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UNITING IDEAS FOR SUCCESSFUL WASTE MANAGEMENT

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"Uniting ideas for successful waste management"

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FOREWORD

The most important expert conference that International Solid Waste Associations (ISWA) organizes is the annual ISWA World Congress. This is an event that brings together in one place and connects all the parties interested in the global problem of solid waste. Every year, representatives of scientific and expert community, representatives of global corporations from this area and political and state officials actively participate in the World Congress. The ISWA Annual Congress 2016 was organized by Serbian Solid Waste Management Association (SeSWA) in Novi Sad, Serbia, September 19 to September 21, 2016.

The theme of this year's conference is "**UNITING IDEAS FOR SUCCESSFUL WASTE MANAGEMENT**". This is the ideal theme for the ongoing global issues of the waste management or mismanagement. As the world moves toward a more urbanized future, the amount of municipal solid waste (MSW), one of the most important by-products of an urban lifestyle, is growing even faster than the rate of urbanization. Locally and globally, existing solid waste management/mismanagement presents challenges and opportunities.

In one hand, in developing countries, poorly managed waste has an enormous impact on health, local and global environment, and economy. Improperly managed waste (open dumps) usually results in down-stream costs higher than what it would have cost to manage the waste properly in the first place. Moreover, collection efficiency of solid waste is less than 50% in many developing countries, causing spread of malaria, dengue fever, cholera, typhoid, respiratory and skin diseases. In some cases uncollected solid waste causes flooding in many developing urban cities.

On the other hand, *in developed countries, collection is not an issue. The major challenges for waste management in developed countries are: (1)* Lack of available space for new landfills, and (2) In some countries with successful recycling program and with waste to energy facilities, are running out of waste to operate their waste to energy facilities.

Therefore, waste management hierarchy may not be same for all countries and all kinds of solid waste; in other words, **ONE SOLUTION DOES NOT FIT ALL**. Therefore, we need to unite our ideas between developing and developed country needs and provide flexible but robust enough solutions for sustainable waste management.

This year's congress, we have received more than 500 (five hundred) papers for presentations and poster presentation from more than 50 different countries. Reviewing all these papers and posters was a major undertaking and the editors with support of scientific committee spent many hours working on them and finally putting them together as "ISWA 2016 Conference Proceedings".

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CONTENTS

MULTI-CRITERIA DECISION ANALYSIS METHODS AS A DECISION SUPPORT TOLLS IN WASTE MANAGEMENT PLANNING – A CASE STUDY OF LANDFILL SITE SELECTION

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Abstract

Decision making process in complex environmental problems often involves large number of independent and sometimes irreconcilable factors. Analysing and comparing environmental, technological, economic and socio-political factors, while having in mind all stakeholders views, seems impossible unless supported with a formal decision making framework, which would facilitate understanding of all processes and influential factors related to decision making, including all criteria’s and confronting interests which are specific to the available alternatives for a problem solution.

Having in mind importance of efficient and objective decision making process, the paper gives general description of the MCDA methods used, and through a case study of landfill site selection process elaborates possible MCDA methods application in a waste management problems. Case study use a real data from a Central Eastern part of Macedonia and provide step by step example of using the AHP method as a tool of choice. Results clearly indicate that AHP can provide proper decision making support, allowing optimal solution selection through inclusion of different and otherwise incomparable criterions like the environmental (flora, fauna, visual aspects, cultural heritage...), technical (geological setting, hydrology, odours, accidents...), planning (location compared to the current land usage, infrastructure, future land usage...) and economic criteria’s (investment and operational costs).

Keywords: Environmental, Waste Management, Decision making, Multi-Criteria Decision Analysis, Analytic Hierarchy Processes, Site Selection, Landfill.

Introduction

According to Bhushan & Rai (2004), decision-making can be considered as the choice, on some basis or criteria, of one alternative among a set of alternatives. In a complex environmental problems were large number of independent and sometimes irreconcilable factors are often involved, a decision need to be taken on the basis of multiple criteria rather than a single criterion. This requires assessment of various criteria (environmental, technological, economic and socio-political) and evaluation of alternatives on the basis of each criteria and then aggregation of these evaluations to achieve the relative ranking of the alternatives with respect to the problem. Therefore application of Multi-criteria decision analysis (MCDA) methods has become indispensable toll in decision making processes for different environmental engineering problems.

There is a quite large number of different MCDA methods, so the paper focuses on MCDA methods most frequently used in environmental decision making. Literature research (Huang et al. 2004, Montis et al. 2004, Kiker et al. 2005) published in the literature identifiesfew of the commonly used methods including; AHP (Analytic Hierarchy Process) in all variations, MAUT (Multi-Attribute Utility Theory), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) and outranking methods like PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) and ELECTRE (Elimination and Choice Expressing Reality).

Huang et al. (2011) has clearly pointed growing use of MCDA methods in environmental engineering applications with fairly steady annual increase of papers in most of the methods after 2000, while AHP methods has dominated MCDA methods ever since. AHP is by far mostly used according to total number of papers published with 48% participation, while MAUT and Outranking (combined ELECTRE and PROMETHEE) are used in 16% and 13% of the papers reviewed, respectively. MCDA methods are used in all areas of environmental engineering including waste management, natural resources management, stakeholders, environmental impact assessment, strategy/policy, remediation/restoration, spatial planning and sustainable manufacturing, with EIA and strategy/policy decision categories as a most frequent applications. Same authors conclude that most of the reviewed papers indicate that the MCDA application provides a significant improvement in the decision process and public acceptance of the suggested actions.

Analytic Hierarchy Process in brief

Analytic Hierarchy Process, originally developed by Professor Thomas L. Saaty (Saaty 1980, Saaty 1990) due to its simplicity and ease of use is one of the most widely used MCDA methods. In general, this is a method to derive ratio scales from paired comparisons. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value. AHP method can use objective (measured or calculated values) or subjective (satisfactions levels, preferences) inputs, and can function even with incomplete or inconsistent inputs Bhushan & Rai (2004). The formal AHP procedure involve three phases Montis et al. (2004):

construct suitable hierarchies;

establish priorities between elements of the hierarchies by means of pairwise comparisons;

check logical consistency of pairwise comparisons.

Phase 1 involve construction of hierarchies. In this phase the problem is decomposed to objects and concepts in different levels and relations between them are identified. The hierarchy model consists of at least three levels; level one is goal of the process, level two correspond to criterions and level three to alternatives, respectively. However, it is possible to develop more complex hierarchies (i.e. with more levels), which include a certain number of sub-criteria Montis et al.(2004).

Phase 2 is about pairwise comparisons. Decision maker assigns relative ranks for all pairs of elements and establishing priorities or weights among the elements of the same level. They are compared in pairs with respect to the corresponding elements in the next higher level, obtaining a matrix of pairwise comparisons Montis et al. (2004). Personal preferences are expressed using evaluation scale (Saaty 1988, 1992). 'Saaty's scale' defines 5 levels and 4 mid values with verbally described intensities, used to compare pairs of elements in each level with criterions in the higher level (Tab.1).

Table 1. 'Saaty's scale (ranking explanation)

1	Equally important	Both criteria or alternatives contribute to the objective equally
3	Moderately important	Based on experience and estimation, moderate preference is given to one criteria or alternative over the other
5	Strictly more important	Based on experience and estimation, strict preference is given to one criteria or alternative over the other
7	Very strict, proven importance	One criteria or alternative is strictly preferred over the other; its dominance has been proven in practice
9	Extreme importance	The evidence based on which one criteria or alternative is preferred over the other has been confirmed to the highest confidence
2, 4, 6, 8	Mid values	

Phase 3 identifies inconsistencies of the decision maker in pairwise comparisons. Degree of consistency is evaluated using 'consistency index' C.I. = $(\lambda max - n)/(n-1)$, where λ max is principal eigenvalue. Consistency ratio (C.R.) is obtained by dividing C.I. with so called 'random index' (R.I.), which increases as the order of the matrix increases (see Tab. 2).

Tab. 2. Values of a random index (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49

If consistency ratio is equal or below 0.10, pair wise comparisons are considered acceptable. In case C.R. has a value above 0.10, it is necessary to investigate the causes for inconsistency and perform new pairwise comparisons. The final result is a complete ranking of the evaluated alternatives.

Although widely used in all kinds of applications, the AHP was criticized from several viewpoints and mostly about rank reversal problem (Ishizaka A and Lusti M, 2006). However the method survived and its usage significantly grows over the last decade and especially with introduction of specialized software's tools.

Decision support for landfill site selection

In order to present 'real life' method application, a step by presentation of AHP method application is given through a case study of landfill site selection in Central Eastern Region of Macedonia. The process involved 11 sites throughout the region and after the process of elimination and reduction, only four sites qualified in the finical selection phase.

Table 3. Alternative landfill locations in CE region

	Alternative	ID
1	Stip, active municipallandfill	A1
2	Karbinci, naturalterrain	A2
3	Probishtip – Sudik ,naturalterrain	A3
4	Bogoslovec, abandoned mine site	A4

As well known, waste disposal operations could have significant environmental impacts if proper preventive and protective measures are not in provided in timely and efficient manner. Proper site selection is definitely one of the most important preventive measures and could significantly increase disposal operations efficiency, both in terms of environmental and financial results. Therefor decision making process should be based on detailed assessment of entire set of different criterions like the environmental (flora, fauna, visual aspects, cultural heritage...), technical (geological setting, hydrology, odours, accidents...), planning (location compared to the current land usage, infrastructure, future land usage...) and economic criteria's (investment and operational costs). Full set of criterions used in our analysis is given below (table 4).

Table 4. Selection criterions

Environmental	Technical	Planning	Economic
Environmental value of the flora	Permeability of the lower soil layer	Gross-net surface ratio	Land acquisition expenses
Environmental value of the fauna	Presence of impermeable layers in the lower soil layer	Interference to infrastructure use	Access to the landfill expenses
Negative impact on the ecosystems	Soil subjection to solidification	Distance to the dwelling areas	Transportation expenses
Cultural-historic value of the area	Position of vulnerable objects related to the underground water flow direction	Distance to industrial, tourist/recreation areas	Personnel and maintenance expenses
Possibilities for visual incorporation into the area	Levels of underground waters and river waters	Distance to natural protected areas	Additional expenses for environment protection
Land use and geomorphology	Odour and air pollution in surrounding area	Distance to the main road	After use rehabilitation expenses
	Disturbance by the traffic	Distance between the landfill location and the waste creation concentration	
	Risks to the surrounding area	Consequences to the agricultural planning	
	Other unpleasantness to the surrounding area	Possibilities for final use	

In order to provide basis for above criterion assessment extensive data collection process involving desktop studies, site visits and public consultations, was undertaken. Special focus was placed on public consultations as a way for collecting all stakeholders' views and inclusion of their assessment of selected criteria. This provide better public acceptance for the decisions taken and reduce effects of NIMBY syndrome.

Analysis of large data sets and comparison of independent and sometimes irreconcilable factors is impossible unless supported with a formal decision making framework like AHP, which would facilitate understanding of all processes and influential factors related to decision making, including all criteria's and confronting interests which are specific to the available alternatives for a problem solution. Decision process involved assessment of all criterions groups separately, but in order to simplify presentation the process for only one of the groups (environmental criterions) is given below. Alternative with highest ranking in two or more criteria groups were selected as the most acceptable site for the landfill location.

As a first step decision matrix for each criterion groups are created (Tab.5). Since the description used is qualitative, predefined quantitative values are used for each of the descriptors used (Tab.6.).

Table 5. Decision matrix for environmental criterions group

	K1	K2	K3	K4	K5	K6
	Min	Min	Min	Min	Max	Min
A1	Extremely high	High	High	Extremely high	High	Extremely high
A2	Average	Low	Average	Extremely high	Average	Extremely high
A3	High	Low	High	Extremely high	Extremely high	Extremely high
A4	Extremely high	High	High	Extremely high	Extremely high	Extremely high

Table 6. Quantitative values for descriptors conversion

Qualitative description	Very bad	Bad	Average	Very good	Excellent	Criterion
Quantitative value	1	3	5	7	9	Max
	9	7	5	3	1	min

Converted decision matrix is given in the table below (Tab.7).

Table 7. Converted decision matrix

	K1	K2	K3	K4	K5	K6
	min	min	min	Min	max	min
A1	1	3	3	1	7	1
A2	5	7	5	1	5	1
A3	3	3	3	1	9	1
A4	1	3	3	1	9	1

Actual AHP process starts with problem decomposition and hierarchy construction. A simple two level hierarchy was developed defining relations between goal (optimal landfill site selection), criterions and alternatives (Fig. 1)

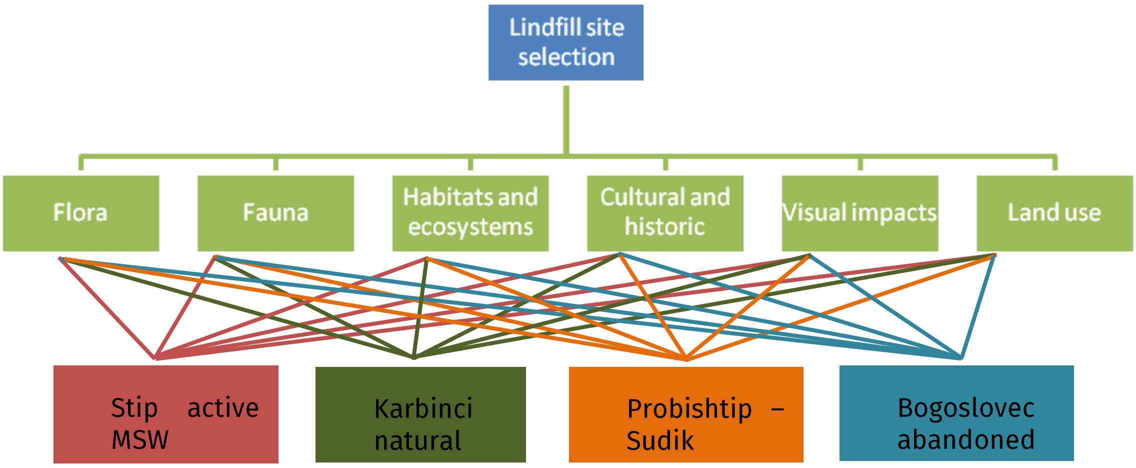

Figure 1. Hierarchy construction

In order to solve the given model, an approximate procedure for obtaining the eigenvector was applied for the first level hierarchy – criterions (environmental group). This procedure involves pairwise comparison in the matrix and sum calculation for elements in each column (Tables 8);

Table 8. Criterions pairwise comparison matrix

	K1	K2	K3	K4	K5	K6
K1	1.00	1.00	1.00	1.00	1.00	1.00
K2	1.00	1.00	1.00	1.00	1.00	1.00
K3	1.00	1.00	1.00	1.00	1.00	1.00
K4	1.00	1.00	1.00	1.00	2.00	2.00
K5	1.00	1.00	1.00	0.50	1.00	2.00
K6	1.00	1.00	1.00	0.50	0.50	1.00
Su	6.00	6.00	6.00	5.00	6.50	8.00

Normalized relative weight for each of the elements (Tab. 9) is calculated by dividing the elements of each column by the sum of values of that column in the table above (Tab. 8). Elements in each row are summarized and average determined (Tab.9).

Table 9. Normalized relative weights and Eigen vector

	B1	B2	B3	B4	B5	B6	B7	B8
	K1	K2	K3	K4	K5	K6	Sum	Average
K1	0.1667	0.1667	0.1667	0.2000	0.1538	0.1250	0.9788	0.1631
K2	0.1667	0.1667	0.1667	0.2000	0.1538	0.1250	0.9788	0.1631
K3	0.1667	0.1667	0.1667	0.2000	0.1538	0.1250	0.9788	0.1631
K4	0.1667	0.1667	0.1667	0.2000	0.3077	0.2500	1.2577	0.2096
K5	0.1667	0.1667	0.1667	0.1000	0.1538	0.2500	1.0038	0.1673
K6	0.1667	0.1667	0.1667	0.1000	0.0769	0.1250	0.8019	0.1337

Column containing the averages is actually the normalized eigenvector, also called the priority vector (Table 9). Given that the vector is normalized, the sum of all elements in the priority vector equals to 1. The priority vector for first level hierarchy represents the relative weights of the criterions compared (Tab. 10).

Table 10. Priority for first level hierarchy (environmental criterions)

K4	0,2096
K5	0,1673
K1	0,1631
K2	0,1631
K3	0,1631
K6	0,1337

Considering that the comparison is based on a subjective evaluation, determination of consistency is necessary in order to ensure the accuracy. Consistency ratio (C.R.) is obtained by dividing consistency index (C.I.) with so called 'random index' (R.I.), which increases as the order of the matrix increases (see Tab. 2). For environmental criterions group, consistency ratio is 5.8 %, determined as described in the AHP phase 3 discussed above.

Same approach was used to calculate priority levels for second level hierarchy, alternatives relative to each criterions from the group (Tab. 11).

Table 11. Priority for second level hierarchy (alternatives relative to environmental criterions)

K1		K2		K3		K4		K5		K6	
A4	0,42401	A4	0.4240	A4	0.4240	A4	0.4240	A1	0.3875	A3	0,3889
A1	0,40128	A1	0.4013	A1	0.4013	A1	0.4013	A4	0.3875	A2	0,3889
A3	0,08990	A3	0.0899	A3	0.0899	A3	0.0899	A3	0.1202	A4	0,1534
A2	0,08480	A2	0.0848	A2	0.0848	A2	0.0848	A2	0.1047	A1	0,0687

Process is finished through a solutions synthesis, by multiplying alternative weights within each criterion (Tab.11), with respective criterion weight (Tab.10). Alternative ranking is calculated by summarizing values calculated in Table 12, for each alternative respectively (Tab. 13). Same process is repeated for all criterions group.

Table 12. Solution calculation

K1 = 0,16	A1 = 0,06547
	A2 = 0,01383
	A3 = 0,01467
	A4 = 0,06917
K2 = 0,16	A1 = 0,06547
	A2 = 0,01383
	A3 = 0,01467
	A4 = 0,06917
K3 = 0,16	A1 = 0,06547
	A2 = 0,01383
	A3 = 0,01467
	A4 = 0,06917
K4 = 0,21	A1 = 0,08412
	A2 = 0,01778
	A3 = 0,01885
	A4 = 0,08888
K5 = 0,17	A1 = 0,06484
	A2 = 0,01752
	A3 = 0,02011
	A4 = 0,06484

K6 = 0,13	A1 = 0,05363
	A2 = 0,01133
	A3 = 0,09497
	A4 = 0,41791

Table 13. Alternative ranking for environmental criterions group

Alternative	Rank
A4	0,41791
A1	0,39899
A3	0,09497
A2	0,08813

Highest ranking alternative is actually optimal solution for respective criterions group, as Alternative 4 is relative to environmental criterions. Alternative 1, was ranked second, but highest ranked in all other criterions groups and therefore selected as an optimal landfilling site in our case study (Tab. 14).

Table 14. Alternatives ranking relative to all criterions group

Environmental criterions		Technical criterions		Planning criterions		Financial criterions	
A4	0,41791	A1	0,4025	A1	0,4072	A1	0,34806
A1	0,39899	A4	0,3242	A4	0,2620	A4	0,24031
A3	0,09497	A3	0,1436	A3	0,1482	A2	0,22163
A2	0,08813	A2	0,1298	A2	0,1826	A3	0,19000

Conclusion and discussion

According to Huang et al. (2011), over the last decade the Multi-Criteria Decision Analysis (MCDA) methods emerged as a formal methodology to face available technical information and stakeholder values and support decisions, especially for environmental engineering applications. What is even more important, the same authors report that in a cases where several methods (analytic hierarchy process - AHP, multi-attribute utility theory- MAUT and outranking) were used in parallel with the same problem, indicates that recommended course of action does not vary significantly with the method applied, thus clearly explaining one of the reasons behind increased usage and confidence in MDCA methods application.

Our case study of landfill site selection in Central Eastern Region of Macedonia, clearly presents MCDA applicability in solving waste management problems, as much as AHP ability to include qualitative descriptors and therefore include personal or public views and assessment of all criterions types.

Having in mind available software support ranging from add ins to sophisticated full packages and ever increasing knowledge base for MCDA methods application, it is clear that this tools can and should be used by environmental practitioners as a tool for making structured and sustainable decisions for problems that require integration of heterogeneous information in relation to the human ambitions and a technical applications.

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