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Research Paper

Identification of criteria and Indicators for locating waste transfer station sites in urban areas by Delphi consensus

Planning

KEYWORDS : Municipal Solid Waste, Solid Waste Transfer Station, Delphi method, Criteria & Indicators

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ABSTRACT

Population growth and an increase in the quantity of municipal solid waste have made it more difficult to locate appropriate sites for waste disposal in urban area because of NIMBY (Not in my backyard concept) prevalent in present urban communities. Unlike landfill sites that are to be located far from density areas, sites for waste transfer station are to be located near waste generation centers that are human populated areas. It is primarily located in central locations from where waste can be easily transferred to final disposal points. Because of its location these transfer station sometimes creates nuisance to the nearby areas in the form of noise, offensive odour etc which became objectionable for its sitting. Thus it is very important to give due consideration to different social factors also apart from only economic and environmental factors such as public acceptability, distance from important socio cultural points etc. This study focuses on identification many such important criteria and indicators (C & I) with principle goal of assessing suitable sites for locating waste transfer station sites within urban areas. These criteria and indicators would be multidisciplinary and cover all aspects in assessing location of waste transfer station sites because of its repulsive nature. In this study C & I were identified using Delphi approach with the help of multidisciplinary panel team. Three round of Delphi is conducted for discussion and dissemination of research to the panel members. Each criteria and indicator were then standardized with their measuring class interval in terms of suitability with the help of field experts. The study is useful for urban planners and city engineers in ranking identified sites within urban fabric for locating waste transfer station and it would also be useful in preparing decision supports model for locating waste transfer station sites.

Introduction

These days municipal solid waste (MSW) is one of the major concerns in cities. The nature of cities is very dynamic and ever changing in modern world. Currently consumption driven society produces mass volume of waste every day. Moreover due to continuous population growth, industrialization, urbanization and economic growth, a trend of significant increase in municipal solid waste generation has been recorded worldwide (Kaushal 2012). MSW generation has been observed annually in proportion to the rise in population and urbanization. The per capita generation of MSW has increased tremendously with improved lifestyle and social status of population in urban centers (Sharholy 2008). This trend also has its repercussions on increasing urban sprawl with increase in population densities and also on increase in concern of population for the concept like NIMBY (Not in my backyard) (Vasconcelos, Marques and Mart n.d.) which has made it even more difficult for the city managers and planners to locate waste dumping facilities within urban areas.

MSW which is commonly known as trash or garbage that consist of discarded items such as packaging material, grass clipping, furniture, clothing, glass, food items etc. Important component of integrated solid waste management includes collection, transportation, treatment, recycling and finally disposal of waste in dumping sites. Despite of large amount of waste being recycled, huge amount of waste is finally disposed off in landfill sites in India (Vasconcelos, Marques and Mart n.d.). As per State Pollution Control Boards / Pollution Control Committees (in between the year 2009-12), 1,27,486 tons/day (TPD) MSW is generated in the country during 2011-12 out of which 89,334 TPD almost 70% of MSW is collected and 15,881 almost 12% is recycled and treated. The huge amount of waste which is not being recycled is being disposed off in landfill sites or large open lands. Huge areas for dumping of waste are difficult to find in highly populated urban areas. As a result of which such facility are to be located far off from populated areas which results in increase in overall disposal cost of waste.

A waste transfer station is a facility located close to waste generation points where people reside like areas with residential and commercial land use. It is a facility where waste can be temporarily stored and transported to distant landfill or composting facilities sites (USEPA 2004). Transfer station provision could reduce transportation cost and management expenses up to 18% of energy consumption along with reduction in environmental pollution in the form environmental nuisance caused in transportation of waste (Khorasani 2007). Additionally these transfer station helps in consolidation and compaction of waste which helps in reduction of waste quantity significantly before final disposal of waste to landfill sites. One of the major challenges in municipal solid waste management is to determine suitable location for waste disposal and treatment facility in urban areas as they creates environmental nuisance (Tchobanaglous, Theisen and Eliassen 1997). Thus, finding suitable location for landfill site is a major challenge in solid waste management plan for a city. Up till now most of the studies have focused on the location of suitable sites for large dumping sites that are termed as landfill. But with the increase in urban sprawl and spread in city's fabric now it is an appropriate time to focus on finding suitable sites for intermediate waste transfer stations sites within urban fabric (Gholamalifard 2006).

In recent years many studies were conducted that have focused on finding suitable location of waste transfer station based on different methods and approaches. Kripa and Erkip (1988) used a mathematical programming approach to determine location of Waste transfer station in Istanbul. It was an economic model which primarily focuses on economic aspect of location at minimum cost (Rafiee, Khorasani and Mahiny 2011). Massam studies computer based decision support system to determine suitable location of waste transfer station. It considers seventeen criteria including ecological, political, transportation, economic and spatial components (Massam 1991). Nichiliyan determines location of waste transfer station in 22 districts of Tehran using a multi criteria analysis approach. It accounts certain criteria such as accessibility and distance from waste generation points to final disposal sites, geology, and topography etc. The relative weight has been calculated by pair wise comparison method (Nilchiyan 2002). USEPA published a user manual that can be used by the decision makers for planning site selection and design of waste transfer station. It has classified various criteria for site selection broadly in exclusionary, technical, and community specific criteria. The manual although serves all the necessary factors helps in identifying suitable locations but requires site specific contextual knowledge before continuing further (USEPA 2004).

(Gil and Kellerman 1993) in a study "A Multicriteria Model for the Location of Solid Waste Transfer Stations: The Case of Ashdod, Israel" identified indicators for ecological, political, transportation, economic and spatial criteria. (Abah and Ohimain 2010) considers Distance from nearest water source, Dept of filling of waste, Area of the dumpsite, Ground water dept, Permeability of soil, Ground Water quality, Distance to critical habitats such as wetlands and reserved forests, Distance to the nearest airport, Distance from surface water body, Type of underlying soil (% clay), life of the site for future use (years), Type of waste (MSW/ HW), Total quality of water at site, Quantity of waste disposed, Distance to the nearest village in the predominant wind, Flood proneness, Annual rainfall, distance from the city, Public Acceptance, Ambient air quality CH_4%, Hazardous contents in waste %, Biodegradable fraction of waste at site, Age of filling, Moisture of waste at site, BOD of leachate, TDS of leachate and COD of leachate in their study of "Assessment of Dumpsite Rehabilitation Potential Using the Integrated Risk Based Approach: a Case Study of Eneka, Nigeria". (Rafiee, et al. 2011) discusses criteria for siting transfer station for municipal solid waste using a spatial multi criteria analysis. Distance to highway, distance to residential area, distance to riverbeds, soil, geological material, slop, distance to fault, distance from generation centre were the criteria for siting. (Singh and Vidyarthi 2008) argue optimal allocation of land fill disposal site which deem more than fifty indicators for accessibility to the site, receptor related factors, environmental related factors, socio-economic factors, geological related factors and waste management practices related. (Shari and Retsios 2004) consider many factor for waste disposal site selection through spatial multiple criteria decision analysis. It classifies factors into biophysical criteria and socio-economic criteria. (Tayyebi, et al. 2010) in a study "Combining multi criteria decision making and dempster shafer theory for landfill site selection" considers only economic criteria and environmental criteria. (Pandiyan, et al. 2011) develops a decision making tool for hazardous waste landfill site selection. A toolkit landfill technology (DGGT/DWA-VKS-Technical Committe 2009) suggests topography, morphology, geology, geohydrology, hydrology, seismic condition, pedologic, climatic / meteorological conditions, geotechnical situation, surface water, landuse, natural protection, cultural sites, military areas, distance to settlements and distance to airport to site landfill.

This study intends to identify all relevant criteria and indicators which are effective for deciding the location of waste transfer station in urban areas in Indian context using Delphi approach. The criteria and indicators would be multidisciplinary covering all aspects of social economical, environmental and exclusionary factors that should be considered in determining suitable location for transfer station. Study results would help in providing standard method which tracks all important criteria and indicators useful in determining suitable sites for waste transfer station.

Methods and tools

In this study, Delphi method has been considered to select criteria and their respective indicators. The Delphi method is an iterative process which is designed to achieve a consensus on the specific subject. The method is most effective means for participant to identify suitable criteria and indicators for locating waste transfer station sites in urban areas, since it falls under the category of repulsive urban activity (Khorasani 2007). It is an excellent way to generate a consensus of expert opinion when any specific scientific data is unavailable on specific subject. In number of previous researches, major focus while locating waste transfer station was on environmental and economic aspects whereas criteria such as public acceptability, distance from culturally important areas were often not being considered. In countries like India prescribed standards and regulation related to waste management like solid waste management and handling rules 2000 does not specify any criteria for locating facilities like waste transfer station. Whereas many environment regulatory manuals gives specification for locating large waste dumping sites that are often termed as landfill sites.

Firstly, existing information on present recommendation about the aspects related to the location of waste transfer station from the wide range of sources has been taken including manual on waste transfer station by USEPA (USEPA 2004). At next level Delphi approach was used to build a consensus on subject area of research. The method allows systematic collection of expert opinions or judgment on a particular topic through a systematically arranged questionnaire feedback, interspersed with the summary of information on option from earlier responses (Turoff 1975).

The method was shown to be reliable qualitative research approach with potential to solve problems, contribute to the decision making and reach to a group consensus on wide variety of areas. Selection of experts in Delphi technique is very important (Gracht n.d.). There is a need of a balance panel and it is to be ensured that an element of judgment is involved in achieving such a panel across wide spread of experts with different backgrounds. The person invited to be a panel of expert should be knowledgeable about the subject area. The sample size could vary from as small as 10 to large sample size up to 200 (Skulmoski 2007). In this study, we had engaged a panel of 107 experts from different fields, professionals and practitioners form India as well be outside India as the targeted research is multidisciplinary in nature. Three round Delphi process was processed to prepare a final list of criteria and their respective indicators. Initial list of C&I was prepared based on literature review (Column II, Annex 1) which need to be included as initial base for Delphi survey. Further statistical tools like Descriptive analysis tool comprises of measures of central tendency (median, mean), dispersion (standard deviation), and frequency distributions (histograms and frequency polygons) are used to further analyse the data. Final list of criteria and their respective indicators were prepared after Delphi process.

Delphi Process and Analysis

The Delphi process has been used in various fields of study with different scopes. In this study three round Delphi process has been used. Experts were brought at round one after their confirmation of full participation during the study. Acceptability of criteria and indicators were asked in this round. Other suggestions were also considered. Experts were categorized into group of academic people, local authorities and practicing people of solid waste management. In round two the number of experts brought down to 100 based on their experience. Experts were asked to tag degree of importance to each indicator in terms of numeric value. Mean value of the degree of importance were computed and arranged in descending order. A histogram chart for cumulative frequency were prepared and discussed based on theory of Pareto scale for exclusion of the indicators to site the transfer station. The analysis process was repeated for all 100 experts and three groups of selected expertise also.

Round three tries to build consensus at the end of Delphi process. In this level the result of mean and mode value of the degree of importance based on the round two were sent to the experts and their final comments were invited. Comments were also asked for standardization to indicators of the criteria.

3.1 First Round of Delphi

A formal invitation with an enclosed questionnaire was sent to all the panel members. It was an acknowledgement and looking for commitment that was required for survey process. Thirty indicators were listed from literature review and experts were asked to accept or reject the indicators with comments. First round responses were analyzed and summarized for further rounds. Percentage distribution of acceptability of 30 indicators is being presented in 100% stacked column chart (Figure: 1).

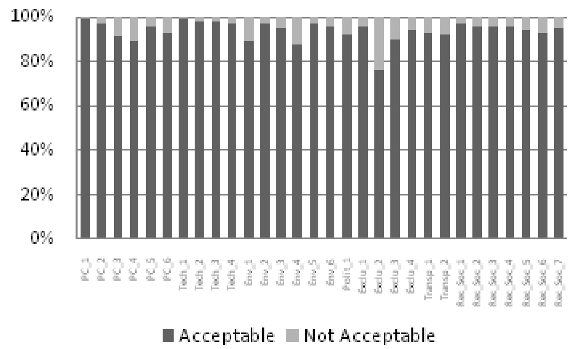

Figure 1: Acceptability of the indicators to site transfer station

Out of 30 indicators 25 got more than 90% experts acceptability. Administrative boundary, native vegetation, geological material, culturally sensitive is below the level of 90% but above the 80% acceptability. Zoning and landuse were suggested to treat as a single indicator. Use of nearby area might be related to existing activity while landuse should be discussed as permissible use. Distance to landfill site to site a transfer station could be one more indicator of planning criteria. Climatic criteria were suggested to add as eighth criteria. Wind direction, humidity and rainfall might be its indicator.

3.2 Second Round of Delphi

A revised list of eight criteria and 33 indicators were prepared having all old 30 indicators of round one and suggested three new indicators of climatic criteria. Degree of importance of indicators was measured in round two. Degree of importance increases from not at all important, equally important, moderate important, strongly important to extremely important. These degrees of importance are rated 0, 1, 2, 3 and 4 respectively. 100 experts from academic, local authority and practicing people were invited to take part in second round out of 107 experts. Seven experts from academic were excluded to balance all three classes of experts. Initially all 100 experts' suggestions were treated together. Ratings of degree of importance to different indicators by experts are being presented below:

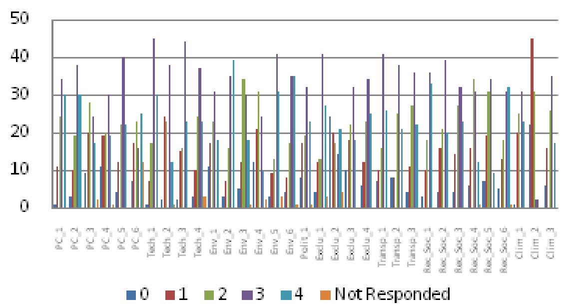

Figure 2: Experts' perception for degree of importance to different indicators

Distance to water bodies (Env_2) got maximum value of degree of importance in total followed by size of the transfer station (Tech_1) and ground water prospect (Env_5). Similarly humidity (Clim_2) got minimum degree of importance followed by nearness to airport (Exclu_2) and Geological Materials (Env_4).

The goal of second round and any other subsequent round using questionnaire was to achieve a consensus or stability to reach. After this step data has been compiled and analyzed statistically. Finally a highly rated mean value was selected and all relevant C&I were shortlisted based on Pareto scale.

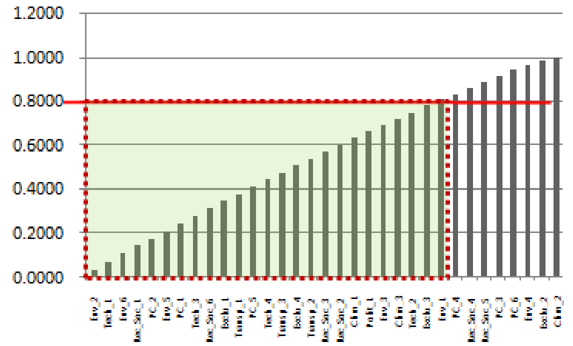

Figure 3: Pareto 80:20 prioritization rule on relative mean of degree of importance

Clim_2 (humidity) has minimum relative mean vale of degree of importance followed by Exclu_2, Env_4, PC_6, PC_3, Rec_Soc_5, Rec_Soc_4 and PC_4 outside the priority range of Pareto principle of 80:20. PC_4 (Land use) got less number of degree of importance comparatively. It was also mentioned in round one comment of experts that zoning and Land use should be treated as a single entity. Rec_Soc_4 (Property Value in nearby area) was not considered significant. Experts from academic and practicing people suggest that infrastructure required for public purpose should be given prime attention especially when environmental consideration comes. Thus land value to as an indicator to site a transfer station is avoided by experts from academic and practicing people. Rec_Soc_5 (Public utility facility within 2 km) were avoided by local authority. They advocate that public utility facilities outside the transfer station are planed separately. Environmental protection and conservation measure protect outside public utility facility. PC_3 (Topography) of the site is significant to plant any establishment. But site preparation for transfer station requires major cutting and filling create a level difference between vehicles of waste collection and transportation to landfill site. For PC_6 (Land ownership) experts group had similar disparity in thought like property value. Exclu_2 (Nearness to airport) were considered an indicator of exclusionary criteria from literature because criteria and indicators were commonly collected from literature based on transfer station as well as landfill site. Since waste is stored temporally in transfer station thus many experts gave less degree of importance to this indicator.

Later same process of prioritization were followed for three groups of experts separately. A comparative study of relative mean degree of importance of all indicators of different criteria group was made based on the opinion of three experts group. 25 different set of indicators from each group of experts were prioritized.

3.3 Third round of Delphi

In the third round, results were sent to the expert for consensus building. All 100 experts were informed with the analysis process and the results. They were informed about the list of prioritized indicators suggested from the different group of experts. Their comments were again invited on the result and asked to suggest how these criteria would be helpful to site the transfer station. Only 27 experts responded and made comments on the analysis result based on relative mean degree of importance.

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Results and Discussion

Experts in round one were agreeing with the criteria and indicators identified from the literatures. All seven criteria and thirty indicators were accepted by 107 experts. Distance from the airport keep significance to site a landfill site but it is not same for transfer station. Nearness to airport was least acceptable indicators to site the transfer station while zoning and size of the transfer station were most acceptable indicators. Size of transfer station depends upon population. Land area required for a transfer station site is calculated based on maximum permissible density for its range. Therefore more transfer station area would be required in future if the density increases within same range.

Second round of Delphi examines the degree of importance for thirty-three indicators. Pareto principle of 80:20 for prioritization was used to exclude less significant indicators of different criteria. All the experts were broadly classified into three groups of academic, practitioners and local authority based on their maximum period of experience. Relative mean of degree of importance for each indicators were assessed separately for all three experts group and results were compared with their combined opinion. Env_4, Exclu_2 and Clim_2 are suggested to exclude from the list to site a transfer station. PC_4 and Rec_Soc_5 might be excluded as the rating of degree of importance suggested by academic and local authority experts. Local authority and practicing experts together suggests excluding PC_6 only while PC_3 are suggested combined by academic and practicing experts PC_3, PC_4, PC_6 and Rec_Soc_6 are also in the list of all experts to exclude which are suggested by two different groups of experts to exclude. Rec_Soc_4 is the only indicator of the receptor related criteria which is suggested to exclude by local authority and also by the all experts group. Thus Rec_Soc_4 is very strongly suggested to exclude by local authority. Public purpose is strongly supported by local authority.

Experts in third round of Delphi were agree with the combined result to exclude indicators based on relative mean degree of importance. Geological materials, nearness to airport and humidity might be excluded from the list of the indicators to site transfer station. Topography might be major concern for the case of hilly area. Administrative boundary of wards and zones is significant as solid waste management is prime responsibility of municipality. Zoning might be merged with landuse as it is based on FAR, density and landuse and population density has already been considered in Rec_Soc_1. Vegetation within the proposed site has significant environmental consideration compare to native vegetation. Geological material and soil are suggested to consider in terms of its pollution. Local authority ignores the political will but considers people's willingness. Academic experts ignores interference with traffic they recommend waste transportation with a defined schedule after the study of traffic survey. Distance to nearest building should be considered and there might be a green buffer to save from the bad impact of transfer station. Property value might be considered if there is some alternative opportunity on other land. Public utility facility should not be commonly used for the transfer station. Public utility criteria might be merged with access to services and utilities. Flexibility for facility expansion is dependent on the availability of vacant land. These two criteria might also me merged. Proximity to school and hospital should be considered.

Table 1: Acceptable indicators based on relative mean degree of importance by different group of experts

Criteria	Academic Experts	Experts from local authority	Practicing Experts	All Experts
PC_1				
PC_2				
PC_3				
PC_4				
PC_5				
PC_6				
Tech_1				
Tech_2				
Tech_3				
Tech_4				
Env_1				
Env_2				
Env_3				
Env_4				
Env_5				
Env_6				
Polit_1				
Exclu_1				
Exclu_2				
Exclu_3				
Exclu_4				
Transp_1				
Transp_2				
Transp_3				
Rec_Soc_1				
Rec_Soc_2				
Rec_Soc_3				
Rec_Soc_4				
Rec_Soc_5				
Rec_Soc_6				
Clim_1				
Clim_2				
Clim_3				
	Prioritized indicators by the experts to site transfer station			
	Indicators suggested to exclude from the list to site transfer station			

Locating waste transfer station in urban areas is a complex process that requires careful consideration on number of factors that involves not only environmental factors but also number of socio economic factors which needs to be given priority. In this context this study demonstrates use of Delphi approach to design a set of potential C & I useful in identification of suitable sites for activities which are repulsive in nature. It was an iterative for identifying and generation C&I and involve multidisciplinary panel of 107 professional, academic persons and practitioners having required expertise.

Three rounds of Delphi process was used for identifying C&I working out suitable sites for locating waste transfer station, the consolidated list of identified criteria and indicators were sent to experts prepared from literature. In the first round 7 criteria and 30 indicators were identified which was increased to 8 criteria and 33 indicators at the end of first round.

In the second round experts were asked to indicate the degree to which they agreed with the particular criteria and indicator in the scale of 0-4 from 0 indicated criteria as not at all important to 4 as extremely important. At the end of second round consensus on 8 criteria and 30 indicators were made. Initial studies and researches create indicator and criteria on the particular subject focusing mainly on economical and environmental criteria. The present study extended the spectrum by including social, cultural and political factors also. Thus the survey creates a comprehensive set of indicators which covers all dimensions relevant in sitting Waste transfer station in urban areas.

Conclusion

In nearly every developing country, the capital city has grown to the extent that transfer stations need to be considered. Not only distance to disposal, but travel times (due largely to traffic congestion) have dramatically increased in the past decade. As a general thumb rule, if the distance of waste generation points to the dumping site is more than 10 km, intermediate transfer stations should be provided (Cointreau n.d.). Locating facilities like waste dumping and storage areas has always been challenging for planners and decision makers (Rafiee, Khorasani and Mahiny 2011). Thus, locating such facilities in urban areas has to be supported by regulatory provisions so that there would be least opposition and objections. Accept for few developed countries many countries do not have set criteria for locating facilities like solid waste transfer station (Ogawa, Hisashi n.d.). In the absence of which, locating such facility would be more and more difficult for city managers and planners to plan for such facilities. Many previous researches and studies have given different set of criteria and indicators relevant to particular context of city only. (Massam 1991).

The Delphi approach is one of the most suited approaches to select relevant criteria's and indicators that are universally accepted. The study also show that it is possible to define a set of C&I which becomes the base for solving complex problem like waste transfer station in populated urban areas. The same C&I could be used for researches exploring suitable sites for waste transfer station in urban areas targeting to extend the study with different perspective.

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Annex 1: Indicators flow in Delphi Process

Literature Review		Author	Delphi Process		
Column I	Column II	Column III	Column IV	Column V	Column VI
CRITERIA	INDICATOR	Code	Round One	Round Two	Round Three
PLANNING CRITERIA	Zoning	PC_1	Accepted	Accepted	Accepted
	Distance from collection areas	PC_2	Accepted	Accepted	Accepted
	Topography	PC_3	Accepted	Accepted	Accepted
	Administrative Boundary	PC_4	Accepted	Accepted	Accepted
	Landuse	PC_5	Accepted	Accepted	*Mearged to PC_1*
	Land Ownership	PC_6	Accepted	Accepted	Accepted
TECHNICAL CRITERIA	Size	Tech_1	Accepted	Accepted	Accepted
	Access to services and utilities	Tech_2	Accepted	Accepted	*Mearged to Rec_Soc_5*
	Availability of vacant land	Tech_3	Accepted	Accepted	Accepted
	Flexibility for facility expansion	Tech_4	Accepted	Accepted	*Mearged to Tech_3*
ENVIRONM ENTAL CRITERIA	Native Vegetation	Env_1	Accepted	Accepted	Accepted
	Distance to water bodies	Env_2	Accepted	Accepted	Accepted
	Soil	Env_3	Accepted	Accepted	Accepted
	Geological Materials	Env_4	Accepted	Rejected	
	Flood Hazard	Env_5	Accepted	Accepted	Accepted
	Ground Water Prospect	Env_5	Accepted	Accepted	Accepted

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POLITICAL CRITERIA	Pressure to locate transfer station in low status neighborhoods or outside community areas	Polit_1	Accepted	Accepted	Accepted
EXCLUSIONARY CRITERIA	Environmental sensitive areas	Exclu_1	Accepted	Accepted	Accepted
	Nearness to airport	Exclu_2	Accepted	Rejected	
	Culturally sensitive areas	Exclu_3	Accepted	Accepted	Accepted
	Archeological preserved sites	Exclu_4	Accepted	Accepted	Accepted
TRANSPOR-TATION RELATED	Proximity to major transportation corridor	Transp_1	Accepted	Accepted	Accepted
	Interference with local traffic	Transp_2	Accepted	Accepted	Accepted
	Proximity to Landfill Site	Transp_3	Accepted	Accepted	Accepted
RECEPTOR RELATED (SOCIO-ECONOMIC CRITERIA)	Population density	Rec_Soc_1	Accepted	Accepted	Accepted
	Public acceptability	Rec_Soc_2	Accepted	Accepted	Accepted
	Distance to nearest building	Rec_Soc_3	Accepted	Accepted	Accepted
	Land Value	Rec_Soc_4	Accepted	Accepted	Accepted
	Public utility facility within 2 km	Rec_Soc_5	Accepted	Accepted	Accepted
	Proximity to Social Infrastructure	Rec_Soc_6	Accepted	Accepted	Accepted
CLIMATIC CRITERIA	Wind Direction	Clim_1	Suggested to add	Accepted	Accepted
	Humidity	Clim_2	Suggested to add	Rejected	
	Rainfall	Clim_3	Suggested to add	Accepted	Accepted

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