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AN ANALYSIS UPON VARIOUS MODELLING FOR OPTIMISATION OF MUNICIPAL SOLID WASTE COLLECTION BY GIS

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An Analysis upon Various Modelling For Optimization of Municipal Solid Waste Collection by GIS

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Abstract – Uncontrolled growth of the urban population in developing countries in recent years has made solid waste management an important issue, so the system for collection of solid waste thus constitutes an important component of an effective solid waste management system.

A GIS optimal routing model was designed for efficient collection path for municipal solid waste to minimum time, labor, distance efficient collection paths for the solid wastes.

Waste collection and transport (WC&T) constitutes a large fraction of the total municipal solid waste (MSW) management costs worldwide. In Greece currently this may account for 70-100% of the total MSW costs, most of it being spent on salaries and fuel. It is therefore crucial to improve the WC&T system through routing optimisation. Geographic Information System (GIS) technology provides an advanced modelling framework for decision makers in order to analyse and simulate various spatial waste management problems, including waste collection. In this study a methodology for the optimisation of the waste collection and transport system, based on GIS, was developed.

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INTRODUCTION

Waste management issues are coming to the forefront of the global environmental agenda at an increasing frequency, as population and consumption growth result in increasing quantities of waste. Moreover, technological development often results in consumer products of complex composition, including hazardous compounds, which pose extra challenges to the waste management systems and environmental protection at the end of their useful life, which may often be fairly short (e.g. cell-phones and electronic gadgets).

These end-of-pipe challenges are coupled with the deepening understanding that the Earth's natural resources are finite by nature and their current exploitation rate unsustainable, even within a midterm perspective. The self-cleaning capacity of the Earth systems is often also viewed as a «natural resource» under stress, with climate change being the most pronounced expression of this risk.

Local authorities (LAs) constitute worldwide the main providers of municipal solid waste (MSW) management services, either directly or indirectly through subcontracting part or all of these services. Especially waste collection and transport (WC&T) are typically provided at the local municipality level and constitute the main interface between the waste generator and the waste management system. Assessing the different components of the solid waste management costs is a complex, poly-parametric issue, governed by a multitude of geographic, economic, organisational and technology selection factors (Eunomia, 2002; Lasaridi et al., 2006). However, in all cases WC&T costs constitute a significant component of the overall waste management costs, which may approach 100% in cases where waste is simply dumped. For modern waste management systems WC&T costs vary in the range of 50-75% of the total, which overall is significantly higher, as advanced treatment and safe disposal take their own, large share of the total costs (Sonesson, 2000).

Therefore, the sector of WC&T attracts particular interest regarding its potential for service optimisation as (a) waste management systems with more recyclables' streams usually require more transport (Sonesson, 2000) and (b) this sector, even for commingled waste services only, already absorbs a large fraction of the municipal budget available to waste management (Lasaridi et al., 2006). Optimisation of WC&T making use of the novel tools offered by spatial modelling techniques and geographic information systems (GIS) may offer large savings, as it is analysed further in this study. In spite of their proved utility and a significant development of the relevant research in the last decades in many parts of the world, including most Greek local authorities, WC&T is typically organised empirically and in some cases irrationally, under public pressures.

Solid waste generated by the daily activities of the people needs to be properly managed in such a way that it minimizes the risk to the environment and human health. Inadequate collection and disposal of solid waste is a major factor in the spread of disease and environmental degradation. One of the most visible problems in the provision of solid waste management (SWM) is the collection route developed and save the cost of fuel and time of service of the solid waste, which is the subject of this paper. Solid waste management is undoubtedly an increasingly important element in terms of efficiency and profitability for any municipality .The routing optimization problem in waste management has been already explored with a number of algorithms. Moreover, the successful implementation of vehicle routing software has been aided by the exponential growth in computing power since 1950; the emergence of accurate and sophisticated Geographic Information Systems (GIS) technology induced multiple algorithmic solutions.

The growth in Municipal Solid Waste (MSW) in urban centers has outpaced the population growth in recent years. MSW is produced at alarming rate, particularly due to the rapid growth of urban areas, rural urban migration and the increase in per capita income (Agamuthu and Khan 1997).One of the consequences of the global urbanization is increasing volumes of solid wastes. At present, the annual generation of solid wastes equal to 1.6 billion metric tons approximately. The report of high power committee on urban MSW Management in India stated that there is no system of segregation of organic, inorganic and recyclable wastes at the household levels (Planning commission 1998, Sethuraman 2007). Further, the disposal of the MSW is an unplanned and uncontrolled open dumping at the landfill sites.

MSW in cities is collected and transported to designated disposal sites, which are normally located at out-skirts of the city. In most of the areas, the MSW collection is disorganized and less than 25% of the MSW produced is actually collected for disposal and the remaining 75% is allowed to remain, causing health hazards and pollution to the environment would lead to better options and opportunities for its scientific disposal, otherwise life of existing disposal facilities is decreased (Singhal and Pandey 2006). However just collecting the waste from different parts of city does not solve the problem, it requires disposing the waste in environmentally safe and economically sustainable manner. Thus an effective solid waste management system is needed to ensure better human health and safety (Ghose *et al*., 2006). A study conducted in the Istanbul predicted that annual collection expenditure of solid waste can be reduced to 50% when the collection routes are optimized (Kinaci *et al*., 2000).

GIS MODELLING FOR THE OPTIMISATION OF WASTE COLLECTION AND TRANSPORT

The optimisation of the routing system for collection and transport of municipal solid waste is a crucial factor of an environmentally friendly and cost effective solid waste management system. The development of optimal routing scenarios is a very complex task, based on various selection criteria, most of which are spatial in nature. The problem of vehicle routing is a common one: each vehicle must travel in the study area and visit all the waste bins, in a way that minimises the total travel cost: most often defined on the basis of distance or time but also fuel consumption, CO2 emissions etc. This is very similar to the classic Travelling Salesman Problem (TSP). However, the problem of optimising routing of solid waste collection networks is an asymmetric TSP (ATSP) due to road network restrictions; therefore adaptations to the classic TSP algorithm are required, making the problem more complex.

As the success of the decision making process depends largely on the quantity and quality of information that is made available to the decision makers, the use of GIS modelling as a support tool has grown in recent years, due to both technology maturation and increase of the quantity and complexity of spatial information handled (Santos et al., 2008). In this context, several authors have investigated route optimisation, regarding both waste collection in urban and rural environments and transport minimisation, through improved siting of transfer stations, landfills (Despotakis & Economopoulos, 2007) and treatment installations for integrated regional waste management (Adamides et al., 2009; Zsigraiova et al., 2009).

Optimisation of WC&T making use of the novel tools offered by spatial modeling techniques and GIS may provide significant economic and environmental savings through the reduction of travel time, distance, fuel consumption and pollutants emissions (Tavares et al., 2008).

STATUS OF MUNICIPAL SOLID WASTE MANAGEMENT IN INDIA

Solid waste management is usually related to materials produced by human activities, and is generally undertaken to reduce their effect on health, environment or aesthetics. Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential and industrial environments. Management of nonhazardous residential and institutional waste in metropolitan areas is usually the responsibility of local government authorities. Solid Waste Management is a part of public health and sanitation, and according to the Indian Constitution, falls within the purview of the State list (MoEF, 2000). This activity being local in nature is entrusted to the Urban Local Bodies (ULBs). The ULB undertakes the task of solid waste service delivery with its own staff, equipment and funds. In a few cases, part of the work is given to private enterprises on contract basis. 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 is disposed of unscientifically in open dumps and landfills, creating problems to public health and the environment (Nishanth et al., 2010). Generally local bodies suffer from non-availability of adequate resources, staff and expertise in proper SWM. In India, most of the municipalities are currently unable to fulfill their obligation to ensure environmentally sound and sustainable handling of waste generation, collection, transportation, treatment, and disposal of MSW. 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). For medium and small towns, funds have been provided under Urban Infrastructure Development for Small and Medium Towns (UIDS & MT) schemes. Thus, finance does not appear to be a constraint in proper solid waste management. However, the growing complexities of the issues involved in integrated solid waste management demands advanced knowledge based tools to support the complete solid waste management system. The application of Decision Support System (DSS) appears appropriate at this stage to streamline the whole process for effective outcome.

THE ROLE OF GIS FOR SUSTAINABLE WASTE MANAGEMENT

Geographic Information Systems (GIS) are one of the most sophisticated modern technologies to capture, store, manipulate, analyse and display spatial data. These data are usually organised into thematic layers in the form of digital maps. The combined use of GIS with advanced related technologies (e.g., Global Positioning System – GPS and Remote Sensing - RS) assists in the recording of spatial data and the direct use of these data for analysis and cartographic representation. GIS have been successfully used in a wide variety of applications, such as urban utilities planning, transportation, natural resources protection and management, health sciences, forestry, geology, natural disasters prevention and relief, and various aspects of environmental modelling and engineering (among others: Brimicombe, 2003). Among these applications, the study of complex waste management systems, in particular siting waste management and disposal facilities and optimizing WC&T, have been a preferential field of GIS applications, from the early onset of the technology. Nowadays, integrated GIS technology has been recognised as one of the most promising approaches to automate the process of waste planning and management (Karadimas & Loumos, 2008).

As mentioned above, the most widespread application of GIS supported modelling on waste management lies in the areas of landfill siting and optimisation of waste collection and transport, Additionally, GIS technology has been successfully used for siting of recycling drop-off centres, optimising waste management in coastal areas, estimating of solid waste generation using local demographic and socioeconomic data (Vijay et al., 2005), and waste generation forecasting at the local level.

CONCLUSION

In this study GIS technology was used for the optimization of commingled municipal solid waste collection. GIS technology supports the optimisation of municipal solid waste management as it provides an efficient context for data capture, analysis and presentation. Two main categories of GIS-based waste management applications can be identified in the international literature. In the first, GIS is used for the selection of waste disposal landfills, and to a smaller extent, other waste treatment facilities. Most of these applications benefit from map overlay GIS functions and spatial allocation modelling methods.

The implementation of GIS-based modelling for waste collection optimisation in many countries with different socioeconomic conditions and technological background shows that significant savings could be achieved in most setups. The optimisation of routing has a direct positive impact on cost savings (reduction of fuel consumption and maintenance costs) as well as significant environmental impacts due to the lower levels of sound pollution within the urban environment and the reduction of greenhouse gases emissions.

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