



GIS based Decision Making Model for Landfill Site Selection

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Abstract: Project is the main concern of developers in developing countries today. It has been reported by numerous studies that development activities have the potential to harm the environment. The rapid growth of construction projects has not only benefited humanity by providing social requirements such as infrastructure, buildings, drainage, dams but it also contributes significantly to the economic development of countries. Apparently it contributes significantly to the production of large amount of construction waste, unreasonably excessive consumption of resources, and creates negative impacts on the environment. Construction industry suffers from the large amount of Construction and Demolition waste (C & D) in several countries, including Pakistan. The selection criterion for existing landfills does not meet all the environmental consequences. Therefore, this paper comes with the decision making model to select suitable land for landfill GIS. It would be an effective approach to select viable landfill, which incorporates all the essential factors considered in an EIA study for landfills in practice. The approach to land suitability can also be extended to other development projects also in the future.

Keywords: Construction Waste, Landfill, Land Suitability, Decision Making

1. INTRODUCTION

It is observed that development activities in a particular area cause damage to the environment. Development activities, like large construction projects, industries, high speed rail projects, secure landfill facilities, petrol filling stations [i] have high potential to cause damage to the natural resources and environment. A sustainable development approach to resolve such problems is a major challenging issue for the planners today to protect the environment due to such development activities (Samarakoon and Rowan 2008) (Khahro *et al.*, 2012).

The rapid growth of construction projects benefited humanity by providing social requirements such as infrastructure, all types of building projects, drainage, dams, etc. It contributes significantly to the economic development of countries as well. Apparently, it contributes to the production of large amounts of construction waste significantly, excessive consumption of resources, and creates negative impacts on the environment. These challenges compel practitioners to adopt the principles of sustainable development in construction. The design and traditional construction focuses on cost, time and quality triangle, while the environmental impacts are given insignificant attention. However, sustainable construction combines sound responsible environmental practices in a discipline that analyzes environmental, economic and social effects of

a construction projects. Benefits of sustainable construction using less amount of resources in the construction and operation processes, reduces negative impacts on the environment, minimizing construction waste, reduces the risk of planning, quality construction and long life feasibility (Tuzmen and Sipahi 2011).

Construction industry suffers to large amount of construction and demolition waste in several countries, although they are different in their economic, social and cultural characteristics. Construction waste is one of the major sources of urban waste and is often 10-30% of all waste received at many landfills around the world. In 2003, Japan had faced 20% of the total waste generated by the construction and 70% of the illegal dumping of waste has been linked to construction activities (Ying *et al.*, 2007). And it should be taken as an alarming situation.

In Hong Kong, construction waste accounts for 30-40% of total waste (Huang *et al.*, 2006) and resulted in both public areas and filling landfill space within this decade. (Deepa 2012) In mainland China, construction waste constitutes 30-40% of total waste and rapidly increasing due to rapid urbanization and the growing population of the region. (Anifowose *et al.*, 2012) In Europe, construction waste accounts for 30% of total waste. In United States, construction waste constitutes 29% of all solid waste and 35% of landfill space is

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occupied by construction waste (Tuzmen and Sipahi 2011). Therefore, construction waste is an urgent issue that should be dealt with in a sustainable manner. (Fig.1) shows an example of environmental degradation cycle.

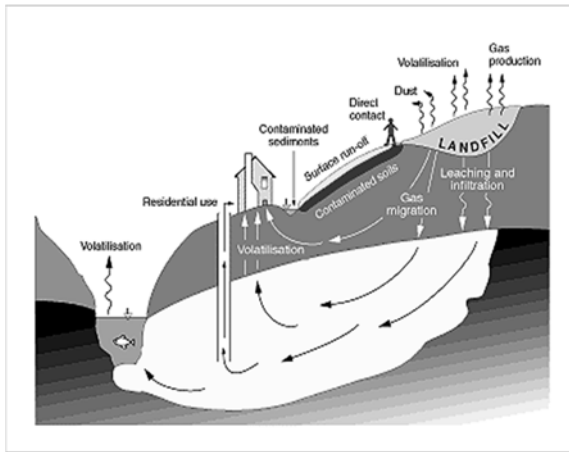


Fig. 1: Environmental Degradation Life Cycle

Construction waste often includes a significant percentage of all waste received at landfills in many cities around the world. To protect the environment and ensure sustainable development, an effective construction waste management has attracted the attention of various stakeholders especially government authorities, which are responsible for construction of waste management (Tuzmen and Sipahi 2011).

A Landfill is an important entity but it is a hazardous facility. Hence, special care should be taken during its site selection. Survival of such facilities greatly related to optimal selection of the site. A poorly selected location will lead to an inefficient use of resources (Tuzmen and Sipahi 2011). Site suitability is an ability of the selected land parcel to support a defined use. The principles of sustainable development make site suitability analysis complex due to consideration of various factors like creating deterioration with time, socio-economic problems, environmental issues and cost overruns (Duc 2006).

Environmental Impact Assessment (EIA) was introduced to examine, analyze and assess the planned activities in order to ensure those environmentally sound and sustainable. It is a systematic process, presenting a framework for collecting, documenting information and provides views regarding the environmental consequences of the facilitative activities. Thus, It can be regarded as an effective planning and management tool (Malczewski 2007). EIA leads to improved decision-making by providing the development control process with a superior information. Thus, it helps to determine whether any development should be permitted or otherwise (Snell and Cowell 2006).

An optimum site selection for landfill facility involves various factors including population, economic conditions, geographic and governmental policies, thus involves increasing data layers. Hence, decision makers should work on many data layers at the same time. This issue forces decision makers to use an efficient and intelligent approach. Geographical Information System (GIS) is proved to be an efficient tool to assists the decision maker to solve such spatial problems (Snell and Cowell 2006). It provides an opportunity to identify suitable land parcels by encountering various factors involved in the decision making. On the other hand, Multi Criteria Decision Making (MCDM) technique is used to assist the role of influencing factors in selection of suitable land parcel for landfills. Analytical Hierarchy Process (AHP) has been successfully used several times in various studies as a MCDM technique (Ying *et al.*, 2007). Such GIS-based MCDM approaches are successfully carried out including suitability analysis of nuclear waste disposal site (Huang *et al.*, 2006), site suitability analysis of decentralized treatment plants (Deepa 2012), waste disposal site selection (Anifowose *et al.*, 2012), and installing new petrol filling stations (Snell and Cowell 2006) (Afzali *et al.*, 2011).

In this paper, GIS-based decision making model has been developed for landfill site selection by using an integrated Spatial Multi Criteria Decision Making Approach (SMCDA), which can be used as a tool by the governmental agencies and decision makers to select the sites for landfills which incorporate all the environmental influencing factors.

2. ROLE OF MULTI CRITERIA DECISION MAKING IN THE LAND SUITABILITY ANALYSIS

A Multi Criteria Decision Making (MCDM) approach enables the decision makers to investigate a number of different alternatives. Despite the development of a large number of defined Multi Criteria Decision Aid (MCDA) methods, none can be considered as the 'super method' appropriate to all decision making situations. However, the Analytic Hierarchy Process (AHP) and its variants have long been used in numerous scientific MCDM applications. However, Saaty (1980) has successfully introduced the AHP. It is a decision support tool used to solve complex decision problems. It uses a multi-level hierarchical structure including objectives, criteria's, sub criteria's and alternatives (Tuzmen and Sipahi 2011) (Deepa 2012) (Matori and I. Chandio 2011).

3. RESEARCH METHODOLOGY

According to the framework, EIA influencing factors would be identified in the beginning through a detailed literature review, and existng EIA reports and interviews from various professionals involved in such

studies. The identified factors would be designed in the form of a pair wise comparison questionnaire to get the experts' opinion regarding the identified factors.

AHP manages several factors of any problems (Objective) into a hierarchy based approach. The objective is structured into different elements or group of elements like criteria's, subcriteria's and alternatives (indicators) and a pair wise comparison of elements in each group would be made to calculate the weight ages and consistency ratio (CR). The weight ages and consistency ratios can be calculated manually, MS Excel, IDRISI and Expert Choice software package. But in this study, Expert Choice 2000 package would be used due to ease, accuracy and lesser laborious job.

At the end to achieve the main objective of the research the spatial data would be collected from the different governmental and private agencies. Spatial data would be used in the Arc GIS 9.3 software package to identify the suitable land parcels for secure landfill facility in urban areas (Fig.2) is showing the integration of GIS data sent with AHP to get the final land suitability.

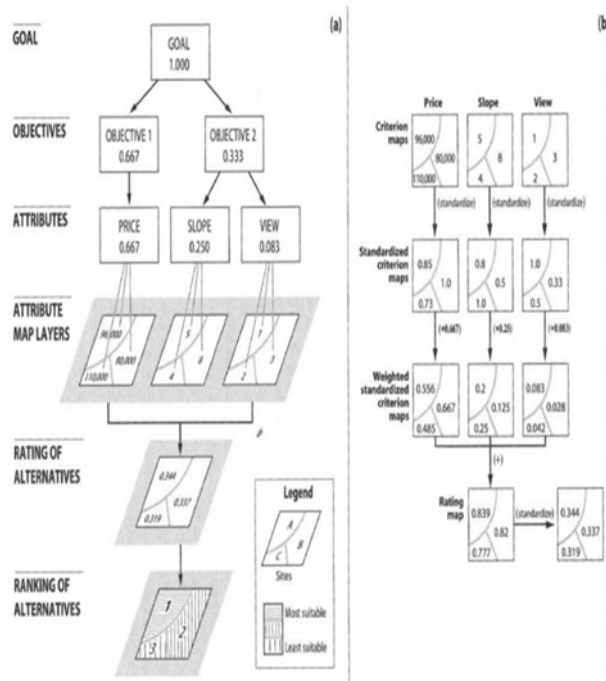


Fig. 2: Integration of GIS data sets with AHP [xii]

The data sets will be prepared first along with their relative weights. In the later stage, the weighted overlay method will be used to combine all of the data layers with their priority ranks to get the final land suitability map. (Fig.3) shows an example for data layer preparation and overlay.

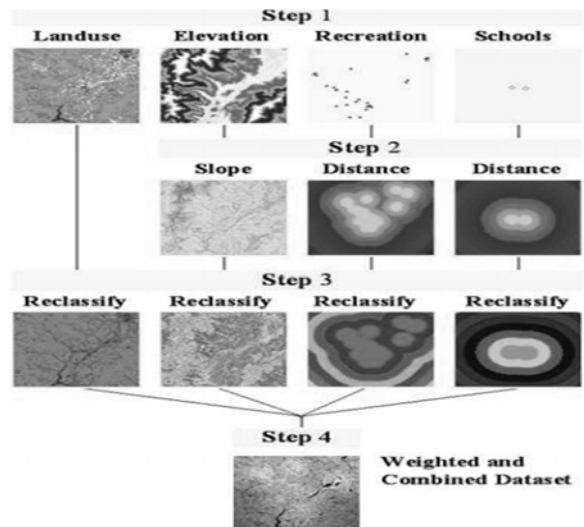


Fig. 3: Data Preparation Phases [xiii]

GIS helps the user to determine which locations are most/least suitable for the particular development. As such, several reasons Arc GIS is chosen to be utilized in this research is its popularity and also much easier to be integrated with AHP software Expert choice 2000.

4. GIS-BASED MODEL FOR LAND SUITABILITY

Following (Fig.4) shows the complete GIS based decision making model for landfill site selection. Various factors are incorporated in this model which are normally considered as important factors in EIA studies for such facilities.

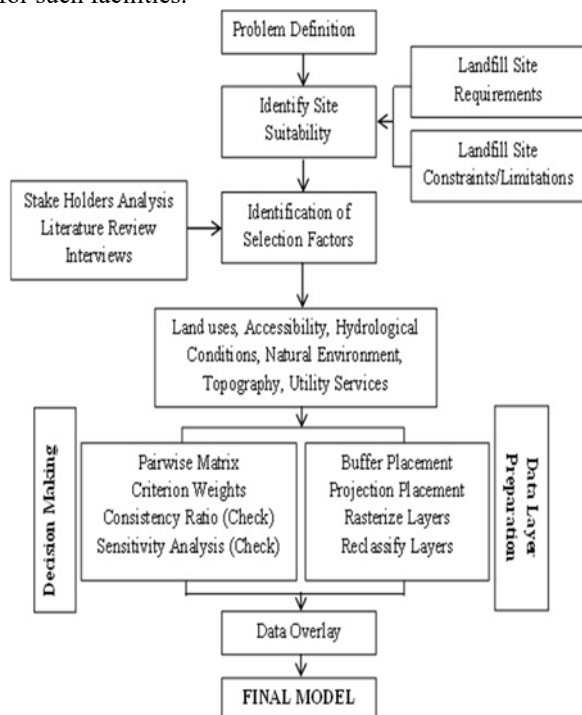


Fig. 4 Landfill Suitability Model

5. CONCLUSION

A number of attempts have been made to site suitability for landfills, whereas factors considered in an EIA assessment study for landfill sites are not incorporated. This paper provides an integrated GIS based decision support approach towards site selection in perspective to EIA study so as to have the best possible solution to such land suitability problems. This automated approach will select the suitable site keeping the constraints given by the user. It can accommodate different constraints with varying priorities. GIS is quite smart handling such data sets and solving such land suitability problems. Using this approach will save time and provides multiple choices for the stake holders to take the final decision to such land suitability problems. The level of severity of the existing landfills in terms of their land suitability can also be evaluated using this model by providing the coordinates of the existing landfills in the area. Remedial measures can be carried out to make the vulnerable landfills. This model will be a useful tool to the governmental offices and the practitioners to select the site for landfills in a robust geographical manner.

6. FUTURE DIRECTIONS

This GIS based land suitability model can be extended for other development projects including all scale industries, petrol filling stations, public parks, economic sectors etc. The model can also be extended using other decision making techniques like ANP, Revised AHP & Neural Network.

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