M. Alamgir, I.M. Rafizul, S.M.T. Islam and M.H. Hasan (Eds.)
ISBN 978-984-34-2306-1

Proceedings of the WasteSafe 2017 – 5th International Conference on
Solid Waste Management in South Asian Countries
25-27 February 2017, Khulna, Bangladesh

VEHICLE ROUTE OPTIMIZATION AND EFFECTIVE WASTE COLLECTION PROCESS IN KHULNA CITY: CASE STUDY ON KHALISHPUR THANA

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ABSTRACT

Over 1.4 million people are residing in Khulna metropolitan city within 47 km^2. According to Khulna City Corporation (KCC), on an average of 475 tons of waste is generated per day, waste is removed two times a day, masonry collection point is nearly about 1200, there are another 150 larger collection points around the whole metropolitan area. Average compostable portion of the waste in KCC area is estimated as 78% while the non-compostable portion is 22%. The idea is to fit 78% compostable waste, which is about 370 tons/day. Solid Waste Management (SWM) is a noteworthy procedure where waste collection process plays a vivacious role in progressive metropolitan city like Khulna. Solid waste (SW) collection reflects the quality of life of that city or community. Around the city overall waste collection process is managed by Khulna City Corporation (KCC). This research contains computation of a possible amount of wastes generating in every neighborhood and plan and Software based monitoring of a collection process bringing all the neighborhood throughout whole Khalishpur area in an eco-friendly manner under SWM. Optimized routing for collector vehicles to provide services most of the part of city and dumping or reusing by further processing of these solid wastes. In this research, Geographic Information System (GIS) based time efficient and cost effective route had been executed from door to door daily waste disposals to larger dumping stations of all forms of waste collector vehicles throughout whole Khalishpur area in an eco-friendly manner. The software (GIS) was used to determine optimal routes for small collection groups and outlines the workflow and best practices for future analysis.
***Key words**: KCC, SWM, GIS, compostable waste, eco-friendly, dumping station.*

INTRODUCTION

Solid waste management on transportation sector has got significant priority in developed countries rather than developing and underdeveloped countries like Bangladesh (Hadia and Misty 2015). Waste generation is a daily issue either in urban cities most significantly from residential units or manufacturing and processing based industries. The amount of waste generated in urban areas basically depends upon numerous factors such as characteristics and degree of commercial and industrial activity, animal husbandry, living standard and food habit of the locality of public in a certain area. Wastes are generally categorized as household, commercial and industrial waste. About 380 metric tons of solid waste generated in 1998 and by 2020 it would be around 922 metric tons (Roy 2011). Waste management is highly dependent on conveying from generation points to the final disposal point at Rajbandh landfill area is located at a distance of 9 kilometers from city center (Ahsan et al. 2009). KCC is the sole authority to manage the whole metropolitan area municipal waste. KCC and community based NGOs-CBOs are looking after of 60% of total where the remaining wastes are untreated (KCC 2010). On this basis, the amount of SW generated in Khulna city is about 0.3 Kg per capita/day where according to (KCC Year book 2000), per capita / day waste carried out to the final dumping site is about on an average of 0.2 Kg. The rest 0.1 kg (average) amount of waste are remain left in the dustbin where most of them are unlocated inside the residential area including some drop off from the conveying trucks because of inattentiveness of the operating and collecting staffs (Ahsan

et al. 2009). Waste collection process is maintaining so called antique technique followed by some man pulling van and trucks. There is no appropriate evidence of solid waste generating in transport sector in Khulna city as both waste generation and transportation are not considered seperately (Hadia and Misty 2015). Collection/transportation system for SW in an optimized way is very problematical task for a planner to do manually as it comprises of a number of selection measures (Kallel et al. 2016). No universal standard was found for relocating the waste bin over or optimizing the routes and collection services depend on the local conditions such as one-way streets and road construction (Malakahmad et al. 2014).

STUDY AREA AND CONTEXT EVALUATION

This research has been conducted to promote GIS based solution to optimize the waste collection process in KCC. To evaluate the current situation Khalishpur Thana consisting of 10 wards has been selected for this study purpose to validate the process according to the context. As being KCC, the sole authority dealing with waste collection and transportation system, has been following the traditional method from residential, commercial units through pulling carts and collector trucks. Besides, there are 3 - 4 NGOs are working seperatedly depending on the conciousness of the local authorities (Field survey 2016). Almost all the city corporations and municipalities have no distinct department for SWM and that is organized and run by conservancy section of the urban local organizations (DOE 2004). “Most cities and towns are already over-burdened, and simply cannot meet the growing demand for municipal services, resulting in unhygienic and filthy living condition in the neighborhoods” (Enayetullah et al, 2005). Approximately 64 ton/day SW is being generated from Khalishpur Thana and due to improper management, lack of resources and during unpleasant cilmatic condition door to door waste collection is being hindered. Analyzing GIS based Detailed Area Plan 2014 data, over 64% area is surrounding as residential units where commercial and manufacturing processing zones are covering 9.24% and 9.86% respectively in Khalishpur Thana.

ISBN 978-984-34-2306-1

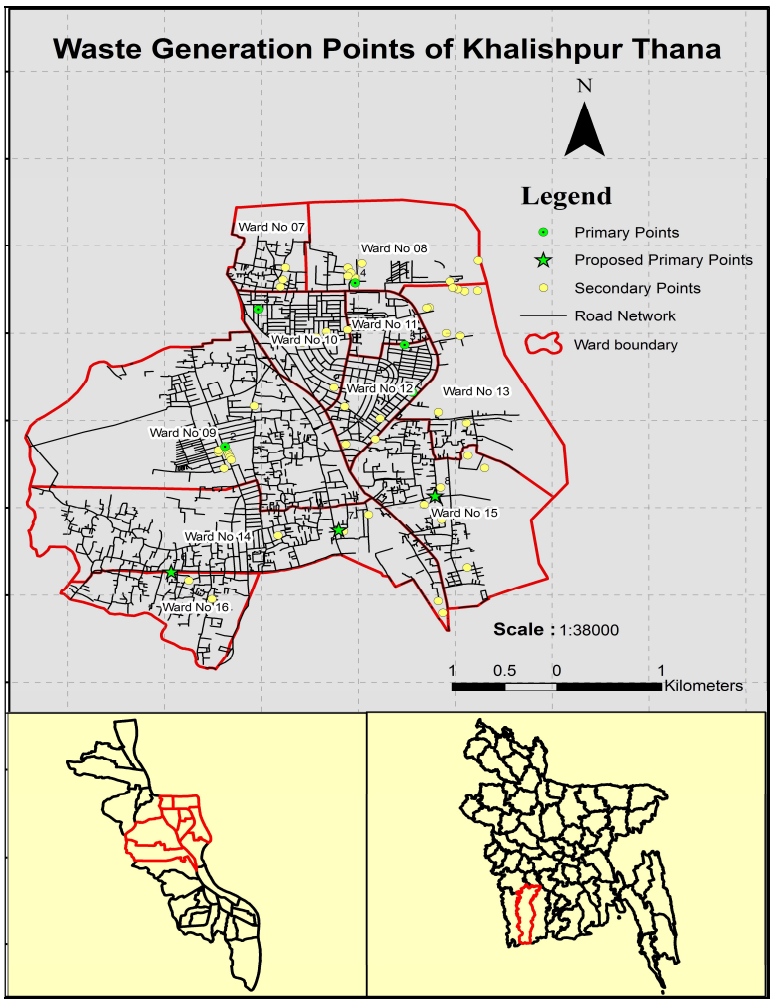

Figure 1: Map of the study area

METHODOLOGY AND TOOLS

The strategy of the proposed analysis is locating a standard sized 1100 litre community dust bins and optimized collection process based on GIS technology as it has become an effective mean to import, manage and analyse spatially based data (Chalkias and Lasaridi 2009). Two basic procedural steps have been followed: assembly and design of spatial data in geodatabase and analysis of the results including secondary information of the locality (Kallel et al, 2016). To manage the unplanned scenario routing for efficient SW collection is performed following Network Analyst tool in ArcGIS 10.1.

Data Assortment and Spatial Database (SDB) Preparation

Both primary and secondary data have been gathered and articulated to generate the SW quantity produced by each wards and collection process in an effective manner. Field survey has been conducted to evaluate and validate the secondary sources. Community disposal point identification, pulling carts collection process, focused group discussion with local residents, NGO officials and daily labors had completed the primary data collection process. Spatial GIS based data such as road network, ward boundary, local disposal points, Satellite Image have been obtained from government and non-government bodies. Wardwise population data, SW density have been retrieved from population census, research paper and journals.

The following data have been processed in suitable forms (vectors, tables and raster) using the software ArcGIS 10.1. To perform analysis, store, query, and manage both spatial and nonspatial

ISBN 978-984-34-2306-1

data a file geodatabase has been created. Spatial data and attributes have been organized and stored in geodatabase.

Reallocation of Community Waste Bins

According to Detailed Area Plan (DAP 2014) of Khulna City, there have been 60 places found as waste disposing points around Khalishpur Thana. No proper prerequisites have even been taken to dispose the wastes which remained uncovered and exposed on the roadside. Severe environmental degradation and public-health risk due to uncollected dumping of waste on streets and off-streets, blocked drainage system by indiscriminately dumped wastes and by contamination of water resources near uncontrolled dumping sites (Bahauddin and Uddin 2012). To overcome the unplanned disposal and collection system, possible approach to has discussed in this paper to locate 8 major disposal points termed as secondary points from the existing 60 primary locations. To ensure daily waste collection and transportion in time and cost effective manner relocating the secondary points to convey SW from primary locations through current transport resources such as pulling carts and trucks.

Routing – Network Analysis (NA)

To perform study over network based problems, ArcGIS NA is a user-friendly powerful modelling package that has been utilized to get the most efficient route solutions (Kallel et al. 2016). The optimal path searching procedure is followed by Dijkstra's algorithm (Chalkias and Lasaridi 2009) which solves the problem of selecting the best possible route based on a nonnegative weighted undirected graph in a reasonable computational time (Kallel et al 2016). Main objective of the process is to build a cost matrix containing costs (length) between origins and destinations and these points correspond to pairs of vehicle stop point (location of the bins).
In ArcGIS NA, according to the distance and time criteria where total travel time is the sum of the vehicle operating time and the time of waste loading/unloading feasible routes can be calculated. Multi factors depending on the scenario can be set by the user and can be modified according to the context. Several solutions can be attained with modifying attributes of the parameters. The shortest distance, the road network, optimized route considering historical barriers, restrictions and social and environmental implications lead the solution following the analysis procedure.

RESULTS AND DISCUSSION

Ward Wise Waste Generation Scenario:

Ward wise daily waste generation has been calculated multiplying generated waste per person and individual ward population. In KCC, daily waste generation rate per person is 0.27 kg/capita/day (Eftekhan Enayetullah 2005). About 64 ton solid waste is being generated from 10 wards locating Khalishpur Thana. Each ward is having individual characteristics in terms of land use, most of them are residential but ward 7 and 8 have major portion of industrial units. The research basically concerned with residential solid wastes. Wastes are being dumped daily at 60 spotted disposed locations around Khalishpur but the collection process from different units varies upon the individual local authority's activity and intervention of different NGOs. City Corporation trucks maintains the collection from scattered disposal points in an unorganized manner where some secondary and minor disposal points being ignored on daily basis (Field survey 2016).

Determination of Required Waste Bins

First step of door to door waste collection and convey it to the secondary disposal points have been performing by workers guided by ward wise local authority and NGOs. This management process includes installation of proper amount primary waste bin to cover the daily domestic waste. The number of primary waste bins required is proportional to the daily production of waste (Kallel et al. 2016). The number of waste bin can be calculated following this equation:

$$Number\ of\ waste\ bins = \frac{Total\ waste\ generated}{SW\ density * Container\ capacity} \quad (1)$$

SW density is also called collection point density of residential areas in Khulna City is 0.299 Ton/ m^3 and available waste bins are not very similar in size, shape or capacity. Following the standard size of waste bin about 1100 liter or 1.1 Ton capacity for residential areas (Eftekhan Enayetullah 2005) the required bins are calculated.

Table 1 Ward wise waste generation scenario and required bins

Ward No.	Population	Waste generation (Ton/capita/day)	Required bins
Ward No. 7	14808	3.99	12
Ward No. 8	18545	5.01	15
Ward No. 9	34614	9.35	28
Ward No. 10	18518	4.99	15
Ward No. 11	19398	5.24	16
Ward No. 12	52036	14.05	43
Ward No. 13	19959	5.39	16
Ward No. 14	26444	7.14	22
Ward No. 15	25724	6.95	21
Ward No. 16	4972	1.34	4

Source: (Author's created)

The available dumping points have no such organized facility and standard sized waste bins. Although 60 locations spotted for disposal points, very few of them have some barrels or containers and at some primary points there are a large broken triangular shaped metal storage from where trucks generally collect the SW. To maintain eco-friendly waste management process, suitable amount of waste disposal points facilitated with well-equipped waste bins should be provided under concerning City Corporation of all metropolitan areas.

Proposed Primary Locations

According to DAP 2014, there are 60 dumping locations surrounding Khalishpur Thana and 5 of them are primary and remaining are secondary disposal points (Field survey 2016). On an average of 0.1 kg amount of SW are remain untreated in the dustbin and some drop from the open truck while conveying to the final dumping site because of inattentiveness of the operators (Ahsan et al. 2009). Ward wise SW is being collected from the residential households through pulling carts, vans to the secondary and primary points. Some of the garbage disposal points are not located because these are created due unconsciousness of the dwellers. Local residents said that lack of door to door waste collection practice is not maintained strictly, so they throw away the garbage to nearby open spaces. Moreover, KCC trucks basically covers roadside 1200 masonry points situated on the major roads (Ahsan et al. 2009). As a result, wastes generated inside the residential area which are not conveyed to the primary points are being dumped in the nearby river or canals. Designing 3 secondary points to primary points in the residential areas showed in Figure 1 which can mitigate the untreated SW amount immediately. Accessible routes regarding the proposed primary points have been formulated that will eliminate fuel consumption and collection time for the trucks. Van, pulling carts will carry out wastes from the secondary and unlocated points to the primary points which will maintained by concerning local authority and NGOs ward wise.

Optimized Routes and SW Collection

Performing analysis regarding 5 available primary disposal points and 3 proposed primary points, four trips are required in regular basis to collect about 64 ton waste by the available two TATA trucks according to the one of the KCC personnel (Field survey 2016). He also added that "although the capacity of each truck is about 7-8 ton but it carries 10 ton maximum amount of SW in regular manner with compaction." As a result, to design the alternative routes the capacity of the truck is considered 10 ton and all 8 primary points will be covered to convey 64 ton SW. There are numerous number of alternative routes to collect the SW but the efficient and optimized route should consider minimum trips and less consumption of fuel and time. The collection process of the trucks begin from KCC and the optimum amount of trips required are four to collect all the SW from Khalishpur Thana to the final disposal point situated from 9 km distance at Rajbandh have been calculated. Trip 1 will start from

ISBN 978-984-34-2306-1

collecting ward no 15 and conveyed to the disposal point through ward 14 has showed in Figure 2. Then, trucks will continue the process for Trip 3 and 4 entering through ward no 14 and then to the final disposal points. All 8 primary points will convey 64 ton of SW from the four trips. But current scenario includes all the secondary points which is fuel and time consuming and not efficient. Following the method considering the current context will be more sustainable referring to the other developed and developing countries.

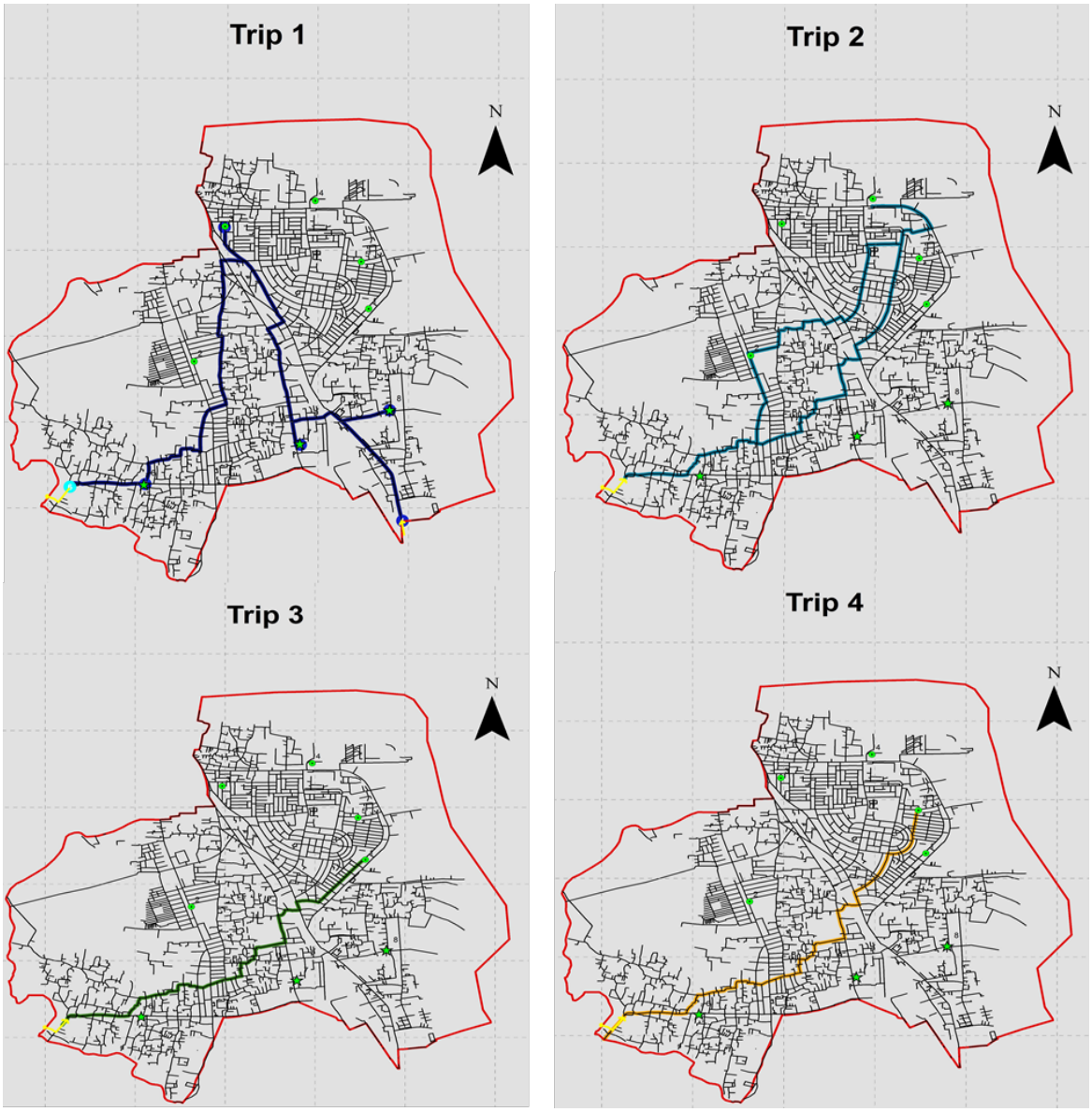

Figure 2: Optimized routes for SW collection process

LIMITATIONS AND CONCLUSION

The study is performed which includes 10 wards of Khalishpur Thana, so determination of number waste bins, the origin and destination points of optimized routes have been performed for the certain portion of KCC. The authority relating waste collection process KCC could not able to provide the precise information about the total consumption of fuel amount by the trucks, so cost is not considered in terms of determining the optimal routes.

In this study, an optimization was developed using the ArcGIS NA tool in order to improve the efficiency of the collection and transportation of waste in the Khalishpur Thana. Results indicate that the outcoming scenario is more competent in terms of travelled distance and collection time of SW. These savings are highly related to a lesser amount of fuel and time consumption (Chalkias and Lasaridi 2009). Wastes are collected three or hardly four times a week, but it basically covers the primary dumping stations. As a result, a certain amount of SW are being left mistreated which creates pollution in the environment from different aspects.

GIS technology has become popular in different sectors in our country in recent years. As a waste collection process with tool optimization, NA not only capable of measuring spatial, qualitative and quantitative changes but also help as guiding force in decision making. Following the method, future work should emphasize on sectorization of wider waste collection areas. (Chalkias and Lasaridi 2009) Consideration of financial and environmental cost while optimizing the routes and setting up collection points will pave the way implementing the method in sustainable manner.

ACKNOWLEDGEMENT

We are expressing our heartiest gratitude to Javed Hossain who is one of the active members working with “Shotota-Shopno” NGO in Khalishpur Thana for all information. We are thankful to the local people and KCC who provide us the valuable information about waste generation process to come through the solution.

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