Urban Solid Waste Management Using GIS Technique: A Case Study on Mohammadpur Thana at Dhaka of Bangladesh

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ABSTRACT

Urban Solid Waste Management (SWM) is an integrated concept and a complex issue in an urban area of least developing Asian countries like Bangladesh. The study area of Mohammadpur Thana (11.65 km^2) is a residential area; about 64% of its generated solid wastes were managed by Dhaka City Corporation (DCC). Geographical information system (GIS) was used to propose an efficient scenario with relocating the existing waste bins and containers and another scenario was proposed with number of bins (25), containers (30) and existing illegal dumping sites (14) to attain an 80% waste collection efficiency including optimization and selection of waste collecting routes for Mohammadpur Thana. A participatory Community Management Information System (COMMIS) and further suggestions for an integrated SWM were also recommended.

INTRODUCTION

Bangladesh is a developing country with rapid urban population growth in a limited land area. Solid waste (SW) generation is also increasing proportionately with the growth of urban population. The SWM is an obligatory function of urban local bodies in Bangladesh. At present there are 522 urban centers including 254 municipalities and 6 cities in Bangladesh (SAARC, 2004). Solid waste is non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Palnitkar, 2002). Urban solid wastes 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 has varied in the range of 3500 to 4500 metric tons per day on very rough per capita basis, which has been taken to be in between of 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 6000 tons of Solid Waste will be generated in DCC area (DCC, 2004). So, urban SWM has its significance for Dhaka city.

The issue of solid waste is not only because of the increasing quantities but also largely because of an inadequate management system (Tinmaz & Demir, 2005). Geographic Information System (GIS) is a good decision support tool for SWM planning. The more the layers in terms of information, the more will be better decision analysis (Ogra, 2003). Urban SWM practices require collection of decisive information which is for taking corrective measures as well as for proper planning to ensure sustainability of SWM (Ramachandra & Saira, 2003).

Urban solid waste was defined to include all urban non-liquid materials no longer required by an individual, institutions or industries such as all domestic refuse and non-hazardous commercial, institutional, industrial waste, construction debris and street sweepings. Such a SWM system must also be integrated, that is, be using a range of inter-related collection and treatment options, at different habitat scales, involving all stakeholders, the governmental or non-governmental, formal or informal, profit-or non-profit oriented groups and taking into account interactions between the SWM system and other urban systems (Martin *et al.*, 2004).

The study area of Mohammadpur Thana was located at 23°44′32″N-90°20′E to 23°45′40″N - 90°23′E in Dhaka district of Bangladesh. It was consisting of 198306 house hold units in its 11.65 km² area. The study area was covered with six wards in Dhaka City of 41, 42, 44, 45, 46 and 47 (part) out of 90 wards.

The main desired aims and overall objectives of this study were to explore the current SWM practice including waste generation, location of waste bins, type, size and frequency of solid waste removal from the bins and to propose requirements and relocating of bins by using GIS considering the current practice for better SWM.

METHODOLOGY

Primary data about the SW of the study area were collected through questionnaire and Global Positioning System (GPS) survey. The exact location of the solid waste bins, containers and illegal waste disposal sites were collected by using GPS device (Explorist 200). Preparation of thematic maps includes the digitization of collected secondary data. Questionnaire survey concurrently conducted while taking the GPS data. Spatial data were generated using collected GPS data with using Google Earth Images. An amount of secondary data about SWM associating other relevant information, like demographic, economic data, were collected from various Non-Government and Government organizations (NGOs & GOs).The information of different types and forms has converted into the GIS database. GIS software (ArcGIS 9.2) with its network analyst extension was used to recommend waste bins, containers location and for the preparation of final maps.

RESULTS AND DISCUSSIONS

Current SWM of the Study Area

The study area was covered with six wards of 41, 42, 44, 45, 46 and 47 (part). As DCC managed solid wastes on ward basis, so ward boundary was highlighted in the map of study area as presented in Figure 1. Municipal Solid Waste Management (MSWM) bodies were unable to prove a 100% efficient system and even were not able to reach the efficiency of 70% (Ogra, 2003). So, we couldn't expect 100% efficient SWM practice in urban area. But appropriate SWM could raise the SWM efficiency to a substantial limit. The SWM practice of the study area was moderate. Door-to-Door (DTD) waste collection, initiated by local community and supported by DCC, was observed. But in some areas, the SWM practice was not so maintained recurrently resulting jumbled waste disposal. At the north-western part of the study area (ward-46), there were no such bins or containers for dumping of solid wastes. Waste collecting bodies had no such bin or container at that site. 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 need proper SWM with considering future population projection and rapid urbanization. The southern part (ward 45 & 47) of the study area was fully residential area and DTD waste collection was practiced. In Jafrabad (ward-47), no major illegal site was found at the housing sections (Kaderabad, Jafrabad Housing). Lalmatia, Zakir Hossain Road and Iqbal road were clean and regular DTD collection was practiced in that part of Mohammadpur Thana. With some exceptions of illegal dumping, quite good waste management practices in ward 44, 45 and 47 were observed. The only waste Mini Transfer Station (MTS) of the study area was located at the Lalmatia (ward-45), where the waste container was bounded by concrete partition. In some part of the ward-42, mainly in slum areas, population density was quite 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 containers.

In slum areas (Geneva Camp) of ward 42, local waste collecting bodies were inactive and need proper SWM practices. In slum areas and in quarters, which comprise a huge number of people, SWM practice was not so good. Lethargic waste collection management was responsible for the worst situation of the slum areas of Mohammadpur Thana (Figure 2a). The other section of the ward-42 was clean rather than slum areas. Ward-41 was mainly mixed (residential & commercial area) type area and was quite clean. Except one location, no major illegal dumping was seen at that part of the study area. Two DCC containers and a 10 ton carrier where placed where local waste management bodies dumped wastes. From the questionnaire survey, it was found that more wastes were generated from April-July month of the year. In rainy season, the scenario was quite bad with the flooding the wastes to the roads with rain water. Temporary drainage congestion with flooding of wastes was a regular problem in some part of ward-42.

Comparatively DTD waste collection helps to minimize the SW problem of the study area, but the crevice and timing of waste collection from household by the local SW collecting bodies were responsible for the illegal waste disposal. As the residential area was highly over-populated, people threw their wastes beside the play ground, along the roadside and to the open-spaces as well.

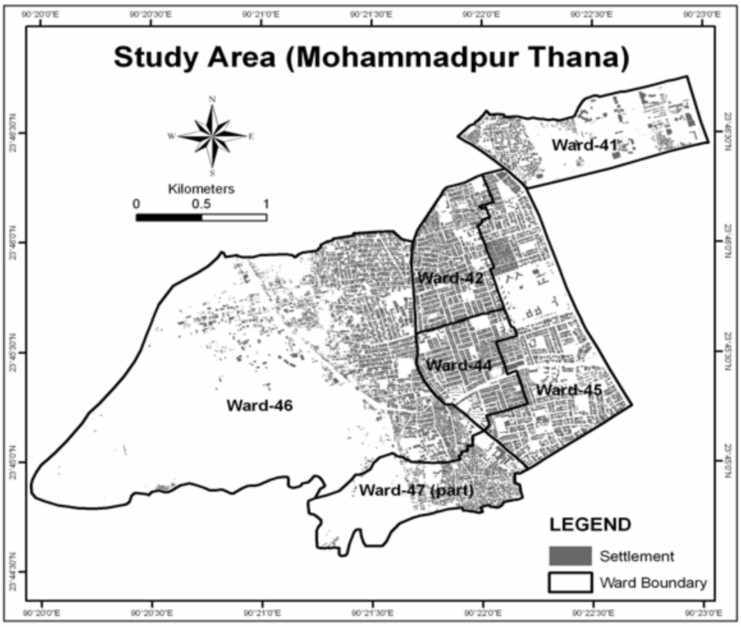

Figure 1 Map of the Study area (Mohammadpur)

Figure 2 a. Illegal wastes dumping at the slum area; b. Placement of waste container induce traffic problem; c. Current waste bins lacking proper maintenance; d. Waste disposal around waste containers initiate traffic and health problem

The managing body and the workers collected wastes at day-time but the DCC trucks collected the wastes at night or at early in the morning. So, the collected wastes plunked for a huge time on the containers which induce odor and health problems. Waste compilation around the waste containers reflected traffic problem. The pedestrians can 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 SWM was essential to minimize waste generation with supporting reuse and recycling options at Mohammadpur Thana.

SWM Practice by DCC

The study area was in zone 3, 6 and 7 of the DCC area. Japan International Cooperation Agency (JICA) started technical cooperation on SWM with DCC in 2000. During the period from November 2003 to March 2006, a development study was implemented. Clean Dhaka Master Plan, the main output of that study was the first master plan on SWM in Bangladesh that covers all aspects of SWM. DCC collect and dump 50.0% and 15.0% are recycled and the rest 35.0% are discarded into streets, drains, ditches, canals and open spaces. Slum and squatter dwellers constitute 35% of city population and only 9% of these populations have any form of solid waste collection service, the remaining 91% dispose their wastes into low-lying lands, road side drains or local drain or canals.

DCC is responsible for secondary waste collection to remove waste from its dustbins/containers, and transport the waste to final disposal sites. Residents are responsible for bringing their waste to DCC's waste collection points where dustbins/containers are located. Three waste management systems are readily seen in Dhaka city and other urban areas of Bangladesh as shown in Figure 3.

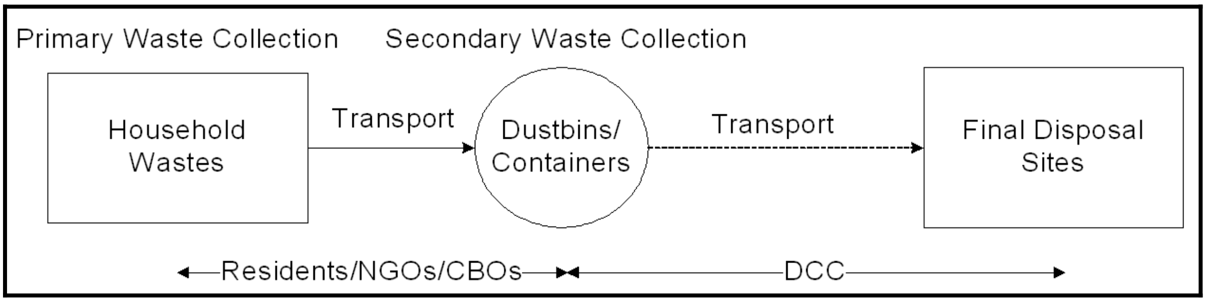

Figure 3 Current waste management flow diagram of Dhaka City (Source: DCC, 2007)

Uncollected waste has been recognized as the root of inferior environment such as scattered garbage, offensive odor; drain clogging, water pollution and mosquitoes. Dhaka City Corporation is mandated the task of solid waste disposal and carries out the task by mobilizing more than 7,000 workers and 300 plus trucks as presented in Table 1

Table 1 Total infrastructure facility of DCC

Manpower		Other Logistics	
Cleaners/Sweepers	7156	Supervision transports -	1 No.
(Male: 4048 + Female: 3108)		Motor Bike-For Inspector	122 Nos.
Supervising staff/officer:	190	Wireless Set -	55 Nos.
Average Cleaners/Ward:	80	Truck/Container Carrier/Hand trolley:	
Total Vehicle Operators:	370	Trucks:	250 Nos.
Dustbins/Containers.		Container Carrier:	300 Nos.
Brick/Concrete Made:	2500 Nos.	Hand trolley:	3500 Nos.
GI Sheet built:	2000 Nos.	Total:	4050 Nos.
De-mountable:	420 Nos.	Dumping Grounds:	4
Total:	4920 Nos.	Matuali	Currently in use
Handcarts:	3000 Nos.	Gubtoly	Not in use
Hand Broom: 1/Sweeper/Month		Amin Bazar	Currently in use
Baskets: 1/Cleaner/Year		Badda	Not in use

(Source: DCC, 2004)

The achievement of cleaning was not yet being appreciated by either of citizens or the government. The waste volume is still increasing as the city grows although DCC not had a confident view to solve the problems of uncollected waste. To solve the collection and transportation problem, an idea of compactor vehicles in the long term to respond to growing demands for Clean Dhaka was proposed by DCC, JICA study team (DCC, 2007).

SW Dumping Sites

The solid wastes collected from the wards of the study area were mainly disposed down to the Beri bund and Amin Bazaar landfill sites. A portion of the waste disposed approximately 65% to the Amin Bazaar site and about 35% (app.) at the Beri bund waste dumping site. As the Amin Bazaar landfill was managed by DCC, the overall management system at that landfill site was quite good. One bulldozer and one wheel dozer were working in the Beri bund dumping site but no other facilities were installed. This site was also filled without soil covering. It was informed that the site was private land and owners requested to DCC to fill by solid waste. In the dry season there was no leachate discharge. As the site was located outside the flood protection band, the site may be flooded in rainy season. Also, it was noted that there are several place filled and/or dumped by solid waste along the flood protection band. A necessity to stop illegal dumping along this important facility was observed during field survey.

Total Generated Wastes of the Study Area

From the DCC statement, it was found that the wastes of the study area were composed of 69% food wastes, 10% paper, 6% wood and dust, 2% plastic contents, 5% sand and dust and 8% other wastes. In recent study, the estimated domestic waste generation was found about 1950 t/d with considering street waste was about 200 t/d in Dhaka city. The generation rate was about 0.34/kg/d/person but considering domestic, business and street section the waste was up to 0.50 kg/d/person.

Table 2 Household and total population of the study area (ward-based)

Mohammadpur (Wards)	Households	Population
41	20750	87240
42	12735	56459
44	8583	44507
45	8566	48581
46	132304	60922
47	15368	64070
	Total: 198306	Total: 361779

(Source: BBS, 2001)

According to Census 2001 as presented in Table 2, total number of population in Mohammadpur thana was about 361779 and the average per capita waste production per day is considered as 0.50 kg. So, the total production of wastes in Mohammadpur Thana was 180890 kg/day per capita.

Capacity of Existing Waste Bins and Containers

The collection capacity is about 85% literally but in real condition many of the waste containers were shared by other adjacent wards as illustrated in Table 3. With considering this sharing of waste bins and containers, trimmed down of 25% waste collection capacity due to other wards contribution to the adjacent bins and containers. About 116250 kg (64%) wastes were collected by the DCC from the study area.

Table 3 Total waste collection from the waste bins and containers of study area

Type	Capacity (Kg)	Total Number	Total Waste Collection (Kg)
DCC Containers	5000	25	125000
Waste Bin (Brick & SI Sheet)	1500	20	30000
			Total: 155000

Required No. of waste bin and containers for the Study Area

By calculation, a waste container was for 14470 people and a bin or a container for 8040 people. With considering space, timing and disposal waste containers were better to manage rather than waste bins.

Table 4 Total waste collection by proposed waste bins and containers

Type	Number	Capacity (kg)	Total Waste Collection (kg)
Waste Bins	25	1500	37500
Waste Container	30	5000	150000
			Total: 187500

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 as presented in Table 4.

Selection of Optimum Location with Current Waste Bins and Containers

At present, about 20 waste bins and 25 containers of the study area were observed. Current route selection was feasible with existing bins and containers but had an over-populated and un-served area as shown in Figure 4. According to the vehicle capacity distribution by Zone 6, the study area wards 42- 46 showed a carrying capacity more than 70% of collection ratio. [Zone 6: Ward 39, 42-46] but 41, 47 wards shows less than of that ratio (DCC, 2007).

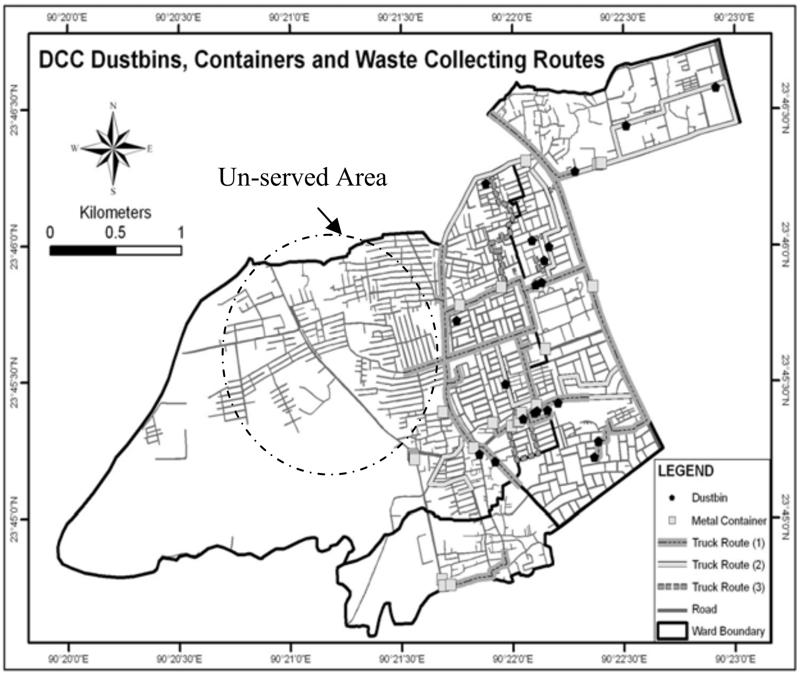

Figure 4 Current locations of DCC dustbins, containers and waste collecting routes of DCC indicating un-served area

The optimum location of waste bins and containers had been suggested with delineating present containers and bins. The relocations of waste bins had been chosen by try and error method. Self judgment was applied to choose the essential locations. The proposed locations were analyzed with 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 site of wastes as shown in Figure 5.

The 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.

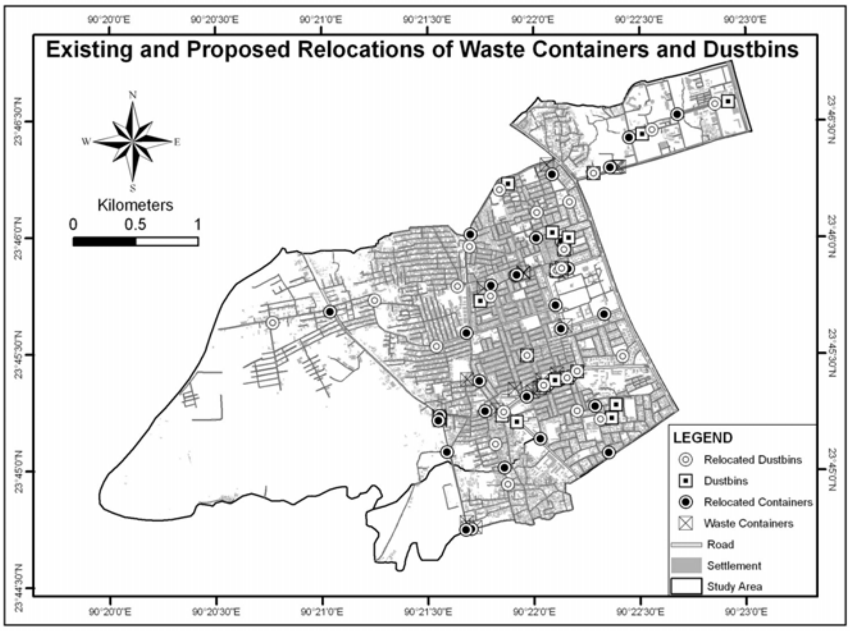

Figure 5 Existing and proposed relocation of waste containers and dustbins of study area

Illegal Dumping, Rag Picking and Recovery and Recycling of Generated Wastes

A common scenario in the open dump site was obnoxious odor at the surrounding environs. About 14 illegal dumping sites were found at the time of questionnaire and field survey (Figure 6a & 6b). The dumping sites were not very big in size but these were seen around the open places and beside the side of the roads as shown in Figure 7. Burning of wastes close to the container site of ward-41 was observed and the burning was a common solution for street wastes which was deteriorating the air quality and initiating many respiratory diseases.

Figure 6 (a, b) Illegal dumping sites of the study area

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 involved in collection of recyclable wastes. 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% total wastes) were collected by the rag pickers of the study area.

Collection and segregation of recyclable wastes were mostly conducted along with the waste collection and dumping. 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 there for their convenience. Ragpickers don’t return the remaining wastes to dust bin or containers after finishing picking recyclable materials.

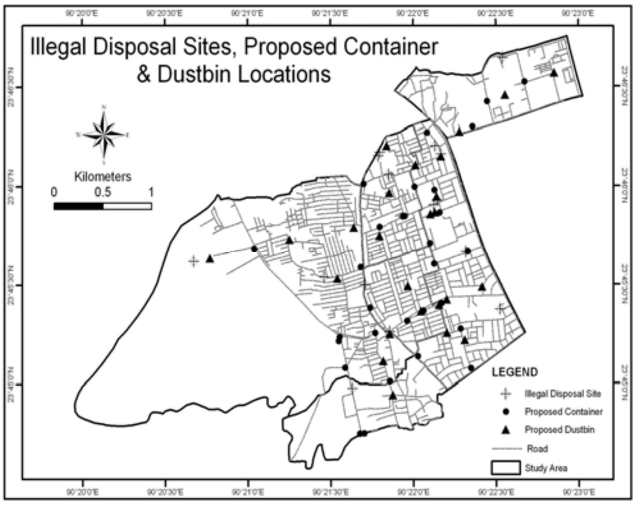

Figure 7 Illegal disposal sites, proposed container and dustbin locations of the study area

Waste Collecting Route Optimization with Proposed Waste Bin and Container locations

The waste collecting routes were proposed using GIS techniques. Present waste collecting routes and self-judgment were put into consideration at the route selection. 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 using network analysis and the routes suggested an overall two trips for each ward of the study area as shown in Figure 8.

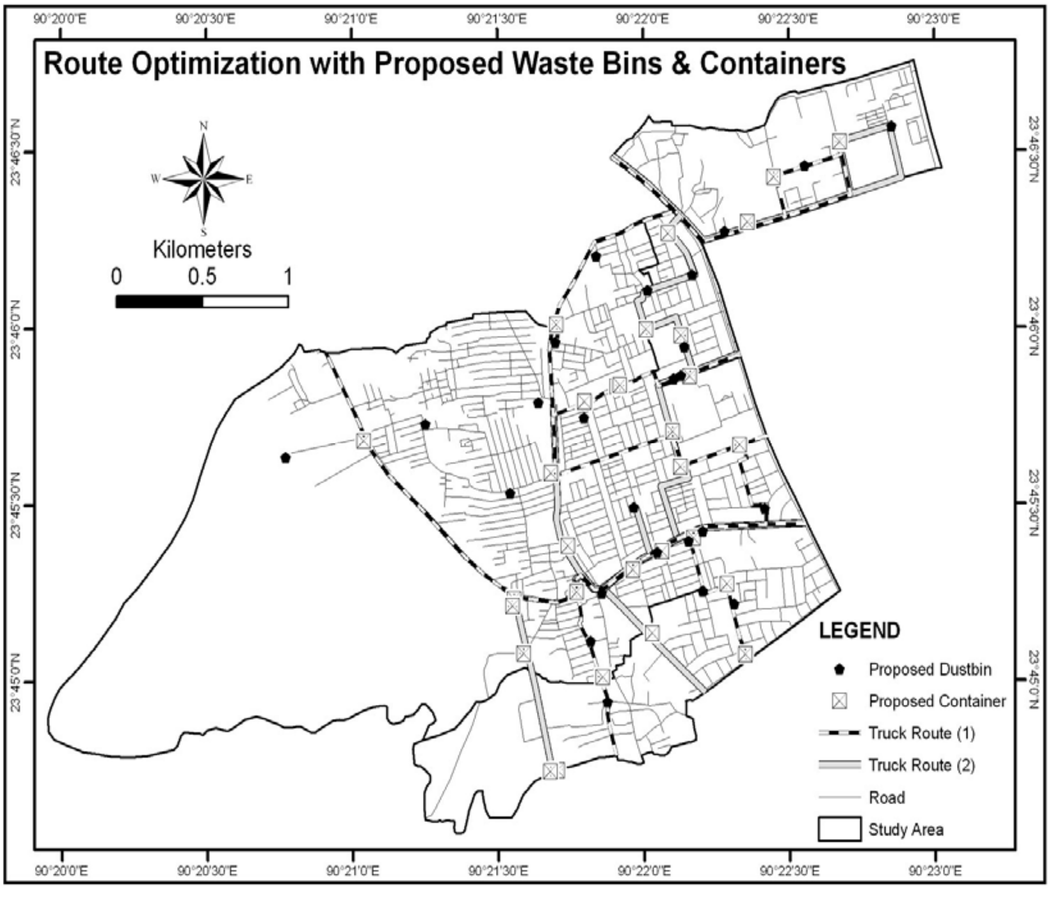

Figure 8 Route optimization with proposed waste bins and containers

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

CONCLUSIONS AND RECOMMENDATIONS

About 64% of generated SW had been collected by DCC with the existing bins and containers. The proposed bin and container relocations were suggested considering the existing number of bins and containers and another suggestion were made with 80% collection efficiency. Based on the present study, it was conducted that about 55% of recyclable wastes were collected by local ragpickers. In addition, this study also depicted that about five hundred people were directly involved with the rag picking and about 14 small illegal dumping site were found around the Mohammadpur Thana. A number of proposed bin and container with their locations and their optimized routes considering present illegal disposal sites were tried to delineate using GIS technique with its associated tools to achieve 80% waste collection efficiency. About 25 waste bins and 30 waste containers would be sufficient to achieve the 80% collection efficiency with reducing existing illegal disposal sites.

For an integrated approach, strategic SWM planning should be taken by the waste management authorities of DCC. Communal bins should be designed according to the waste generation and characteristics. The modified communal bins can help to minimize waste dumping as well saves collection and disposal cost. Lack of management information system (MIS) contributes to a complicated process of setting for proper waste storage, suitable routes assignment for trucks, etc (Mwakalinga, 2005). 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. Segregation of wastes at primary and secondary level at waste collection should be conducted at the study area. So, a Community Management Information System (COMMIS) should be built considering waste generation, collection and transportation (schedule, numbers of truck, etc). People's participation and technology should be incorporated for efficient SWM. GIS technique could be an efficient tools for constructing MIS, such technologies will be helpful for not only minimizing wastes but also to utilize the wastes in different ways. 3R (Reduce-Reuse-Recycle) campaign should be supported at all levels of the waste management and Clean development mechanism (CDM) should be incorporated in SWM model for waste minimization and proper utilization in Dhaka City.

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