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Planning a Municipal Solid Waste Transportation System Using GIS

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Abstract

Fast urban development has carried with it an inescapable issue of metropolitan strong waste administration. A significant part of absolute consumption on strong waste administration (SWM) is spent on assortment and transportation of waste. Improvement of course is consistently a difficult undertaking for city organizers. Geological Information System (GIS) is a significant instrument to take care of the issues of waste transportation from assortment to landfill site dependent on least expense. The cost factor is influenced by the work cost, vehicle cost, time, separation and sort of street among others. ArcGIS programming might be utilized for digitization of spatial information in GIS condition. System Extension module is utilized for finding the course with least expense. The proposed strategy can be utilized as an apparatus by urban nearby bodies to make work plan for effective assortment of strong waste. This strategy has been approved for the city of Varanasi (India). It is seen that the current waste stockpiling and assortment framework in Varanasi is deficient and spontaneous. An underlying venture of approx. Rs. 76.45 million is assessed for development of waste stockpiling and transportation framework and roughly Rs. 52.40 million is required per annum for dealing with these two administrations productively.

Keyword: *Municipal solid waste, GIS, waste collection, transportation, route planning, optimization.*

I. Introduction

The management of municipal solid waste (MSW) is a high priority issue for many communities throughout the world including India. Problems of solid waste management are growing with rapid urbanization and change in the lifestyle of the people. The situation is becoming critical

in many cities with the passage of time. A World Bank report estimated that in the year 2000 urban India produced approximately 100,000 metric tons of MSW daily or approximately 35 million metric tons of MSW annually (Hanrahan et al., 2006). Various studies reveal that about 90% of MSW in India is at present disposed off unscientifically in open dumps and landfills, creating problems to public health and the environment (Kansal, 2002; Rathi, 2006; Sharholy et al., 2008; Ohri and Singh, 2011). Most of the municipalities are currently unable to fulfill their obligation to ensure environmentally sound and sustainable handling of solid wastes in terms of collection, storage, transportation, treatment, and disposal. To improve upon the situation and develop a proper infrastructure for SWM, Government of India sanctioned 2500 Crores (approx. US$500 million) exclusively for solid waste management from the 12th Finance Commission grants. Starting from December 2005, it has also earmarked Rs 100,000 Crores (approximately US$20 billion) over a period of seven years for development of infrastructure in 63 cities under Jawaharlal Nehru National Urban Renewal Mission (JNNURM). Thus, at least now finance does not appear to be a constraint in proper solid waste management. However, the growing complexity of the issues involved in integrated solid waste management demands advanced knowledge based tools such as Decision Support System (DSS) and GIS application to improve the complete solid waste management system.

Among all the component of municipal solid waste management (MSWM), transportation takes a major portion of budget and unplanned transportation system may cause huge loss of funds. Transportation of the wastes at regular intervals is essential to ensure that garbage bins/containers do not overflow and waste is not seen littered on streets. Hygienic conditions can be maintained in cities/towns only if regular clearance of waste from temporary waste storage depots (bins) is ensured. Transportation system has to be so designed that it is efficient, yet cost effective. For efficient planning, transportation system must be synchronized with primary collection and storage of waste; otherwise it is liable to fail. Hence primary collection, storage and transportation must be considered holistically to develop a waste management plan of a city.

Many works have been done all over the world for optimizing collection and transportation systems for municipal solid waste. Chang et al. (1997) developed a multi objective, mixed-integer programming model for collection vehicle routing and scheduling for solid waste management systems synthesized within a GIS environment. Tung and Pinnoi (2000) used operations research technique in waste collection activities. Angelelli and Speranza (2002) presented a model for estimating the operational costs of waste collection, which are strictly related to the distance traveled to collect the waste and deliver it to the disposal points. The model was applied to traditional, side-loader, side-loader with demountable body types of collection systems to compare the performance. Viotti et al. (2003) used Genetic algorithms as a promising tool for optimization of the MSW collection routes. The objectives of the study included reduction in fuel consumption,

labor cost, vehicle maintenance expenditures and improved traffic conditions in urban areas. Ghose et al. (2006) used GIS in planning an effective solid waste management system and an optimal routing model was proposed to determine the minimum cost/distance and efficient collection paths for transporting the solid wastes to the landfill. The model needs information on population density, waste generation capacity, road network and the types of road, storage bins and collection vehicles, etc. Lakshumi et al. (2006) has developed a GIS based model to calculate optimal routes for secondary waste collection vehicles based on distance and time criteria. A comparison is made between the cost of the fuel for the proposed routes and the fuel consumed on the existing routes. Karadimas et al. (2007) used the Ant Colony System (ACS) algorithm in the GIS environment for the identification of optimal routes for MSW collection. Apaydin and Gonullu (2008) developed shortest path model using GIS software MapInfo in order to optimize solid waste collection/hauling processes to minimize emission. Li et al. (2008) considered a truck scheduling problem for solid waste collection in the City of Porto Alegre, Brazil. They attempted designing "good" daily truck schedules as compared to a set of previously defined collection trips, on which the trucks used to collect solid waste in fixed routes and empty loads in one of several operational recycling facilities. The major objective was to minimize the total operating

and fixed truck costs. Tavares et al. (2009) proposed the use of GIS 3D route modeling software which adds one more degree of freedom to the system and allows routes to be optimized for minimum fuel consumption for waste collection and transportation. The model takes into account the effects of road inclination and vehicle weight. Kanchanabhan et al. (2010) have proposed a GIS based collection and transportation model for MSWM. The parameters considered included population density, waste generation capacity, road network, storage bins and collection vehicles. Optimization of the routing system for collection and transport of solid waste is an important component of an effective solid waste management system.

II. Study Area Profile

Varanasi is the fourth largest city of Uttar Pradesh state of India, situated at 25 14' North latitude and 83 03' East longitude (Fig 1). The city is known for its mystic Ghats and rich architectural heritage. The city developed in the area falling between two rivers, "Varuna" and "Assi" and is therefore known as Varanasi. It is believed to be more than 3000 years old and considered as the oldest living city in the world. River Ganga passes through the east of the city. As per census 2001, Varanasi city has a population of 1202443 and an area of 79.79 Sq. Km. It is divided into 90 administrative wards. Average household size of Varanasi is 7.3 which is very high as compared to the national average of 5 persons per household and state average of 6.3 persons per household. The average household size in slums is of 10 members which is much higher than National and State averages.

III. Conclusion

In the present study, an attempt has been made to design and develop an appropriate storage and transportation plan for the Varanasi Municipal Corporation, Uttar Pradesh, India. The proposed model suggests the number of secondary storage containers required on ward wise bases and transportation plan to the disposal site using GIS. The hauled container system proposed in the work uses 4.5 m3, 3 m3, and 1 m3 capacity containers with hydraulic loading/unloading attachments. 9 m3 capacity vehicle (Dumper placer/tipper) are suggested for transportation of waste from waste storage point to disposal site. It is observed that the present waste storage and collection system in Varanasi is inadequate and unplanned. An initial investment of approx. Rs. 76.45 million is estimated for improvement of waste storage and transportation system and approximately Rs. 52.40 million is required per annum for efficiently manage these two services. A GIS-based optimal routing model was used to develop a route map for efficient transport planning. The proposed model can be used as a decision-support tool by the municipal authorities for efficient management of the daily operations for transporting solid waste, load distribution within vehicles, managing fuel consumption and generating work schedules for the sanitary workers and vehicles.

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