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Municipal Solid Waste Management using GIS Application in Mirpur Area of Dhaka City, Bangladesh

Islam, S.M.D.*, Rahman, S.H., Hassan, M. and Azam, G.

Department of Environmental Sciences, Jahangirnagar University, Dhaka-1342, Bangladesh

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ABSTRACT: Identifying Municipal Solid Waste (MSW) disposal sites and appropriately managing them is a challenging task to many developing countries like Bangladesh. It is a complex issue in an urban area, as increasing population levels, rapid economic growth and rise in community living standard, accelerates the generation rate of MSW. The study area is zone-2 (Mirpur-Pallabi) of Dhaka North City Corporation (DNCC) (10.40 km^2) is a residential area, from where about 353.34 ton/day solid waste is generated and among them about 57.43% were managed by DNCC. There are 41 different size containers present at 17 locations in study area. The existing site and waste collecting containers are not sufficient, which deteriorates the environment due to illegal waste dumping and about 15 illegal dumping sites were identified. To identify proper waste dumping site and prevent contamination, Geographical Information System (GIS) was used to propose an efficient scenario with relocating the existing waste collecting containers and another scenario was proposed with number of containers (73) to attain an 93.68% waste collection efficiency including optimization and selection of waste collecting routes for the study area. This study also indicate that the application of GIS is an efficient and low cost tool to study and select appropriate dumping site so as to facilitate decision making processes.

Keywords: Dhaka North City Corporation (DNCC), environmental impacts, routing, waste collection, waste transportation.

INTRODUCTION

Waste is an unavoidable by product of human activities, economic development, urbanization and improving living standards in cities, have led to an increase in the quantity and complexity of generated waste. Rapid growth of urban population and industrialization in developing Asian countries in recent years has degraded the urban environment and places serious stress on natural resources, which undermines equitable and sustainable development. According to the United State Environmental Protection Agency (USEPA, 2005) solid waste is defined as any garbage, refuse, sludge from a waste water treatment plant, water supply treatment plant or air dried materials, including solid, liquid, semi-solid or contained gaseous materials resulting from industrial, commercial and agricultural operations and from community activities. Municipal Solid Waste (MSW) disposal has been enormous concern in developing countries due to poverty, population growth, urbanization and ineffectual fund (UNDP, 2004). MSW management is a big challenge due to number of problems including; inadequate management, lack of technology and human resources, shortage of collection and transport vehicles, and insufficient funding. Waste disposing is

* Corresponding Author Email: smdidarulislamju@gmail.com, Phone: +8801557300552

another important part of waste management system, which requires much attention to avoid environmental pollution. The most common problems associated with improper dumping includes; diseases transmission, fire hazards, odour nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (Basagaoglu *et al*., 1997; Mohammedshum *et al*., 2014). The effectiveness of solid waste disposal depends upon the selection of proper site and current global trend of waste management problems stems from unsustainable methods of waste disposal, which is ultimately a result of inadequate planning (Abbas *et al*., 2011).

Bangladesh is a developing country with rapid urban population growth in a limited land area. MSW generation is also increasing proportionately with the growth of urbanization. At present there are 522 urban centers including 254 municipalities and eight cities in Bangladesh (BBS, 2014). Among, Dhaka, the capital city of Bangladesh, is expanding with an enormous growth of population at a rate of around six percent a year. MSW are being generated at a faster pace, posing a serious management threat. Rapid growth of industries, lack of financial resources, inadequate trained manpower, inappropriate technology and lack of awareness of the community are the major constraints of solid waste management for the fast growing metropolis of Dhaka (Rahman and Rahman, 2009). The estimates for solid waste production for Dhaka city has varied in the range of 3500 to 4500 metric tons/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/day at present, and with a five percent growth rate of population, the city is apprehended to have a proportionate increase in solid waste generation (Rahman and Rahman, 2009). The issue of solid waste is not only because of the increasing quantities, but also largely because of an inadequate management system (Tinmaz and Demir, 2006). So, MSW management has its significance for Dhaka city.

Recently, there has been an increase in research that uses Geographic Information System (GIS) application as a tool for MSW management estimation and planning. MSW management practices require collection of decisive information which is for taking corrective measures as well as for proper planning to ensure sustainability (Ramachandra and Saira, 2003). Studies such as Chang *et al*. (2007), Sharholy *et al*. (2007), Wilson and Vincent (2008), Sumathi *et al*. (2008), Rahman and Rahman (2009), Nishanth *et al*. (2010), Khajuria *et al*. (2011) and Mohammedshum *et al*. (2014) described the role of GIS in solid waste management. Due to the rapid expansion of population and urbanization, it is badly needed to develop controlled solid waste dumping site to prevent contamination problems through illegal dumping. So, this study aimed to explore the current MSW management practice, including waste generation, location of waste bins, type and size of the bins. The study also propose the potential waste disposal sites with route optimization using GIS technique for better MSW management of Dhaka city.

METHODOLOGY

Study area

Geographically, the study area is located between 21º48´ and 22º50´ N latitudes and between 90º20´ and 90º24´ E longitudes (Fig. 1). The study area is in zone-2 (Mirpur-Pallabi) of Dhaka North City Corporation (DNCC), which cover five wards. The total area of the study area is 10.40 sq. km with 177332 no of households and 696835 no. of population (BBS, 2011; DNCC, 2015). The area is mainly a residential area and the solid waste mainly generated from domestic uses like; food and vegetables waste, waste paper, plastic, poly bags, metals, glass and wooden materials (Tania, 2014). Waste

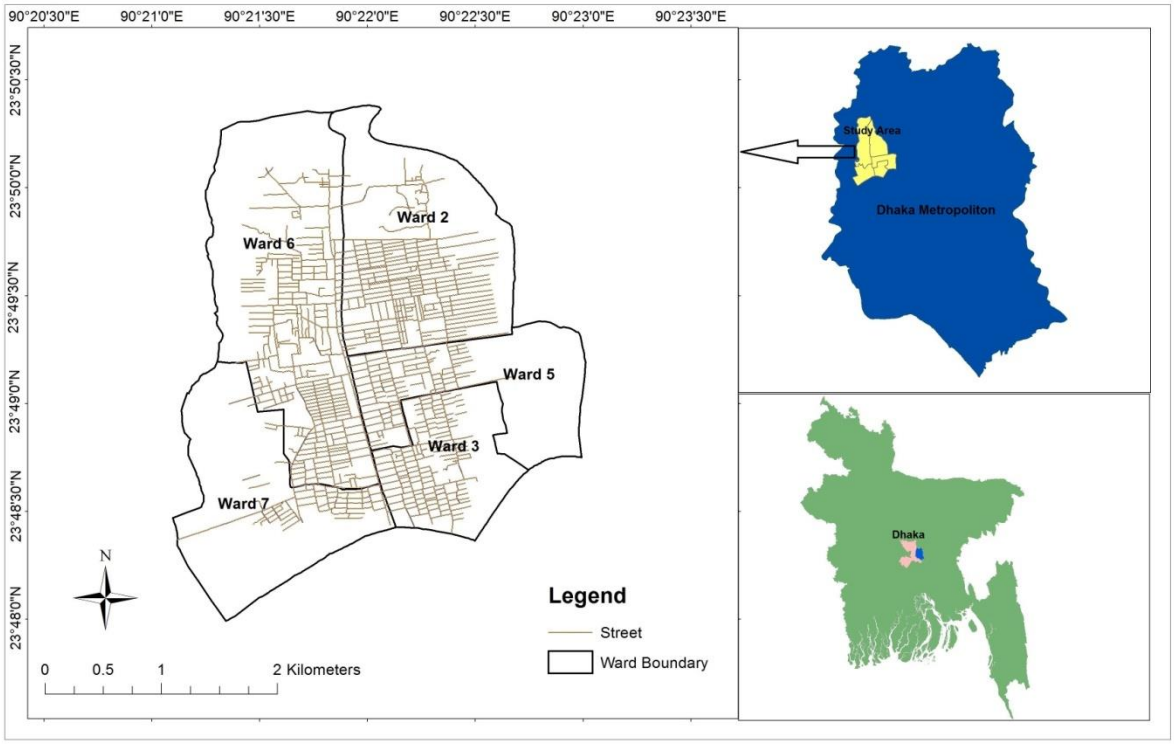

Fig. 1. Map of the study area

management department of City Corporation is collect, transport, and finally dispose in landfill site.

Data collection and analysis

The study uses both primary and secondary data. Primary data about the MSW of study area were collected through key community interview and Global Positioning System (GPS) survey. The exact location of the waste bins and illegal waste disposal sites were collected by using GARMIN handheld global positioning system (GPS). Preparation of thematic maps includes the digitization of collected secondary data. Spatial data were generated using collected GPS data using Google Earth Images. An amount of secondary data about MSW management associating other relevant information, like demographic and economic status was collected from various Non-Government and Government organization. The information of different types and forms has converted into the GIS database. GIS software (ArcGIS 10.1) with its network analyst extension was used to recommend waste bins location, optimization of the route and for the preparation of final maps.

RESULTS AND DISCUSSION

MSW generation, composition and characteristics

The composition and the quantity of MSW generated the basis on which the management system needs to be planned, designed and operated (Sharholy *et al*., 2008). The amount of waste generated and its composition, varies from country to country depending on the socio-economic situation, industrial structure, waste management regulations as well as life style (Nasrin, 2014). Characterization of waste is important to determine its possible environmental impacts (Hai and Ali, 2005). Per capita waste generation would obviously depend on a number of socio-economic parameters affecting consumption and other

behavioural characteristics. A survey has been conducted to determine the composition of solid waste generated in the city. The results from the survey revealed that the MSW generation rate is 0.46 kg/capita/day. It was estimated that about 353.34 tons MSW were generated per day in the study area (Table 1).

Table 1. Total waste generation of the study area per day

`	Households	Population	Generation rate (kg/capita/day)	Total waste generation (tons/day)
Mirpur-Pallabi (Ward No. 2, 3, 5, 6 and 7)	177332	696835	0.46	353.34

Table 2. Total waste generation and its distribution by source

Solid waste generation (ton/day)	Contribution of different sources (%)				
	Residential	Commercial	Industrial	Hospital	Street
353.34	61.00	23.00	12.00	2.00	2.00

Source: DNCC (2015)

Municipal solid wastes in the study area are mostly generated from residential (61%), commercial (23%) and industrial (23%) sources. Also a portion of wastes comes from street sweeping (Table 2). Hazardous wastes from industries and hospitals are frequently mixed with municipal wastes, which in turn are poorly collected and disposed, thereby creating public health hazards. As the area is mainly a residential area, the solid waste mainly generated from domestic uses like; food and vegetables waste, waste paper, plastic, poly bags, metals, glass and wooden materials. It was found that the wastes of the study area were composed of 82% food wastes, 6.5% paper, 3.5% plastic and polythene, 3% wood and leaves, 0.4% glass and ceramics and 4.6% other wastes (Table 3).

Current MSW management practice and dumping sites

Dhaka North City Corporation (DNCC) is the only formal organization responsible for collection, separation and disposal of solid waste in the study area (Fig. 2). Usually the households bring their refuse to the nearby communal bins or containers located on the street side, while in some specific areas there is a system of house to house collection of garbage with the initiative and efforts of the community. These collected wastes are deposited in the bins on some convenient spots of the streets. The household, commercial, institutional and medical wastes are deposited in the same waste collection bins located on the streets.

Table 3. Solid waste composition of the study area

Waste composition	Percentage (%) by weight
Food wastes	82
Paper	6.5
Plastic and polythene	3.5
Wood and leaves	3
Glass and ceramics	0.4
Others	4.6

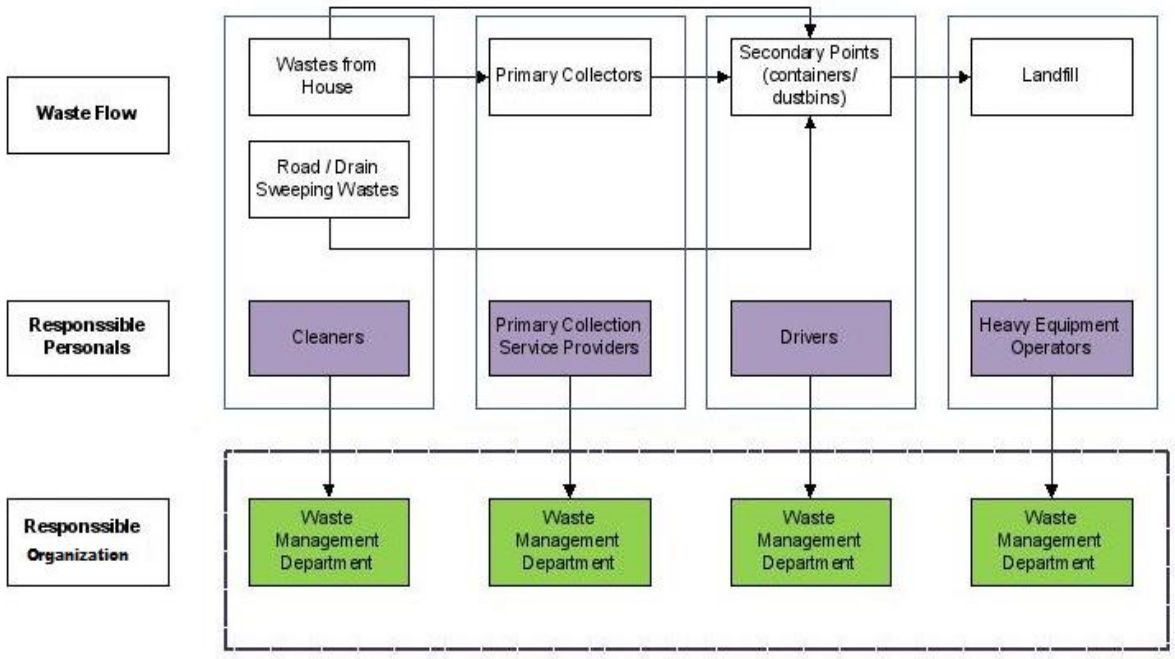

Fig. 2. Waste management system by DNCC

There are 41 different size DNCC containers in 17 location of the study area which its capacity is about 203 tons (Table 4). The existing waste bin and containers can hold about 57.43% generated waste of the study area. Rests of the waste (42.57%) are dump illegally here and there. The current locations of waste bin with illegal dumping site are shown in Figure 3.

Street sweeping is done manually and debris is loaded from the curbside into the hand trolleys and delivered to the collection bins. About 340 DCC sweepers and cleaners sweep roads and clean drains and then dump the waste into nearby dustbins or containers using hand trolleys in the study area. The whole system, however, does not operate in an environmental friendly manner. House-to-house waste-collection service has been launched in residential areas. It is operated by Community Based Organizations (CBOs) or through private initiatives. The households are charged on the basis of the collected amount. Rickshaw vans are used to transport the waste from the houses to municipal waste bins or containers.

Table 4. Total waste collection from the waste bins and containers of study area

Mirpur-Pallabi (Wards)	Capacity (tons) × No. of containers	Total No. of containers	Total waste collection (tons)
2	5×4= 20	4	20
3	5×8=40 3×3=9	11	49
5	5×5=25	5	25
6	5×9=45 3×4=12	13	57
7	8×4=32 5×4=20	8	52
Total		41	203 (57.43%)

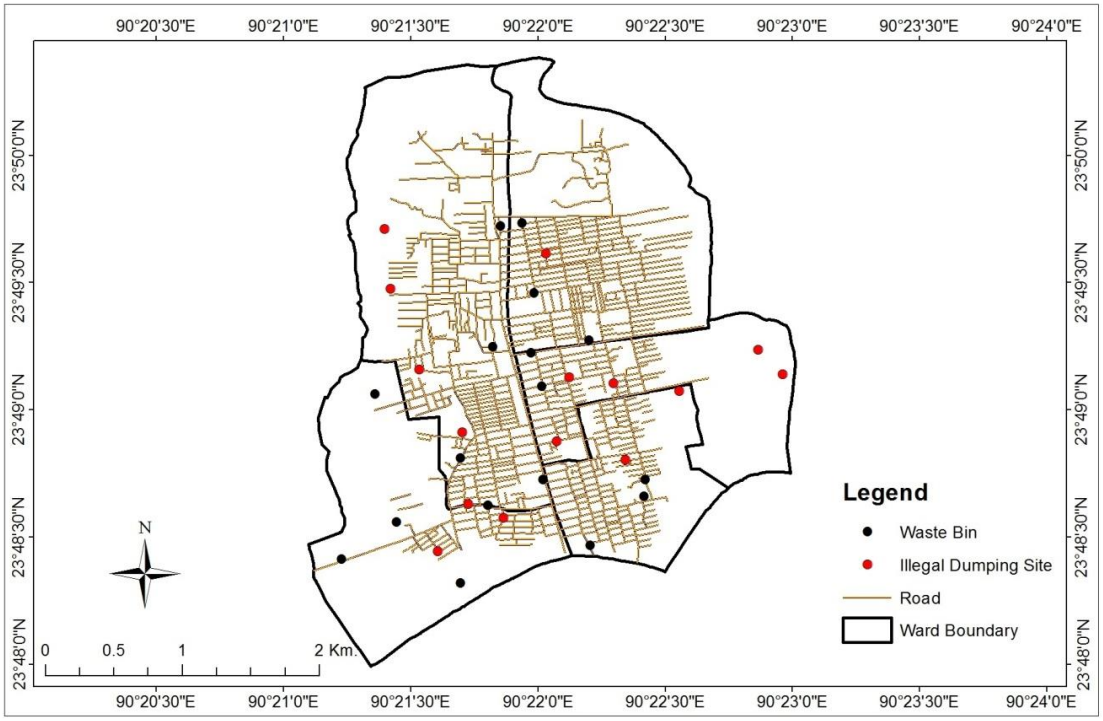

Fig. 3. Current locations of DNCC waste collecting containers with illegal dumping sites

The solid wastes collected from five wards of the study area were mainly disposed down to the Amin Bazar landfill sites. From the DNCC statement, seven trucks of different capacity collect wastes from the study area for disposing to the Amin Bazar landfill site at different trips. The Amin Bazar waste dumping site is situated within the low-lying floodplain of the Karanachhali River in Savar, Dhaka. The area is located at 23º47'48"N and 90º17'50"E. Dhaka-Aricha Highway is used to access the site. This is a 50 acres semi-aerobic landfill site which facilitates rapid decomposition of waste.

Illegal dumping and its effects on environment and health

The solid waste management system in the study area is not well organized. About 15 illegal dumping sites were found in the study area during questionnaire and field survey (Fig. 3). The disposal of municipal solid waste by the roadside in the study area has negative impacts on the general environment. Improper solid waste management in Dhaka city and blockage of drains can lead to increased flooding attacks every year and induce malaria which is a cause of child mortality every year (Menon, 2002). Uncollected solid wastes diminish aesthetic and causes unpleasant odour and irritating dust. The most obvious contamination of land in the study area is caused by illegal dumping of waste and these contaminations diminish the civic pride and lose property value of that area. The infiltration of rainfall or surface water in solid waste dumps can produce leachate which enters surface or ground water and causes severe water pollution (Tauhidur-Ur-Rahman, 2006).

Human health risk ascends from the improper MSW management. Human fecal matter is present in every solid waste system in developing countries due to lack of a proper sanitation systems or onsite septic systems which create a variety of insects and spread diseases such as cholera, malaria, and dengue. Using water polluted

by solid waste for drinking, bathing, washing and cooking purposes exposes individuals to different disease organisms and contaminations (Nasrin, 2014). A research project by the U.S. Public Health Service classified 22 human diseases which are connected to improper solid waste management (UDSU, 1999). Ahmed and Quader (2011) reported that, Bangladesh is facing public-health risk such as, asthma, diarrhea and even skin diseases etc. due to uncollected disposal of waste on streets and other public areas, drainage congestion by haphazardly dumped wastes and contamination of water resources near uncontrolled dumping site.

Selection of optimum number of waste bins and locations

Dhaka city saw the importance of utilizing GIS in determining optimum locations of solid waste collection places at the neighborhood level since 2004. The ultimate goal was to find out the suitable location of waste collection points in order to improve the MSW system of the community (Anwar, 2004). GIS as a tool was used in the analysis of the existing situation and then selected some suitable locations and required number of the waste bins in the present study area. This situation assisted to improve the service efficiency. Determinations of required number of waste containers were done based on the population of each ward and the capacity of each container. As the waste containers were needed for primary and emergency collection, about 93.68 % waste collection can be achieved with increasing number of waste containers as presented in Table 5.

Table 5. Total waste collection by proposed waste containers

No of location	No of container	Capacity (ton)	Total Waste Collection (tons)
23	23	3 tons	69
	46	5 tons	230
	4	8 tons	32
Total	73		331 (93.68%)

Determinations of suitable locations were done to avoid situations where a collection point generated would not be viable due to constraints such as legal or environmental. This is a challenge that involves determining the best location of facilities based on criteria like optimum distance, capacity of facility, population density, optimal cost and so on. In this case, the demand points (households) and the proposed points were used for analysis. The proposed locations were analyzed with network analysis and the overall coverage of the study area with the existing containers has been proposed. The waste containers locations were modified with analyzing route optimization and concerning final disposal site of wastes as shown in Figure 4. The result was a spatially balanced set of points that could adequately serve the whole population. The collection time would be reduced and the route selection would be more optimum for the final disposal.

Waste collecting route optimization

Using GIS, solid waste collectors can solve fundamental problems in solid waste management such as determining the distribution of waste generation in an area and the optimal route for disposal. This can be achieved by considering factors that affect selection of disposal sites such as topography, geology, settlements, land use, water bodies, and road networks (Ntarangwi and Odera, 2015). Figure 5 presents the new two waste collecting truck routes which were selected by considering present waste collecting routes and self-judgment based on proposed container

locations, and about 95% of the study area would be covered with the proposed container locations. Optimization of solid waste collection routes in urban area is important where significant amount of the time is spent loading and unloading as well as driving. It reduces the collection time, cost and air pollution emission.

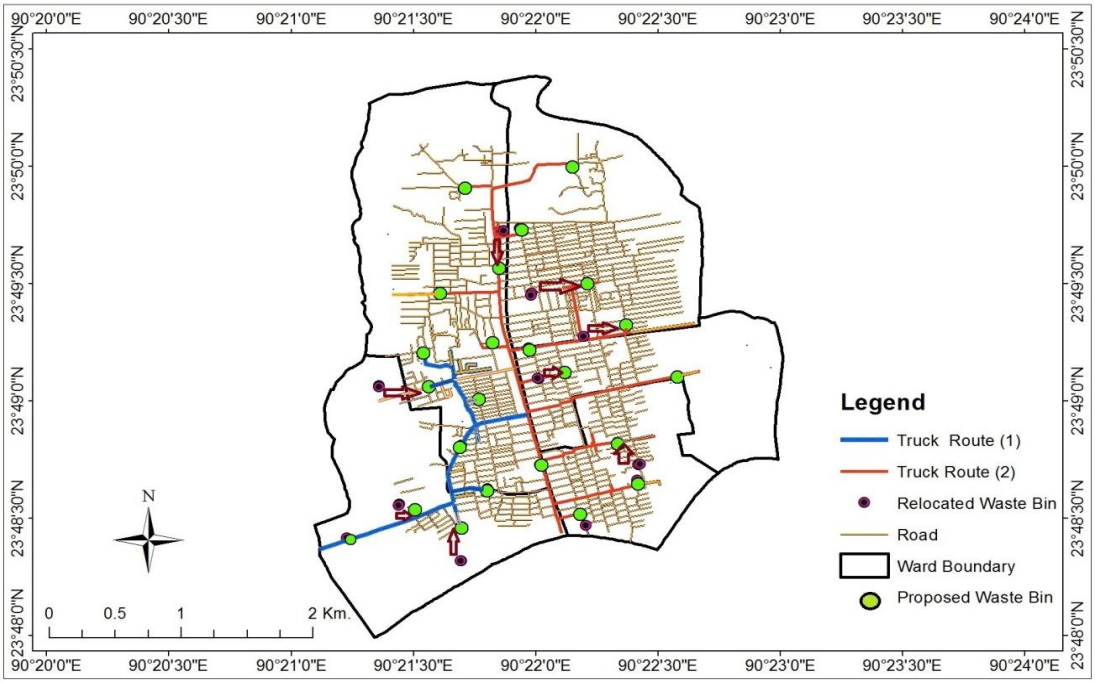

Fig. 4. Existing and proposed relocation of waste containers and bins of study area

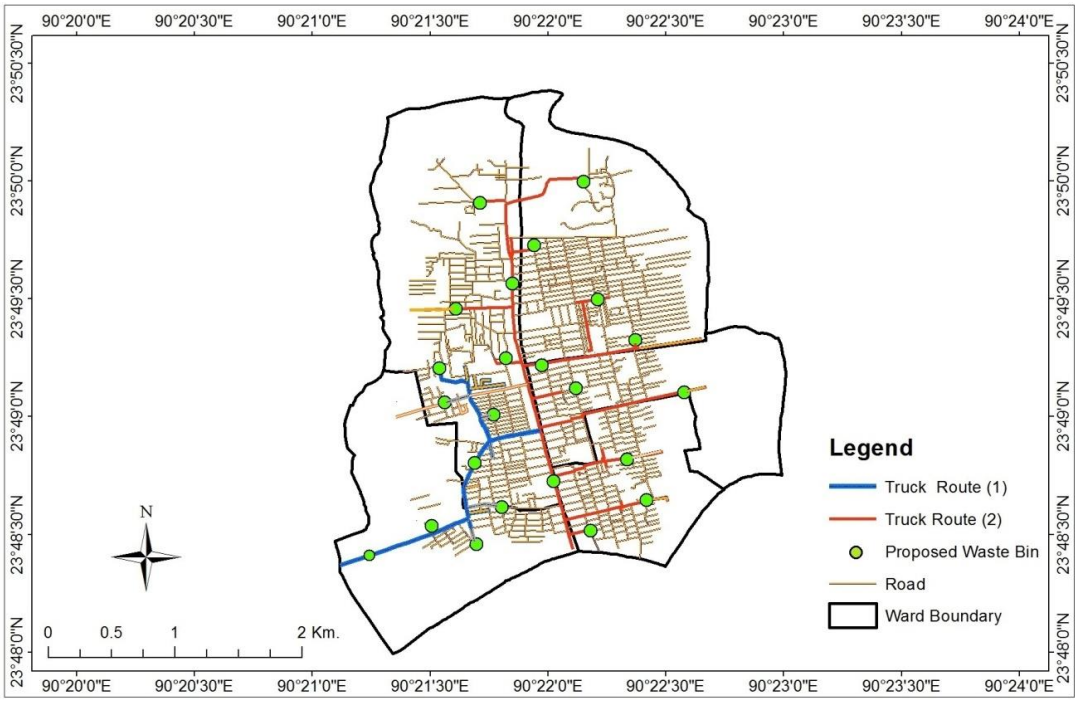

Fig. 5. Route optimization with proposed waste containers

Existing policy and legislation for waste management in Bangladesh

At present there is no separate policy or handling rules for MSW management in Bangladesh. There is no adequate legislation in the country to address the growing problems of solid waste. The six City Corporation Ordinances and Pourshava Ordinance 1977 are the only local law that gives some idea about disposal of municipal waste. According to DCC (Dhaka City Corporation) Ordinance 1983, amended in 1999, Article 78, the DCC is responsible for the disposal of solid waste from bin to disposal site and for cleaning the roads and drains. Ministry of Environment and Forest is currently preparing a comprehensive solid waste management handling rules for the country. Under the Environment Conservation Rules, 1997, which promulgated in furtherance of the objectives of the Environment Conservation Acts, 1995, all municipal land fill sites as well as installation of any kind of incinerators fall within red category and environmental clearance from DoE is mandatory (Rule 7. and Schedule 1 of the Rules). National Environmental Management Action Plan (NEMAP), 1995, is a plan of the Government of Bangladesh (GoB), prepared by the Ministry of Environment and Forest (MoEF) in consultation with people from all walks of life. NEMAP has recommended for actions in the areas of sanitation, solid waste management, water supply, environmental awareness, and etc. Waste concern is promoting 3R, under the Sustainable Environment Management Programme (SEMP) of NEMAP (GoB, 1995). Urban Management Policy Statement, 1998, prepared by the Government of Bangladesh, considers the interest of providing economic, efficient, and reliable services; municipalities shall endeavor to contract out solid waste disposal, public sanitation, drain cleaning, and road maintenance (GoB, 1998a). National Policy for Water Supply and Sanitation, 1998, prepared by the Local Government Division of the Ministry of Local Government Rural Development and Cooperatives gives special emphasis on participation of private sector and NGOs in water supply and sanitation in urban areas. Under this policy, Local Government Bodies (City Corporations and municipalities) may transfer, where feasible collection, removal and management of solid waste to the private sector (GoB, 1998b). Under National Sanitation Strategy, 2005, resource recovery and recycling have been given as top priorities to improve urban sanitation situation instead of disposal. Under Dhaka Environment Management Plant, 2005, waste recycling has been promoted, less land filling encouraged, EMS promoted among industries.

CONCLUSIONS

DNCC is unable to offer the desired level of services with the existing capacity and trend of waste management in study area. About 57.43% of generated MSW had been collected by DNCC with the existing waste containers. In this situation, the application of GIS was used to study the potential solid waste disposal site. The proposed waste collecting containers relocations were suggested considering the existing number of containers for the collection of 93.68% MSW and optimum route for waste transport facility; and another suggestion were made with 93.68% collection efficiency. GIS technique could not be used for minimizing the wastes. So, properly follow the existing laws and regulations and people's participation for implement 3R (Reduce-Reuse-Recycle) should be incorporated for efficient MSW management.

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