APPLICATION OF GIS TECHNIQUES IN URBAN SOLID WASTE MANAGEMENT IN A PART OF DHAKA CITY: MOHAMMADPUR THANA

Shahriar Rahman
Junior Environmentalist, Center for Environmental and Geographic Information Services (CEGIS),
Dhaka-1212, Bangladesh.

Syed Hafizur Rahman
Department of Environmental Sciences,
Jahangirnagar University, Dhaka 1342, Bangladesh.

Abstract
For developing countries like Bangladesh, urban solid waste management (USWM) is a complex issue and an integrated concept as well. Geographic Information System (GIS) was applied in this study to propose better solid waste management in a part of Dhaka city. Mohammadpur Thana comprised of 11.65 km^2 is a residential area and about 64% of its generated solid wastes were managed by Dhaka City Corporation (DCC). The Composite Index on Impacts on Health showed increasing value 1.55 to 1.73 from the year 2002 to 2007 indicating progressive deterioration of health and environmental quality of the study area. This study described two options for better solid waste management practice of Mohammadpur Thana, one was with relocating existing bins and containers and another with a scenario attaining 80% waste collection efficiency including selection and optimization of waste collecting routes with proposed numbers of bins (25), containers (30) and existing illegal dumping sites (14). A participatory management option, Community Management Information System (COMMIS) incorporating Management Information System (MIS), modification of communal bin, establishment of Mini Transfer Station (MTS) at specific sites, 3R (Reduce-Reuse-Recycle) and incorporating Clean Development Mechanism (CDM) in preparing Solid Waste Model were recommended for efficient urban solid waste management.

1. Introduction

Urban Solid Waste Management (USWM) is now a complex issue in Bangladesh due to its increasing population and industrial growth. Solid waste (SW) generation is increasing proportionately with the growing urban population. At present, 522 urban centers including 254 municipalities in 6 cities are present in Bangladesh (SAARC, 2004). So, solid waste management (SWM) is an obligatory function of urban local bodies in Bangladesh. Solid waste is non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Palnitkar, 2002). Urban solid wastes (USW) include commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes and the types of solid waste depend on the commodity usage and lifestyle of the people. The estimates for solid waste production for Dhaka city was varied from 3,500 to 4,500 metric tons per day on very rough per capita basis, which has been taken to be between 0.45 and 0.50 kg. Taking the mid-figure of 4000 tons per day at present, and with a 5 percent growth rate of population, the city is apprehended to have a proportionate increase in solid waste generation. By 2015, more than 6,000 tons of Solid Waste will be generated in Dhaka City Corporation (DCC) area (DCC, 2004).

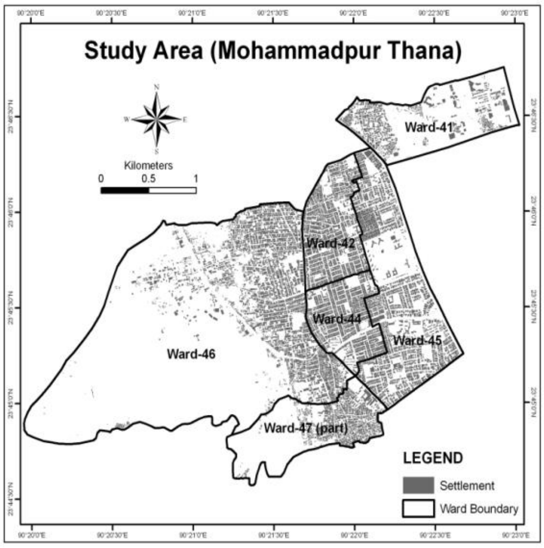
The management issue of generated solid waste is not only multifaceted with its increasing quantities but also with its inadequate management system (Tinmaz & Demir, 2005). In this study, Geographic Information System (GIS), a good decision support tool for waste management planning were used to define the possible option for efficient solid waste management. According to Ogra (2003), the more the layers in terms of information, the more will be better decision analysis. Urban solid waste management practices require collection of decisive information which is for taking corrective measures as well as for proper planning to ensure sustainability (Ramachandra & Saira, 2003).

This study was conducted at the part of Dhaka city, Mohammadpur Thana (11.65 km^2), located at 23°44′32″N-90°20′E to 23°45′40″N-90°23′E geographic boundary of Dhaka district. The study area consisted of six wards, 41, 42, 44, 45, 46 and 47 (part), out of 90 wards in Dhaka City with 198,306 household units. The main objectives of this study were to explore the current Solid Waste Management (SWM) practice including waste generation, location of waste bins, type, size and frequency of waste removal from the bins and to propose requirements and relocating of bins using GIS considering the current practice for better waste management.

2. Methodology

Primary and secondary data were collected to propose options for better solid waste management for Mohammadpur Thana. Random questionnaire survey was conducted at the study area with collecting Geographic Position System (GPS) of existing waste bins, containers and illegal disposal sites using GPS device (Explorist 200). Secondary information about solid waste management associating other relevant information, like demographic and socio-economic data from various governmental and non-governmental sources were collected to decide the viable option for waste management.

Spatial data were generated using collected GPS data and high resolution satellite images (Quickbird Image) of the study area. Thematic maps were prepared for every relevant feature in GIS platform with digitization of collected secondary data. The geo-referencing and geo-processing were conducted to define all the dataset in BTM (Bangladesh Transverse Mercator) projection and to set the specific dataset boundary. Concurrent GIS software (ArcGIS 9.2) with its network analyst extension was used to recommend efficient waste management options through existing and proposed number of waste bins and containers.



3. Current SWM Situation of the Study Area

Mohammadpur Thana is comprised with six wards [41, 42, 44, 45, 46 and 47 (part)] (Figure 1). As the municipal waste management bodies were unable to prove a 100% efficient system and even were not able to reach the efficiency of 70% (Ogra, 2003), apposite waste management could raise the waste management efficiency to a substantial limit. Door-to-Door (DTD) waste collection, initiated by local community and supported by DCC, was observed in the study area. But in some areas, SWM practice was not well maintained resulting jumbled waste disposal.

Figure 2: a. Discrete wastes dumping at the slum area; b. Traffic congestion due to improper container placement; c. Concrete waste bins lacking proper maintenance; d. Waste dumping around the waste container initiate traffic and health problem

At the north-western part of the study area (Ward 46), waste collecting bodies had no such bins or containers and population density of that site (Dhaka Uddan) was lower than the other parts. Community based SW collection vans had collected wastes rarely (once or twice a week) from that site. Emerging housing (Chandrima, Nobodoy Housing) facilities at that part of the study area require proper SWM with considering future population projection and rapid urbanization. The southern part (Ward 45 & 47) of the study area was residential area and DTD waste collection was practiced. No major illegal dumping sites were found at the housing sections (Kaderabad, Jafrabad Housing) of Jafrabad area of Ward 47. Lalmatia, Zakir Hossain Road and Iqbal road were found clean and regular DTD collection was practiced in that part of Mohammadpur Thana. With some exceptions of illegal dumping, regular waste management practices were observed in ward 44, 45 and 47.

The only waste Mini Transfer Station (MTS) of the study area was located at the Lalmatia (Ward 45), bounded by concrete partition. In slum areas of the Ward 42, population density was rather high. These unprivileged peoples had a lack of proper sanitation, drinking water and solid waste dumping facilities and only wastes are collected at night from the adjacent DCC containers. Slum areas and in quarters comprise a huge number of people and lethargic waste collection management was responsible for the unplanned management of solid wastes of the slum areas of the study area (Figure 2a).

Ward 41 (mainly mixed residential & commercial area) was quite clean and except one location no major illegal dumping was found during field survey. Two DCC containers and a ten ton carrier where placed where local waste management bodies dumped wastes. According to participatory survey, it was found that more wastes were generated from April to July months of the year. In rainy season, the scenario was ominous with the flooding of wastes to the roads with rain water. Temporary drainage congestion with flooding of wastes was a regular problem in some part of the study area.

Door-to-Door waste collection technique was found existing in the study area and the main problem with waste management was with the crevice and timing of collecting wastes from the households and also from the DCC concrete bins and metal containers. The local waste collecting committee collected wastes at day-time but the DCC trucks collected wastes at night or at early in the morning. So, the collected wastes were plunked for several hours (more than 10 hours) time on the containers which induce odor and health problems. Waste compilation around the waste bins and containers reflected traffic problem. The pedestrians also get affected by odor problem induced by SW around the containers beside the roads (Figure 2b, 2d).

The ragpickers of the study area were mostly women and children and they might be severely affected by diarrhea or other vector borne diseases collecting SW. The household, commercial, institutional and medical wastes were deposited in the same waste collection bins located on the streets (Figure 2c). As the DTD collection has a remarkable success in SWM in Dhaka city but the local Community Based Organizations (CBOs) of the study area were facing staff problems, service charge collection, evasion, timing of DCC trucks, lack of suitable sites for keeping waste collecting vans and budget problems. So, an initiative for integrated urban solid waste management was essential to minimize waste generation with supporting reuse and recycling options at Mohammadpur Thana.

3.1 Composite Index of Impacts on Health

One of the important requirements of USWM is ensuring public health. Waste that is not cleared regularly or not disposed of safely can pose health hazards. However, the degree of impact will also depend on population density. The overall impact on health is arrived at by combining the three indicators in the following manner (Muraleedharan, 1998):

Composite index = (w_1 × UNCL + w_2 × UNTR) × POPR [Considering, $w_1 = w_2 = 0.5$]

So, Composite Index of Impacts on Health = (1.18 × 0.5 + 0.5 × 1.014) × 1.42 = (0.59 + 0.507) × 1.42 = 1.55 (for the year 2002) [Standard value = 1]

Where,

UNCL (uncleared waste): the ratio of waste left on streets at any point of time to the 2001 base value;

UNTR (untreated waste): the ratio of untreated waste to the 2001 base value;

POPR (population ratio): 1.42% increase for the year 2001 (BBS, 2001)

So, with the increasing population rate of consistent rate (1.42%) the index value was increased up to 1.73 for the year of 2007. A higher value of composite index indicated a progressive deterioration in health and environmental quality of the surrounding environment.

3.2 Waste Dumping Sites

Collected wastes from the study area were disposed to the Beri bund and Amin Bazaar landfill sites. Major portion of the waste disposed (65%) at the Amin Bazaar site and about 35% at the Beri bund waste dumping site. Amin Bazaar landfill was managed by DCC; the overall dumping management system was satisfactory. One bulldozer and one wheel dozer were working in the Beri bund dumping site but no other facilities were installed and the site was filled without soil covering. In the dry season there was no leachate discharge. As the Beri Bund site was located outside the embankment, this dumping site recurrently flooded in the rainy season.

4. Results & Discussions

4.1 Total Generated Wastes

The estimated domestic waste generation rate was 1,950 tons per day in Dhaka city. The wastes of the study area were mainly composed of 69% food wastes, 10% paper, 6% wood and dust, 2% plastic contents, 5% sand and dust and 8% other wastes (DCC, 2007).

The waste generation rate was about 0.34/kg/d/person but considering domestic, business and street section the waste generation per capita per day was up to 0.50 kg.

Table 1: Ward based household number and total population of the study area [Source: BBS, 2001]

Mohammadpur (Wards)	Households	Population
41	20,750	87,240
42	12,735	56,459
44	8,583	44,507
45	8,566	48,581
46	132,304	60,922
47 (part)	15,368	64,070
	Total: 198,306	**Total: 361,779**

Total number of population in Mohammadpur Thana was about 361,779 and the average per capita waste production per day is considered as 0.50 kg (BBS, 2001). So, the total production of wastes in Mohammadpur Thana was 180,890 kg/day per capita.

4.2 Capacity of Existing Waste Bins and Containers

The sharing of waste bins and containers with adjacent wards of the study area trimmed about 21% waste collection capacity due to other adjacent wards contribution to the bins and containers. The collection capacity was calculated about 85% literally but in real condition about 116,250 kg (64%) wastes were collected by the DCC from the study area (**Table 2**).

Table 2: Waste Collection from the existing bins and containers

Type	Capacity (Kg)	Total Number	Total Waste Collection (Kg)
DCC Containers	5,000	25	125,000
Waste Bin (Brick & Sl Sheet)	1,500	20	30,000
			Total: 155,000

4.3 Required No. of waste bin and containers

Analyzing collected primary dataset, a waste container was found for 14,470 people and a bin for 8,040 people. Considering space, time and disposal, waste containers were found better to manage rather than the waste bins.

As the waste bins were needed for primary and emergency collection, 80% waste collection can be achieved with increasing number of waste containers with considering numbers of waste bins (**Table 3**).

Table 3: Waste collection with proposed number of waste bins and containers

Type	Number	Capacity (kg)	Total Waste Collection (kg)
Waste Bins	25	1500	37,500
Waste Container	30	5000	150,000
			Total: 187,500

4.4 Optimal Location of Current Waste Bins and Containers

About 20 waste bins and 25 containers of the study area were found during field survey. Current route selection was competent with existing bins and containers but had an over-populated with an un-served area (Figure 3).

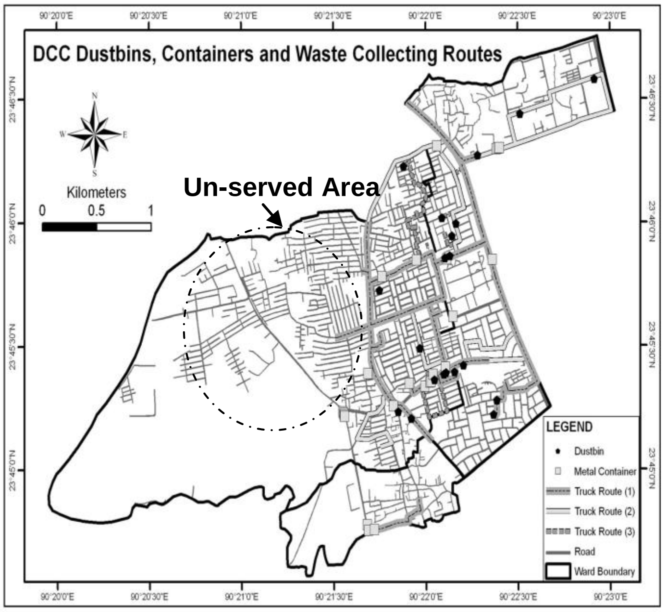


Figure 3: DCC dustbins, containers and waste collecting routes

According to the vehicle capacity distribution by Zone 6, the study area wards 42 to 46 showed a carrying capacity more than 70% of waste collection ratio. [Zone 6: Ward 39, 42-46] but 41, 47 wards showed less than of that ratio (DCC, 2007).

The optimal location of waste bins and containers had been suggested considering present containers and bins. The relocations of waste bins had been chosen by trial and error method. Self judgment and population density were considered suggesting potential locations of bins and containers. The proposed locations were analyzed using network analysis and the overall coverage of the study area with the existing bins and containers have been proposed. The waste bins locations were modified with analyzing route optimization and concerning final disposal sites of the wastes (Figure 4).

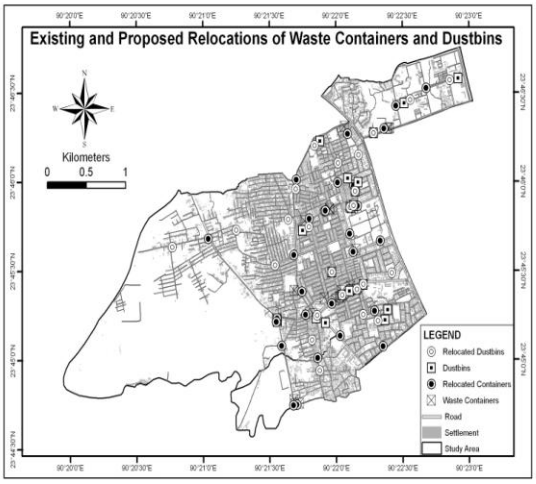


Figure 4: Existing and proposed relocations of

Waste collection time would be reduced and the route selection would be more optimistic for the final disposal. The two ways out to the disposal site (Beri bund Road and Mirpur Road) were taken into account concerning the route selection and relocation of the waste containers and bins. A distance of 200 m was considered for dustbins and 500m for waste containers.

4.5 Illegal Dumping, Rag Picking and Recovery of Generated Wastes

Open dumping sites were polluting the surrounding environs with obnoxious odor and were found responsible for spreading vector borne diseases. During field survey, illegal dumping sites (about 14 sites) were found in different locations of the study area (Figure 5 (a, b). Illegal dumping sites were mostly seen around the open places and beside the side of the roads (Figure 6). Burning of wastes close to the container sites was observed and the burning was a common solution for street wastes which was deteriorating the air

Figure 5 (a, b): Illegal dumping sites

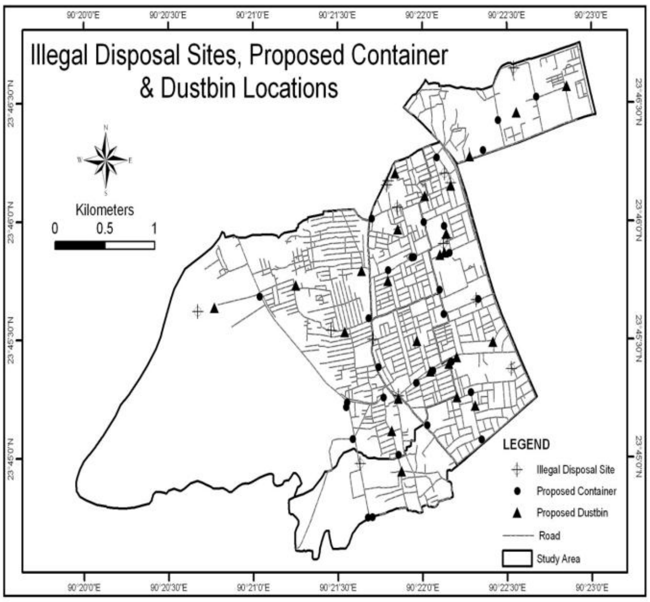


Figure 6: Illegal disposal sites, proposed container and

quality of the surrounding environment and also responsible for initiating many respiratory diseases.

Rag pickers were seen scavenging around the dumping sites and from DTD collecting vehicles. About five hundred waste pickers (mainly children and women) at the study area were directly engaged in recyclable wastes collection. Rag pickers had contributed to the SWM by selling waste materials to the buyers and wholesalers and thereby providing raw material for the recycling. Rag pickers were a part of the whole recycling sector of SWM in the study area. About 55% of the recyclable wastes (6% of total wastes) were collected by the rag pickers of the study area.

Among the places of recyclable waste collection, those conducted around dust bins or containers produce negative impacts to keep the street clean and to remove waste efficiently because recyclable waste collectors spread waste around the bins and containers. Ragpickers don't return the remaining wastes to waste bins or containers after finishing picking recyclable materials.

4.7 Route Optimization with Proposed Waste Bins and Containers

Current waste collecting routes and self-judgment were put into consideration in optimal route selection of waste collection using network analyst tool. A route was proposed using the Beri bund highway considering the wastes collected from N-W part of the study area (Ward 46) and for disposal at Beri bund site. The other routes were considered with derived results from network analysis and the routes were suggested an overall two trips for each ward of the study area (Figure 7).

The routes were mainly were selected based on bins and containers location. So, all the routes which validated utmost locations could not ensure 100% time efficiency (Ward-45).

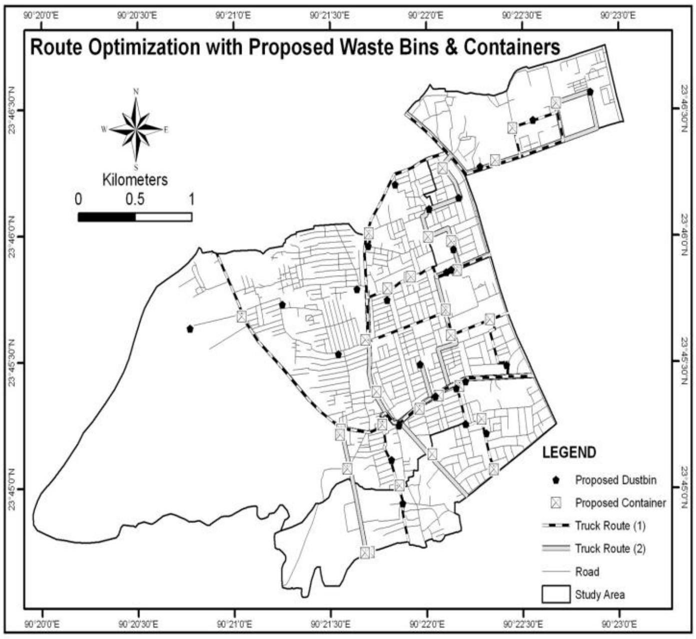


Figure 7: Route optimization with proposed waste bins and

The routes were based on the proposed waste bin (25) and container (30) locations and about 90% of the study area would be covered with the proposed bins and containers.

5.0 Conclusion and Recommendations

Urban solid waste management requires efficient waste collection and dumping system and about 64% of generated wastes had been collected by DCC with the existing bins and containers. The Composite Index on Impacts on Health used as an indicator for health and environmental quality showed increasing value [1.55 to 1.73] from the year 2002 to 2007 indicating progressive deterioration of health and environmental quality. The proposed bins and containers relocation were suggested considering the existing number of bins and containers using contemporary GIS technique with its associated tools to achieve 80% waste collection efficiency. It was found at about 55% of the recyclable wastes were collected by local ragpickers. About 25 waste bins and 30 waste containers would be sufficient to achieve the 80% collection efficiency with reducing existing illegal disposal sites.

For sustainable urban solid waste management, strategic SWM planning should be incorporated in an integrated approach by the waste management authorities (DCC). Communal bins should be re-designed according to the requirements of the community which will help to minimize illegal waste dumping as well saves collection time and disposal cost. Management Information System (MIS) should be incorporated in Solid Waste Model (SWM) for proper waste storage and apposite route selection for the waste collecting vehicles (i.e., trucks). Mini transfer Station should be constructed at each waste container location. As only the single MTS was seen in Lalmatia (Ward 45), such type of construction will reduce the odor and traffic problem but require space. Segregation of wastes at primary and secondary level at waste collection should be conducted. A COMMIS (Community Management Information System) incorporating people's participation should be built considering waste generation, collection and transportation (schedule, numbers of truck, etc). COMMIS will ensure better SWM with integration of people's participation and contemporary technologies. GIS technique is an efficient tools for constructing COMMIS, such technologies will be helpful for not only minimizing wastes but also to utilize the wastes in different ways. Clean development mechanism (CDM) should be incorporated in SWM model and 3R (Reduce-Reuse-Recycle) campaign should be supported at all levels for waste minimization and its proper utilization.

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