Paper ID: CE 0340

A GIS Based Solid Waste Management of Rajshahi City Corporation

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Abstract

Waste management is a global environment issue which has led to both economic and environmental sufferings. It is better to segregate the waste at the initial stages where it is generated, rather than going for a later option which is inconvenient and expensive. The present study involves solid waste management strategies of Rajshahi city corporation. The percentage of different categories of wastes are organic material 70%, garden waste wood 6%, paper 9%, plastic, textile, rubber, leather 9%, metal, glass 3%, others 3%. From 2004 to 2010 waste generation trend is increased 100 tons/day. This problem can easily be solved by using geographic information system (GIS). The number of waste collection bins is not enough in some areas. In order to collect solid waste vehicles are used is not enough to manage waste due to size and other obstacles. Dijkstra's shortest path algorithm vehicle routing problem is solved to manage solid waste in an efficient way.

Keywords: *Solid waste; GIS; Collection bins; shortest path; Spatial Database (SDB).*

1 Introduction

Technological progress, globalization, and population growth have intensified the complexities of processes of urbanization in developed countries that have led to the production of exponentially large volumes of solid waste (SW) in more or less localized areas. This rapid population growth and urbanization reduces non-renewable resources and the indiscriminate disposal of effluent and hazardous waste are the main environmental problems that present threats to human life (Allen et al; 1997). The most important issues associated with unsuitable solid waste management (SWM) include spread of pathogens, fire risks, odor disturbance, air and water contamination, esthetic disturbance and economic losses (Jilani et al; 2002).

Municipal solid waste management is one of the biggest challenges facing city planners around the world. The issue is especially serious in most developed world towns where accelerated urbanization, inadequate planning and lack of sufficient infrastructure add to the poor condition of solid municipal waste management (Obirih-Opareh & Post, 2002; Mato, 1999; Doan, 1998; Mwanthi et al., 1997). Waste disposal without adequate segregation results in both economic and environmental damages, such as environmental degradation, health hazards and economic downturn. Effective planning needs to be carried out for proper waste management through the study of the area's waste situation. Unsustainable waste disposal is a sensitive issue which concerns in today's world about serious environmental issues. The current situation of direct waste dumping without proper inspection and separation leaves serious environmental pollution impact, causing tremendous growth in health-related issues. Domestic, industrial and other waste, whether at low or medium levels, causes contamination of the atmosphere and has become chronic problems for mankind.

The management of municipal solid waste is a major challenge in developing countries. In most of the underdeveloped countries, the generated municipal solid waste is not managed properly and causes serious issues with respect to storage, collection and final disposal. The Asian and Pacific region currently produces 1.5 million tons of MSW each day and is expected to more than double by 2025. Bangladesh is a developing country and is experiencing the problem of solid waste management. Rajshahi holds the status of being a prominent educational hub in Bangladesh, hosting numerous esteemed educational institutions. This distinction draws a significant influx of students from across the nation who converge here for their academic pursuits. Consequently, a multitude of

residential complexes within Rajshahi City Corporation (RCC) accommodate these students, thus constituting a substantial portion of the city's solid waste output. Notably, residential sources contribute a dominant 77.18% share to the overall solid waste generation within RCC (Islam et al., 2022). Projections indicate that by 2025, the per capita waste generation is expected to reach 0.60 kg per day, culminating in an estimated total municipal solid waste (MSW) generation of around 47,064 tons per day. Various methods of solid waste management are employed throughout Bangladesh, including sanitary landfilling, incineration, recovery and recycling, and composting. Within RCC, a disposal site spanning 15.98 acres and measuring 3.5 feet in depth is located in Nawdapara, alongside 35 secondary collection points.

The collection / transport aspect of any SWM system is the most important and expensive part, as it consumes the largest fraction of the budget allocated to SWM by municipalities. To achieve optimum waste collection and transport operation, hauling, machinery, and handling must be done. This is the most important and expensive part of the system, and the goal is to achieve optimum waste collection and transport operation.
Developing the SWM method, however, requires deciding a variety of selection criteria, which is a very difficult process for a planner to manually do. The use of the Geographic Information System (GIS) to examine complex spatial phenomena is recognized as one of the most promising approaches. GIS has been used successfully for a wide range of applications, including geology, natural resource conservation and management, risk management, urban planning, transportation, and various environmental modelling aspects (Brimicombe 2003), (Unwin 1996). Integrated GIS technology nowadays offers an sophisticated simulation platform for decision-makers to evaluate and simulate various SWM related problems. Indeed, the GIS method was used to model various waste management applications such as the location of transfer stations and landfill, optimizing waste collection and transport, and local waste prediction (Khan and Samadder 2014), (Dyson and Chang 2005), (Arribas, Blazquez et al. 2010). Using spatial modelling tools and GIS to optimize selection and transportation will deliver economic and environmental benefits by reducing travel time, distance, fuel consumption and emissions of pollutants (Chalkias and Lasaridi 2009).

This work developed a methodology based on GIS technology to optimize the waste collection system for the Rajshahi City Corporation Municipality (RCC). The technique consisted of removing and reallocating waste disposal bins and rescheduling waste collection by improving the GIS routing. The benefits of the new plan have been measured in terms of reducing collection time, travelled distance, and man-effort, and ultimately the collection system's financial and environmental costs.

2 Materials and Methods

The research employed a comprehensive methodology to assess and optimize the solid waste management system within Rajshahi City Corporation (RCC) using Geographic Information System (GIS) technology. An inventory questionnaire was designed and employed to gather relevant information from the Rajshahi Development Authority, focusing on solid waste generation, storage, treatment, and disposal practices. The collected data underwent rigorous analysis to ascertain the suitability of the existing system for strategic solid waste management planning.

The study area, Rajshahi district, was defined geographically within northwest Bangladesh, encompassing nine Upazilas, 13 municipalities, and 147 districts. Rajshahi City Corporation (RCC) was identified as the focal point of the investigation, with three specific wards (25, 27, and 28) chosen as survey areas due to their waste collection characteristics. A total sample of 60 waste collection points were identified across these wards, utilizing the availability of vehicles such as vans, tractors, and trucks for efficient collection.

The GIS technology formed the core of the research methodology, structured into three phases. The first phase involved establishing a geographic network map of the study area, integrating spatial data into a dedicated Spatial Database (SDB) within the GIS framework. The second phase focused on the reallocation of waste disposal bins through GIS spatial analysis techniques. The third and final phase aimed to optimize waste collection routes by minimizing time and spatial resources.

Key components of the methodology included the development of the SDB, which incorporated analog maps, multimedia data, and GPS-based field data collection. GIS spatial analysis techniques were employed to reallocate waste disposal bins, considering factors such as waste quantity, vacant land, and road accessibility. The ultimate goal was to optimize waste collection routes by employing the principles of vehicle routing, considering vehicle capacities, timing, and disposal facility selection.

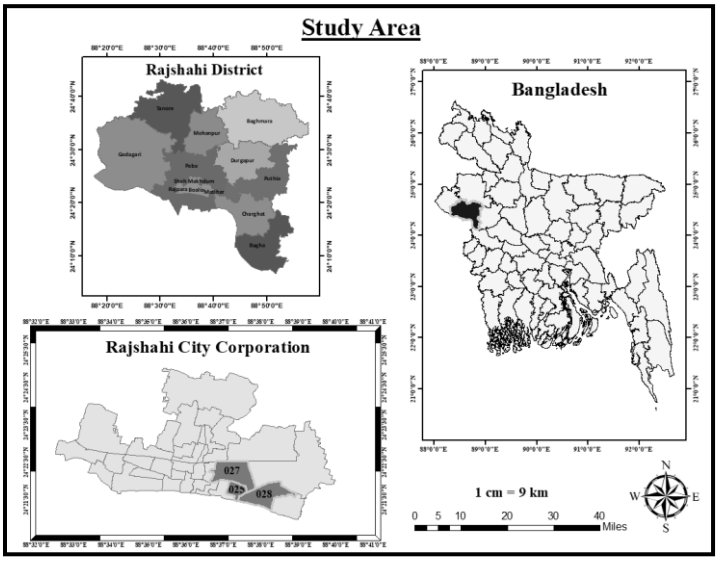

Figure 1: Study Area of RCC

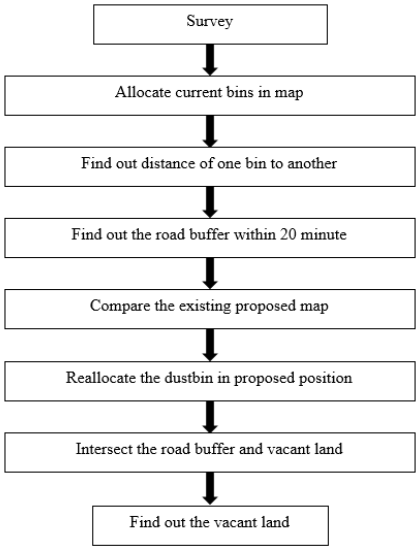

Figure 2. Flow-Chart Under Spatial Database.

a) Spatial Database (SDB) development

In order to evaluate spatial data for the optimisation of the waste collection system in the RCC, a spatial database (SDB) within the GIS framework was created. The overview of this database is given in the previous section of this article. The primary origins of the SDB are (a) analogue maps from RDA, (b) multimedia data from different official suppliers (e.g. RCC) (c) Data obtained from field work / on-site data collection using GPS technologies.

b) Reallocation of waste collection bins

This research was carried out in a GIS setting using advanced spatial analysis functions to reallocate waste disposal containers. The number of bins required was calculated on the basis of waste generated daily and weekly, and the distribution was carried out in compliance with the following rules: redistribution of bins to the road network, average distance of 50 m (in a buffer zone 20 m wide) from current bins to proposed collection bins, and require the positioning of more than one bin at the same intersection. The number of bins occupying the same point of intersection is related to the land use of the surrounding area and the density of the city.

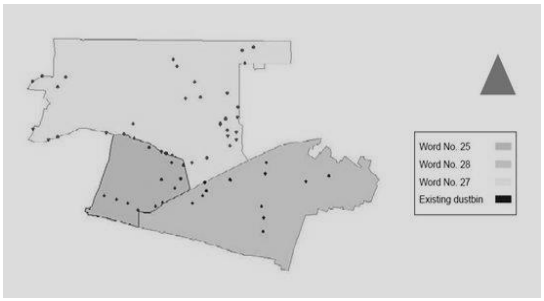

Figure 3. Existing Dustbin of Ward 25, 27, 28

Figure 4. Existing Dustbin Buffer (20m)

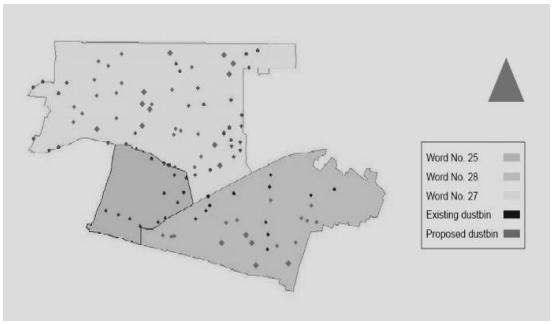

Figure 5. Proposed Dustbin of Ward 25, 27, 28

Figure 6. Proposed Dustbin Buffer (20m)

c) Routing – Network analysis

Since the reallocation of waste collection containers, an analysis of waste collection vehicle routing has been carried out. The optimal route finding algorithm for ArcGIS is a modification of the classic Dijkstra algorithm (Obirih-Opareh and Post 2002) that solves the problem of optimal route selection on an undirected, non-negative weighted graph at a reasonable computational time (Chalkias and Lasaridi 2009).

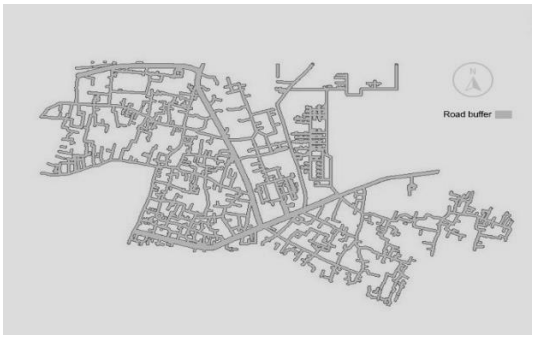

Figure 7. Road Buffer (10m)

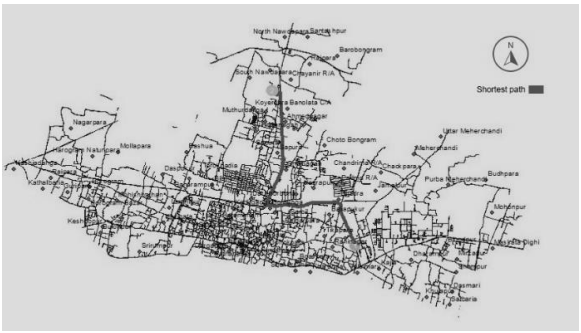

Figure 8. Shortest Route to Disposal Site

Since the reassignment of refuse collection containers, the routing of waste collection vehicles has been analyzed. The optimal route finding algorithm for ArcGIS is a modification of the traditional Dijkstra algorithm (Obirih-Opareh and Post 2002) that addresses the problem of optimal route selection on an undirected, nonnegatively weighted graph in a reasonable amount of time (Chalkias and Lasaridi 2009).

This technique is expanded in the context of ArcGIS applications by employing robust data structures such as dheaps (Sandhu and Chandrasekhar 2006). In order to apply this algorithm to actual transport data, it must be modified to account for specific issue restrictions, such as one-way roads, restricted turns (e.g. U-turns), demand at intersections (nodes) and along the highways, and side-street restrictions, thereby reducing the user-specific cost factor.

The key principle is to construct a cost matrix that compares sources and destinations. These are the pairs of vehicle exits (recycling bins). The total travel time for the optimal route is the sum of the travel times for each segment of the path plus the time required to collect the refuse bins. The user of ArcGIS is able to specify the aforementioned traffic conditions, the stop time for each waste collection container, and the initial and final collection stops. In terms of distance or time, the final performance provides the superior solution.

4 Result and Discussion

The approach mentioned above was used to evaluate the waste management system for the Municipality of Rajshahi City Corporation. Two specific optimization strategies have been considered: 1) the redesign of the temporary storage network by the reallocation of bins to promote their collection; and 2) optimum route analysis for the GIS model built using the proposed bins as stops. The reallocation of bins is based on distance movement (from each residence to the closest bin) and on the general aim to reduce the overall number of bins. Therefore, a maximum distance of 50 meters from each resident to the proposed new bin site has been permitted. In fact, the installation of new bins with a greater capacity to handle the same amount of waste means that the overall number of bins is limited and the recycling ends. As a result , a total of 22 bins in the proposed new locations were added to the existing 60 bins in Wards-24,25 and 27. Fig. 4 indicates the possible reallocation of waste bins to the departments under scrutiny. A higher priority for the distribution of new bins has been given to bin positions in the current scheme and to crossroads in order to promote mutual recognition and storage of vehicle traffic. Different routing approaches have been developed on the basis of the different requirements and limitations implemented in ArcGIS. Routing solutions are developed using a heuristic method (Dijkstra algorithm). This strategy takes account of the placement of 22 additional larger bins.

5 Conclusion

GIS as planning methods are useful resources that can allow decision-makers to identify the best available solid waste collection sites. GIS research involves the compilation of data from various sources in varying formats in order to construct a complete, uniform database. The GIS data will then be revised periodically in order to represent the actual state of the region under investigation.
In this analysis, GIS technology was used to establish a technique for maximizing the MSW array of mixtures. The system uses a range of geographic data (road network, location of waste bins, land use, etc.) in conjunction with specialized GIS spatial analysis software. In the case analysis of one waste collection field of the RCC, the model was used to analyze the routing optimization of the current system and the enhancement of the system by reallocation of bins. The study demonstrated the importance of GIS technology as an optimization method for waste management, capable of driving decision-making. Future research should focus on the sectorization of larger waste management zones, based on geographical modelling rather than on observational methods, as well as the transition of the collection system to the implementation of independent collection systems for specific waste sources and the quantification of fuel and pollution savings.

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