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Optimization of waste collection and disposal in Kampala city

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ABSTRACT

Waste collection and transportation is an important municipal service that involves high expenditures if not handled efficiently. This has hindered waste management in many Sub-Saharan African countries. In this study, Geographic Information System (GIS) tools were used to optimize travel distances, trips and collection time, which leads to maximizing total waste collection, yielding large savings and keeping the environment clean. The study suggested the best waste collection routes, and determined a suitable vehicle fleet and capacity to be used by Kampala Capital City Authority (KCCA), which is the body responsible for waste management in Kampala. The use of the GIS tools led to the reduction in the total number of trips and travel distances, which decreased fuel consumption and vehicle emissions. In addition, the model can be used by the various outsourced private operators, collecting and disposing of solid wastes. Since the current municipal landfill for Kampala city is almost full, the GIS tool was used to identify the optimum location of a new proposed landfill site, based on optimized travel distances. The results of this study can help KCCA to decrease costs of managing wastes and environmental as well as social impacts.

1. Introduction

Waste management involves a lot of difficulties during operation and among these, waste collection is the most aggravated due to the high costs that are involved (UNEP, 2009). Waste collection cost represents over 70% of the solid waste management budget of many municipalities in developing countries (Rotich, Yongsheng, & Jun, 2006; Tchobanoglous & Kreith, 2002) and about 60% or less for the developed countries (Brunner & Fellner, 2007). In many municipalities of cities in the developing countries, the total cost of the solid waste management includes the transportation cost of the waste to different facilities such as transfer stations, temporary storage sites, landfills and also the fixed costs and operational of these facilities (Chang, Lu, & Wei, 1997; Dyson & Chang, 2005). This has forced many municipalities especially in the developed world to start up research that is aimed at cost effectiveness such as route optimization (Chang et al., 1997).

Route optimization is one of the most studied aspects in optimization problems in transportation research, consisting of the design of optimal and cheapest distribution pattern to serve scattered customers (Badran & El-Haggar, 2006; Bosona, Nordmark, Gebresenbet, & Ljungberg, 2013). The common objective of route optimization is to minimize travel distances and reduce the fleet size used so as to reduce on operational costs and minimize on emissions (Apaydin & Gonullu, 2008; Ljungberg, Gebresenbet, & Aradom, 2007; Nuortio, Kytöjoki, Niska, & Bräysy, 2006). Collection of wastes has posed a lot of operational problems for local authorities in many cities involving tasks such as optimal fleet size, type and scheduled route (Torres & Anton, 1999). Sahoo, Kim, Kim, Kraas, and Popov (2005), in their study of route optimization of wastes asserted that in order to achieve effective waste management system, reduction of operational expenses and optimization of vehicle fleet size is necessary. The importance of optimizing waste collection vehicle routing is to minimize on fuel consumption rather than finding shortest distances (Tavares, Zsigraiova, Semiao, & Carvalho, 2009). This is because in the city areas, some of the shorter distances may be inconvenient for driving leading to more fuel consumption, pollution, and/or congestion.

Routing involves the use of extensive spatial data making it possible to use new technologies such as Geographic Information System (GIS). GIS is able to provide effective handling, display and manipulation of both geographic and spatial information. GIS tool

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has been found to play a potential role for solving various types of engineering and management problems in siting of waste disposal sites. GIS enables development of a multi objective model for collection vehicle routing and scheduling for solid waste management systems such as reduction of travel time, cost of site selection and provides a data bank for future monitoring (Sumathi, Natesan, & Sarkar, 2008).

Many surveys have been done in the field of location analysis theory but little has been done on facility location and routing (Salhi & Nagy, 2009). Facility location and routing have aspects related but many scholars have not considered the interaction of the two aspects. Salhi and Nagy (2009) noted that locating a facility is part of strategic planning while routing is a tactical practice. Their explanation was that optimizing of routes is flexible and can be changed anytime. However, locating a facility for instance a dumpsite is more or less permanent and can stay for a longer time. Combining the two into the same framework of work is unsuitable yet both are related (Nagy & Salhi, 2007).

Kampala City is one of the cities facing challenges of solid waste management. On an average, about 1500–2500 metric tons of waste is generated in the City per day (Ojok, Koech, Tole, & OkotOkumu, 2013). The city has a single recognized landfill known as Kiteezi (see Fig. 2). Only about 40–45% of the generated waste is collected and disposed of at Kiteezi landfill (KCC, 2006; Mugagga, 2006; Oyoo, Leemans, & Mol, 2011). From the collected waste, about 600 metric tons are collected by the city authority and approximately 300 metric tons are collected and transported to the landfill by private operators adding up to about 900 metric tons that reaches Kiteezi landfill (Kinobe, Niwagaba, Gebresenbet, Komakech, & Vinnerås, 2015). The majority of the remaining waste is indiscriminately disposed of in drainage channels or open land spaces, where it is later burned. Only a small proportion of the waste comprising of plastics and metals in Kampala is re-used or recycled.

Route optimization of solid waste as a management sphere has not yet been used in Kampala city and the existing waste collection systems are developed based on limited data. As such, an effective and integrated solid waste management system that will consolidate routes; reduce haul distance, time and cost; balance the distribution of waste collection in all the parishes; ensure equitable involvement of all assigned vehicles in waste hauling is needed, not only to reduce costs of waste disposal but also to keep the city environment in a good manner. The main objective of this study was to optimize the collection and transportation of waste to the

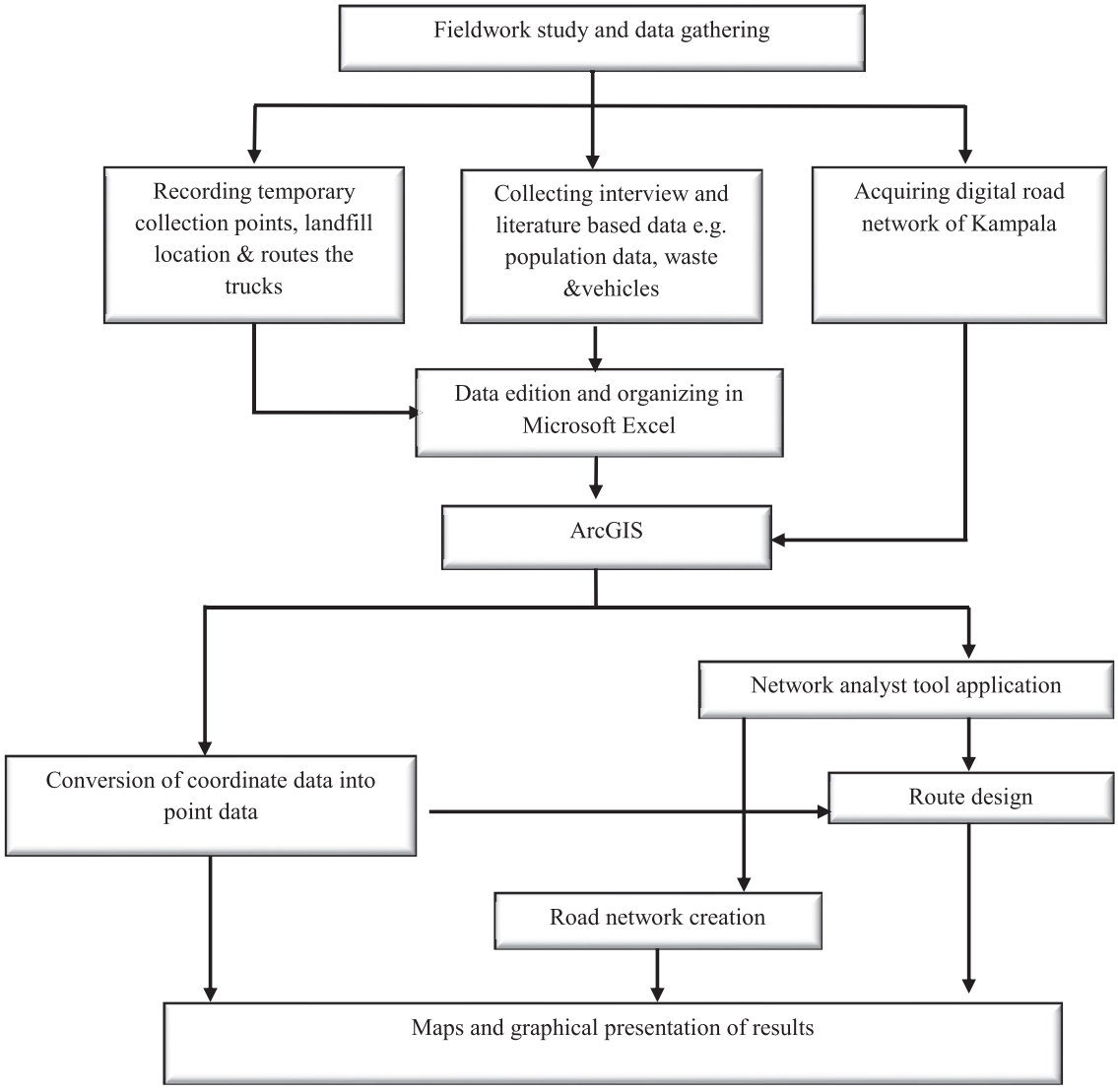

Fig. 1. GIS methodological structure.