by most of the householders to dispose their waste and instead they use drains, roadside, water bodies or any other improper things. This creates poor sanitary conditions in the area due to animals: goats, dogs, cows, cats, crows etc. foraging for food. Further, this waste may cause to block the drainage system and creates flood during raining seasons [2].

Case study of this paper shows that only partial amount of waste is transferred to the transfer station. This is due to the insufficient vehicle fleet, traffic congestion in the city and operation delay in the transfer station. And also, due to the insufficient number of collection bins. Also people tend to dispose the MSW into nearby drains. This reveals that, a proper collection service of MSW is necessary in that ward [3].

Water pollution in the river Yamuna is severely caused due to the solid wastes deposited into the river through various sites in the cities. Wastes being solid in state are non-biodegradable which cannot be decomposed by the microorganisms. Hence these wastes lead to water pollution in the river. Waste remains as it is until it is separated by any physical process. Hence it is prime need of time to stop deposition of solid wastes in the river [4].

Location modeling in GIS environment is an efficient way to improve service coverage and efficiency in municipal solid waste management. The paramount factors that determine the location of a waste bin are environmental constraints and walking distance to the service point. In this study, they have included these factors and applied software that fully integrates GIS with location-allocation modeling, for spatial location of municipal waste bins. There exist open dump at many places. This is due to non-placement of community bins at convenient distance [5]. So it is necessary to find proximity distance of bins and their proper placement.

2 BASIC TERMS AND DEFINITIONS

2.1 Municipal Solid Waste

Municipal Solid Waste is nothing but the waste generated from commercial and residential things in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes.

2.2 Generator of Wastes

It means persons or establishments generating municipal solid wastes.

2.3 Biodegradable Substance

It means a substance that can be degraded by microorganisms.

2.4 Storage

Storage is the temporary containment of municipal solid wastes in a manner so as to prevent littering, attraction to vectors, stray animals and excessive foul odour.

2.5 Collection

Collection includes lifting and removal of solid wastes from waste bins and open dump places.

2.6 Transportation

Transportation means transfer of municipal solid wastes from place to place hygienically through specially designed transport system so as to prevent foul odour, littering, unsightly conditions and accessibility to vectors.

2.7 Disposal

It is defined as final disposal of municipal solid wastes in terms of the specified measures to prevent contamination of ground-water, surface water and ambient air quality.

2.8 Land Filling

Land filling includes disposal of residual solid wastes on land in a facility designed with protective measures against pollution of ground water, surface water and air fugitive dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability and erosion.

2.9 Recycling

It is the process of transforming segregated solid wastes into raw materials for producing new products, which may or may not be similar to the original products.

2.10 Composting

Composting is microbial decomposition of organic matter in a controlled manner.

2.11 Remote Sensing

Remote sensing is the art and science of acquiring information about the Earth's surface without touching it directly. It is the process of analyzing and processing the recorded or transmitted information [7].

2.12 Geographic Information System (GIS)

A Geographic Information System or GIS is a computer based system which allows to map, model, query, and analyze large quantity of data within a single database according to their location. GIS has the power of [8]:

- creating maps
- integrate information
- visualize scenarios
- present powerful ideas, and
- Develop effective solutions.

3 ROLE OF RS AND GIS IN SOLID WASTE MANAGEMENT

RS and GIS play an important role in solid waste management. With the help of remote sensing we can cover a very large area for study. For site selection process we require satellite image of study area. It covers a large region and also fine resolution. GIS helps in creating geo database which is very helpful to take a decision. GIS uses both the map data as well as attribute data. We can see the situation at a glance; it is such an effective tool.

GIS integrates software and hardware for collecting, managing, analyzing the data and showing all forms of geographically information in a computer-based system. It helps to analyze data visually and look patterns, trends, and relationships that might not be visible in tabular or written form. A GIS is different from other information systems, because it integrates common database operations such as query and statistical analysis with the advantages of visual and geographic analysis through maps. Thus, GIS with the aid of control server, solid waste bin can be detect and monitors [9].

To minimize the influence of open-air solid waste dumps on environment, the primary task is to identify, in both quantitatively and qualitatively, the location of open-air dumps of solid wastes. However, these dumps are distributed randomly and their location changes quickly. Thus, the traditional field-investigation method costs a lot of time, labour and money, and moreover, it can hardly follow the change of solid wastes. In contrast, remote sensing technique can provide a rapid and effective way to detect these dumps, owning to its characteristics of objectivity, real-time and macro-scope view [10].

The role of GIS in solid waste management is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations such as customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill, etc. GIS is a tool that not only reduces time and cost of site selection, but also provides a digital data bank for future monitoring programme of the site [11] [12].

Remote Sensing provides an opportunity to visualize the actual ground features. The Geographical Information System (GIS) can provide an opportunity to integrate the various field parameters with population and other relevant data or other associated features, which help in the selection of sites. Site selection procedures can benefit from the appropriate use of GIS. The use of GIS in the site selection process will reduce the time and enhance the accuracy [13].

4 USE OF RS AND GIS IN BIN ALLOCATION

Normally people use a road to go to the bin to dump their waste. Hence the service area of a bin which is a region including the households that dispose waste to the bin in consideration cannot be a circular area. With the help of software we can find network service area of a particular distance around any location on a network. A network service area is an area

that covers all accessible roads which are passing through that location and have specified length. Bins were located at the maximum preferable walking distance of 100 meters by computing service area of each bin, considering road network data. 20m buffer zones were created around schools and religious places and 30 meters buffer zones were created around water features to avoid locating bin at the close proximity of them [2].

The GIS-based optimization technique was applied to bin allocation. The satellite image of the study area was scanned in A4 size JPEG image and imported into GIS in DXF format. The digitization process begins with data coding, which is the process of converting spatially located features to geometric objects (points, lines or polygons). Spatial features which are not related to the study were deleted from the map. Service points were placed. A service point is a designated position where a waste bin is placed so that waste generators can empty their wastes while the service area is regarded as the expected coverage of a particular waste bin. The use of GIS to locate the position of waste bins is based on convenient distance to households, maximum service coverage and consideration of physical and socio-cultural context of the service area. A buffer was created around bins. This gives a platform to identify the potential service points where a waste bin could be placed. The processed information was stored in a spatial database which is a combination of vector spatial data and attributes data with unique identifier for the referenced spatial objects [14].

In case study of Coimbatore city they had developed a Geo spatial database in Arc GIS for the allocation and analysis of collection bins. The database was created with the help of digital maps, satellite image of the study area, interview with government authorities and online capturing with the help of GPS technology [3].

Application of GIS and remote sensing techniques in the field of waste management using a multi criteria decision making technique provides the organized approach for assessing and integrating the impact of various factors as indicators of suitability. It would be chosen according to the opinion and information related to the study field area. The weightage assigned for different parts like drainage, watershed, roads, forests, crops, etc. Buffer zones were created for getting suitable sites [4].

To efficiently manage the municipal solid waste system, detail spatial information is required. This information is related to the geographical background of the area under investigation, as well as to spatial data related to waste collection procedure. It contains study area boundary, population density, satellite image, road network, location, capacity, time schedule of waste bin. For the optimization of the collection process a spatial Geodatabase was constructed, in a standard commercial GIS environment. This ensures compatibility with available data from municipality and many network routs [5].

5 BIN ALLOCATION STRATEGIES

In this study bins were located at the maximum preferable walking distance of 100 meters by computing service area of each bin, considering road network data.100m service area of

a bin without using trim length i.e. this area covers all road sections which are passing through the bin location with 100 meter length from the bin and service area polygon is created by joining end point of these roads. Therefore this service area polygon may exclude some householders who can reach to this bin by walking maximum distance of 100 meters or less than 100 meters. In Fig. 1(b) service area of a bin was calculated same as in Fig. 1(a) but using trim length. Therefore this polygon covers more householders who can reach to this bin by walking 100 meters or less than 100 meters. Therefore this method was used to calculate the service area of a bin [2].
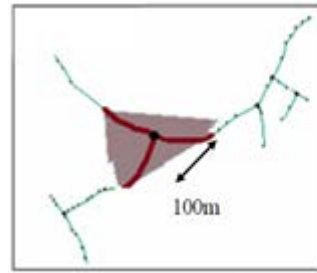
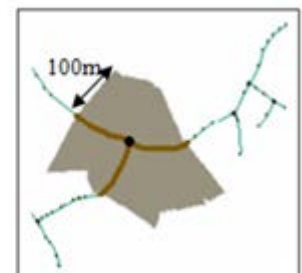

Fig. 1(a):100m Service area of bin without Trim Length.

Fig. 1(b):100m Service area of a bin with 100m Trim Length.

The Following parameter can be considered to eliminate an unsuitable area for placing waste bin [14].
- 30m distance away from environmental sensitive areas such as rivers and streams.
- 30m distance away from infrastructural sensitive areas such as bus stops and intersections.
- 10m distance away from property fence and entrance.
- 20m shoulder space for vehicle manoeuvring during ingress to and egress from service point.

It is also possible to calculate how many bins are required as per capita MSW generation and population. The foolowing equation can be used to calculate a number of bins are required for a particular area [3].

$$N = W / (D * S * F1 * CF) \qquad (1)$$

Where,
N = Number of collection bins.
W = Total quantity of waste generated per day in Kg.
D = Density of waste in Kg/m3.
S = Size of bins in m3.
F1 = Average filling rate of bin. (Generally 80 %)
CF = Collection Frequency.

Then following criteria is used to allocate bins at their proper position [3]:
- With reference to existing bin location,
- The road network and population density and
- Unreserved area.

6 GIS FOR THE OPTIMIZATION OF WASTE COLLECTION AND TRANSPORT

The optimization of the routing system for collection and transport of municipal solid waste is a crucial factor of an en-

vironment friendly and cost effective solid waste management system. The development of optimal routing scenarios is a very complex task, based on various selection criteria, most of which are spatial in nature. The problem of vehicle routing is a common one. Each vehicle must travel in the study area and visit all the waste bins, in a way that minimizes the total travel cost, most often defined on the basis of distance or time but also fuel consumption, CO_2 emissions, etc. [15].

GIS can be effectively used to feature extraction, network analysis, designing thematic maps, access to several layers of data at a time. Also it will help in crossing attribute data with respect to topological and special relationship [16].

A GIS can be effectively used fot the new route identification with the help of various GIS layers to identify a shortest route which will cover less diatance and covers maximum waste bin locations with a less overlaps. GIS provides a solution to choose shortest route for collection of waste. The new suggested route will be cheaper by upto 50% of the old route [17].

7 CONCLUSION

The improper management of waste bins produces many health and environment related issues. RS and GIS can be effectively used in the management of solid waste and waste bin management. To avoid open dump of waste, waste bins must be allocated by finding proximity distance convenient to the people. Bin size should be decided in consideration with the generation of amount of waste and collection frequency to avoid overflow of bins. On the basis of type of waste generated in particular area, type of bin can be decided. GIS can be effectively used in waste collection to decide collection routes, which will reduce the collection cost.

ACKNOWLEDGMENT

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