A Framework for Landfill Site Selection: An AHP-TOPSIS Approach

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Abstract:

Purpose: It is becoming challenging operation for the municipal corporation in India to manage solid waste in a scientific, modern and cost-effective manner. In India the final disposal of municipal solid waste (MSW) are done commonly in landfills. Bhubaneswar, the capital city of Odisha is a fast growing city in eastern India having an unscientific, inefficient and outdated solid waste management system. Following this lead, the main objective of this research is the selection of asuitable landfill site within or nearer to the Bhubaneswar city.

Design/ methodology/approach: Based on real condition of the studyregion and considering various evaluation criteria, a hierarchical model is proposed for solving the solid waste landfill site selection problem. After makingthe required hierarchy, the weights for each criteria are calculated by Analytic Hierarchy Process (AHP) method.Finally, TOPSIS is utilized to choose the best alternative Landfill site.

Findings: Abest candidate site is suggested for the use for landfill purposeas the regionhas a high suitability valuecalculated by the AHP and TOPSIS techniques.

Practical Implication: The outcome of this study offers a framework to support to decision-maker in the solutionof the problem in the management of solid waste for the city.

Originality/value: This study contributes to the understanding ofmanagement solid waste in Bhubaneswar, the capital city of Odisha.

Keywords*:* Solid Waste Management, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Analytic Hierarchy Process (AHP), Bhubaneswar Municipal Corporation (BMC)

1. Introduction:

Population in India have grown alarmingly and continues to grow. Due to higher production from manufacturing and service industries to support the population, higher amount of waste is generated every year. The waste generated from human households, small industries, commercial and municipal activities, water treatment plants, park and street sweepings along with debris of construction and demolition work are collectively referred as Municipal solid waste(MSW). The main steps for solid waste management are generation, collection, transfer, and disposal. Activities in which materials are identified as no longer being of value and are either thrown out or gathered together for disposal. Out of other Landfilling is the most convenient and inexpensive method of disposal. Today, almost all amount of solid wastes

ends up in disposal sites. Therefore to accommodate the advances in technology, it is required to meet the current design system. Accordingly BMC also needs to redesign the MSW system. It has been observed that wastes after being collected are randomly thrown here and there. This 'here and there' sometimes becomes an academic institute's premises or slums (where situation is already pitiful). With the increase of public awareness regarding environmental issues like they pose a health threat to people, plus, decaying wastes also attract household pests and result in urban areas becoming unhealthy, dirty, and unsightly places to reside in. Moreover, it also causes damage to terrestrial organisms, while also reducing the uses of the land for other, more useful purposes. In this context this research assumes its importance by identifying critical factors (criteria) for effectiveness of landfill site selection adopting AHP-TOPSIS approach.

2. Literature Review:

In case of an optimization model, the uncertainty associated with the recognition and the evaluation of the criteria involved is so high that the use of fuzzy concept is an obvious aspect. Siddiqui et al. (1996) used a combined analytical hierarchy process (AHP) and geographical information system (GIS) technique to help in selection of landfill site. Similarly, in Thailand Charnpratheep et al. (1997) used GIS with fuzzy set theory for the ranking of landfill sites. The use of GIS in selection of a landfill site has many advantages but the problem is that itcan make results seem more trustworthy than they truly are and poor surveyors could hide errors and assumptions. If the underlying data is accurate, the results of a GIS analysis can be accurate. The problem with Bhubaneswar is thatthe city does not have adequate information to work with GIS. For the current study, AHP is used with the combination of TOPSIS in a fuzzy environment for tackling the uncertainty involved in the planning of solid waste management. Also this combination of techniques is unique as it gives a ranking between the possible alternatives. Chang and Wie (2000) optimized sitting and routing problems using fuzzy multi-objective programming model by genetic algorithm. Cheng et al. (2002) used MCDA technique to solve the selection of a landfill site problem in Canada.An evaluation of management of solid waste concerning selection of landfill site was carried out by Pokhrel and Viraraghavan (2005). In Barcelona Bautista and Pereira(2006) located collection areas for urban waste management.Al-Jarrahand Abu-Qdais (2006)used fuzzy environment to solve the siting of a landfill site and constructed an intelligence system. Chen (2000) extended the TOPSIS to the fuzzy environment. nut and Soner (2008) selected best transhipment site for solid waste using AHP and TOPSIS in fuzzy environment in Istanbul, Turkey.

3. Material and Method:

3.1. The Study area

Bhubaneswar, the capital city of Odisha is one of the fast growing city of India. The population of Bhubaneswar was 10.6 lakhs in 2011 which has shown an increase of 64 percent than 2004. During the same period the amount of solid waste generated in the city increased from 234 to530 ton per day. This indicates an approximate double increase of generation of solid waste compared to population. BMC (Bhubaneswar municipality corporation) has a budget of 20 crore to be spent on management of SWM in year 2011-12(Mohanty et al., 2014)).In spite of spending a huge amount of money on the management of solid waste, the cleanliness in Bhubaneswar has not shown much improvement.There is no

treatment facility, sanitary landfill or controlled dumps for municipal solid waste in Bhubaneswar.Tulasadeipur and Salia Sahi are the two official dumping yardwhich are used without compaction(Mohanty et al., 2014)). So, Bhubaneswar, the capital of Odisha presents most critical Solid Waste Management systems.

3.2. Methodology

This study is undertaken to define the present scene of waste management practices in Bhubaneswar. It has been observed during the survey of literature and discussion with the municipal corporation personnel that the management of solid waste play a crucial in the sustainability. Since there is scarcity of landfill sites for waste disposal, it is necessary to identify some location for the disposal. While selecting the criteria for selection of appropriate location, it has been found that there is a list of various factors as suggested in published literatures. To manage and solve the landfill site location Analytical Hierarchical process (AHP) has been used by Onut and Soner (2008). In this paper, we are introducing AHP-TOPSIS, a combined methodology to evaluate the weight of selected criteria and to rank the most appropriate site among three selected sites.

3.2.1. Calculating criteria weights by AHP

AHP a multi-criteria decision-making tool is used to analyse the complex structure of a problem by pairwise comparison. While making the pairwise comparison a group of experts or individual decision-maker judge the relative importance of the criteria. These relative importance of selected criteria are converted into numeric values which will be used for pairwise comparison matrix. The steps of converting criteria weights from the pairwise comparison matrix are as follows:

- 1st step: A hierarchy model is constructed by analysing the problem and its factors.
- 2nd step: A decision table was created at each level of hierarchical decomposition by converting the linguistic values to numerical value.
- 3rd step: Weights for each criteria is are calculated from the pairwise comparison matrix.
- 4th step: Consistency ratio is maintained to make the judgement more reliable.

3.2.2. Ranking of the alternatives using fuzzy-TOPSIS

Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) is used to rank the alternatives against the chosencriteria. In the TOPSIS technique,that alternative is chosen best which is near to the Fuzzy Positive Ideal Solution (FPIS) and far from the Fuzzy Negative Ideal Solution (FNIS). An FPIS is defined as the alternative which has the best level for every selected criteria whereas the FNIS consists of the worst level.Forthe calculation of FPIS, benefit criteria are maximized, while the cost criteria are minimized. On the other hand for FNIS the cost criteria are maximized and benefit criteria are minimized.

3.3. Criteria description

When selecting a landfill sitemany criteria are to be considered. In this studythere are eight criteria taken into consideration whilemaking a selectionof landfill site in the Bhubaneswar city. These include Geology, Landuse, Distance from settlement, Distance from surface

water, Distance from protected areas, Distance from roads, Slope and height of the site, Cost of land.Figure -2 shows the hierarchical model of the framework, which consists of four levels. They are Goal, Criteria, Sub-Criteria and Alternatives. A briefillustration of the Criteria employedin this study is demonstrated below.

3.3.1. Geology (C_1)

Leachate from landfills and transport of contaminates are the main source of groundwater pollution. So areas with high level of groundwater pollution risk should not be used for landfills (Wang, 2009).

3.3.2. Landuse (C_2)

When locating a landfill site in the vicinity of a city,the land use of the region should be taken into consideration. Forest lands, agriculture, natural conservation, and residential development are highly unsuitable for location of a landfill.

3.3.3. Settlement (C_3)

Landfill sites are not suitable to locate near the settlement areas as it introducesseveral environmental problems such asadverseeffect of odour and noise from transporting vehicles.

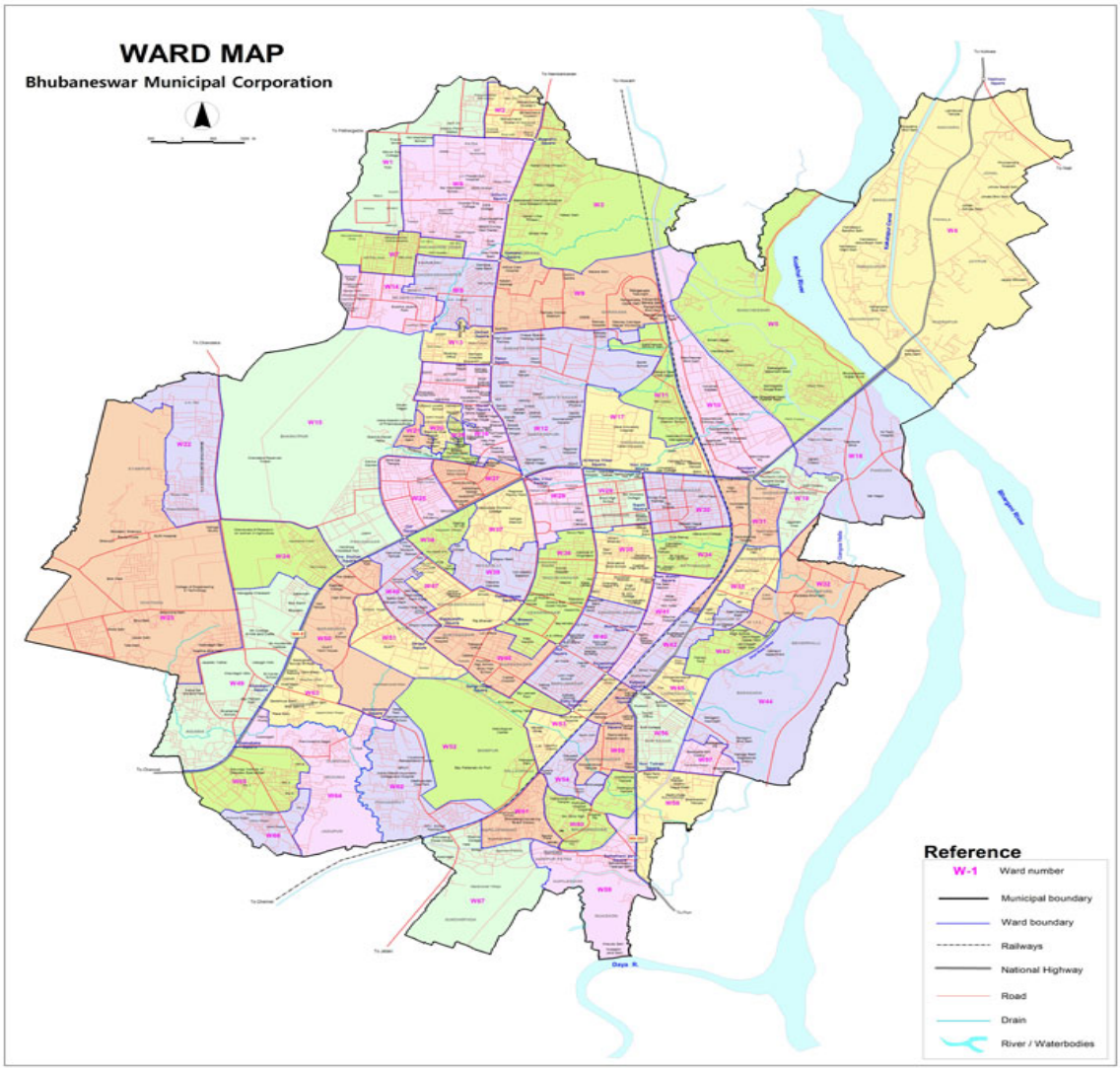

Figure -1

3.3.4. Surface Water (C_4)

The leachate generated from landfillsmay present long-term threats to groundwater sources. So suitable landfills should as far as possible from Surface water sources.

3.3.5. Protected Areas (C_5)

In addition to the natural spaces protected by the Local Government, BMC have also included certain protected areas in their urban planning plans. Therefore, Landfills must be built far from these.

3.3.6. Proximity to roads (C_6)

Landfill sites, if placed at a long distance from present road networks increase transportation cost and the cost associated with the construction of new roads. Additionally, interference with existing traffic is an important factor in transportation of solid waste (Giquin, 2009).

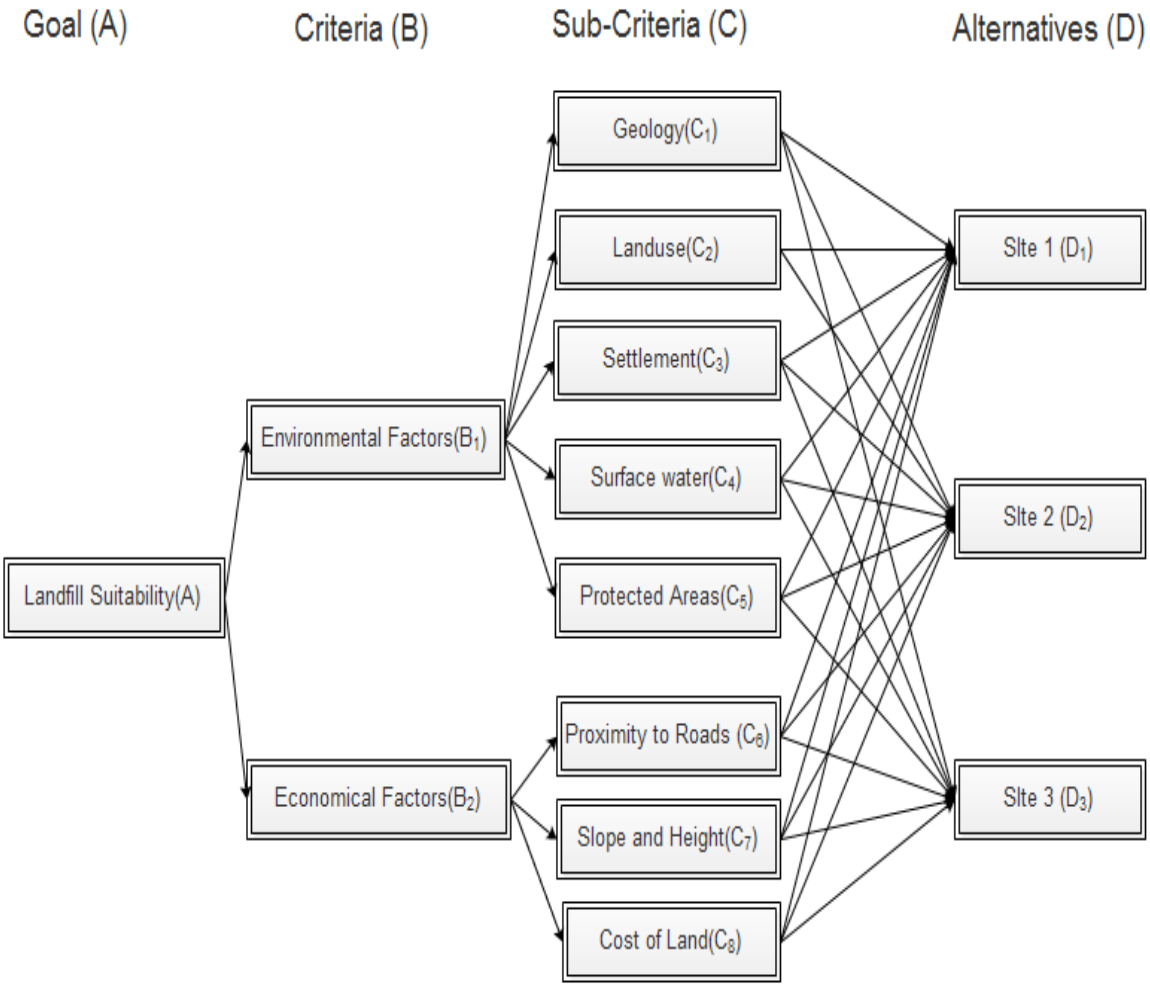

Figure -2

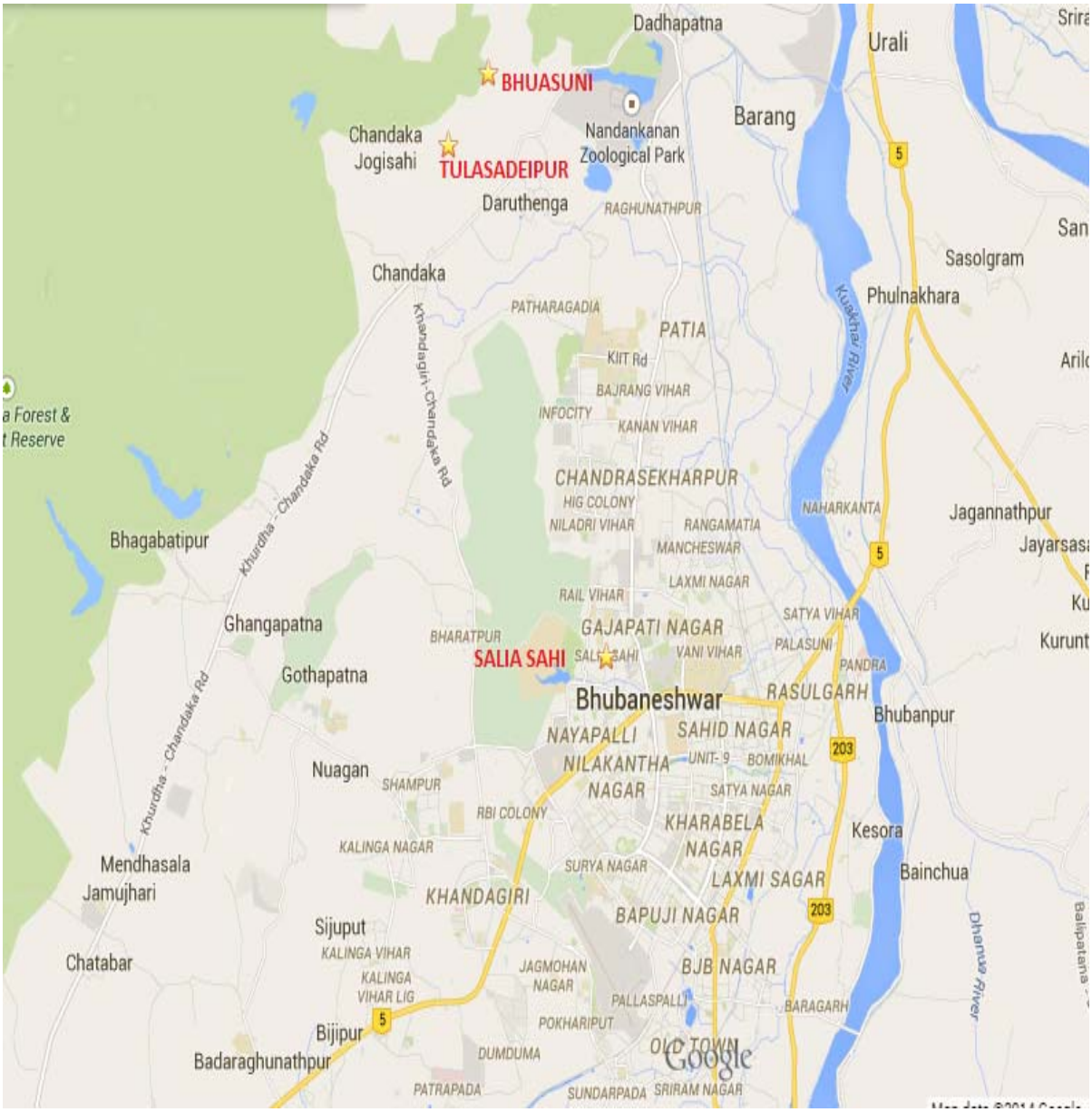

Figure -3

3.3.7. Slope and Height (C_7)

- Soil erosion is the main factor to consider landfill sites with slopes less than 1:5 (Ekmekcioglu et al., 2010).
- The altitude of the area is a vital factor in the selection of a landfill site. Sites having high altitude associate high transportation costs. On the other hand, infection and flooding are main factor to reject sites near sea level (Ekmekcioglu et al., 2010).

3.3.8. Cost of Land (C_8)

Price of lands are not uniform in a city.Suitability of a landfill increases as land prices decreased.

3.4. Alternatives Description:

In this study we have considered three alternative landfill sites named Salia sahi (D_1, Tulasadeipur (D_2), Bhuasuni (D_3). The alternative sites are shown in figure -3. While Salia sahi and Tulasadeipur are two existing landfill sites, Bhuasuni is proposed by BMC to be used in future.

4. Discussions:

Disposal of solid waste requires an area which will satisfy all the criteria of landfill site selection. In this paper an attempt has been made to propose a framework for landfill sitefor the solid waste. This study has undertaken 3 economic criteria and 5 environmental criteria to break the problem into a hierarchical structure. AHP-TOPSIS is a combined methodology to rank the alternatives in order of their suitability. As per the existing literature on landfill site selection this is the first attempt to solve the multi-criteria site selection problem using AHP-TOPSIS.

5. Conclusion:

Since, solid waste management has become a challenge for all of the states in India. Bhubaneswar, capital of Odisha is also facing severe challenge for managing huge amount of solid waste. In particular, in this research a framework using AHP-TOPSIS approach has been proposed.

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