Available online at www.sciencedirect.com
ScienceDirect
Desalination 248 (2009) 1039–1048
DESALINATION
www.elsevier.com/locate/desal

New tool for wastewater treatment units location

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Received 10 July 2008; accepted 22 October 2008

Abstract

In this article, a decision-making process for the potential location of new wastewater treatment units with wide community participation and acceptance is suggested. The main scientific contribution of this work is the elaboration of an independent decision-making tool, which can be used in site selection of wastewater treatment units. Specifically, at a first level, it acts as an intermediary between experts (i.e. engineers, technical advisors) and decision-makers (i.e. electives, appointive advisors), helping decision-makers to use experts' knowledge. At a higher level, it acts as an independent processor of decision-makers' judgments thereby giving a result that is in accordance with pre-chosen criteria. In this way, the local authorities can effectively participate in the decision-making process and avert the violation of possible agreements. Furthermore, the evaluation criteria and the methodology of multi-criteria analysis for new wastewater treatment unit location are presented.

Keywords: Wastewater treatment units; Site selection; Multiple criteria decision-making; Multi-criteria analysis; Evaluation criteria

1. Introduction

Site selection of new wastewater treatment units is one of the most serious local community problems. "Not In My Back Yard" (NIMBY) is often the watch cry for citizens in an area where a wastewater treatment unit is reportedly to be sited. Specifically, NIMBY is a syndrome that is contagious and often irrefutable.

Moreover, non-objective selection procedures, adopted in some cases by the local authorities, decreased the confidence of residents over their authorities. Nowadays, residents living near the candidate wastewater treatment units are sceptical about any procedure the qualified authorities suggest and pre-protest against any decision. In such cases, the failure of the procedure is inevitable.

To go into more detail, a decision on environmental issues cannot be made without the residents' opinion. Local authorities' participation in any decision-making procedure is of great importance. However, such topics require high specialization knowledge. A solution to this problem can be found with special tools,

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Presented at the 2nd Conference on Small and Decentralized Water and Wastewater Treatment Plants (SWAT), Skiathos Island, Greece, May 2–4, 2008

0011-9164/09/$– See front matter
doi:10.1016/j.desal.2008.10.020

which are used as intermediate factors between a complex problem and non-expert users [1].

This article proposes a decision-making process for the potential location of new wastewater treatment units with wide community participation and acceptance. Specifically, a new decision-making tool has been elaborated for improved site selection of wastewater treatment unit. In a first step, an independent team of specialists adopts the tool. In a second step, decision-makers are guided through the evaluation procedure in order to select candidate wastewater treatment units by using several attributes. Finally, data is processed and candidate locations are resulting. The number of stakeholders involved and the extended description of candidate wastewater treatment units by the questionnaire provide an improved basis for decision-making [2].

2. Presentation of the tool

The suggested tool constitutes a third-generation MultiCriteria Decision Support System (MCDSS) [3]. It includes data, dialoging and model subsystems [4]. Furthermore, the proposed tool belongs to level 6 regarding the computer architecture [5] and for its development a high level 5 language (Visual Basic) was used. Modeling course and the main components of the suggested tool are specified in Figs 1 and 2.

The tool's main functions are to provide [2]

- An intermediary between experts (i.e. engineers, technical advisors) and decision-makers

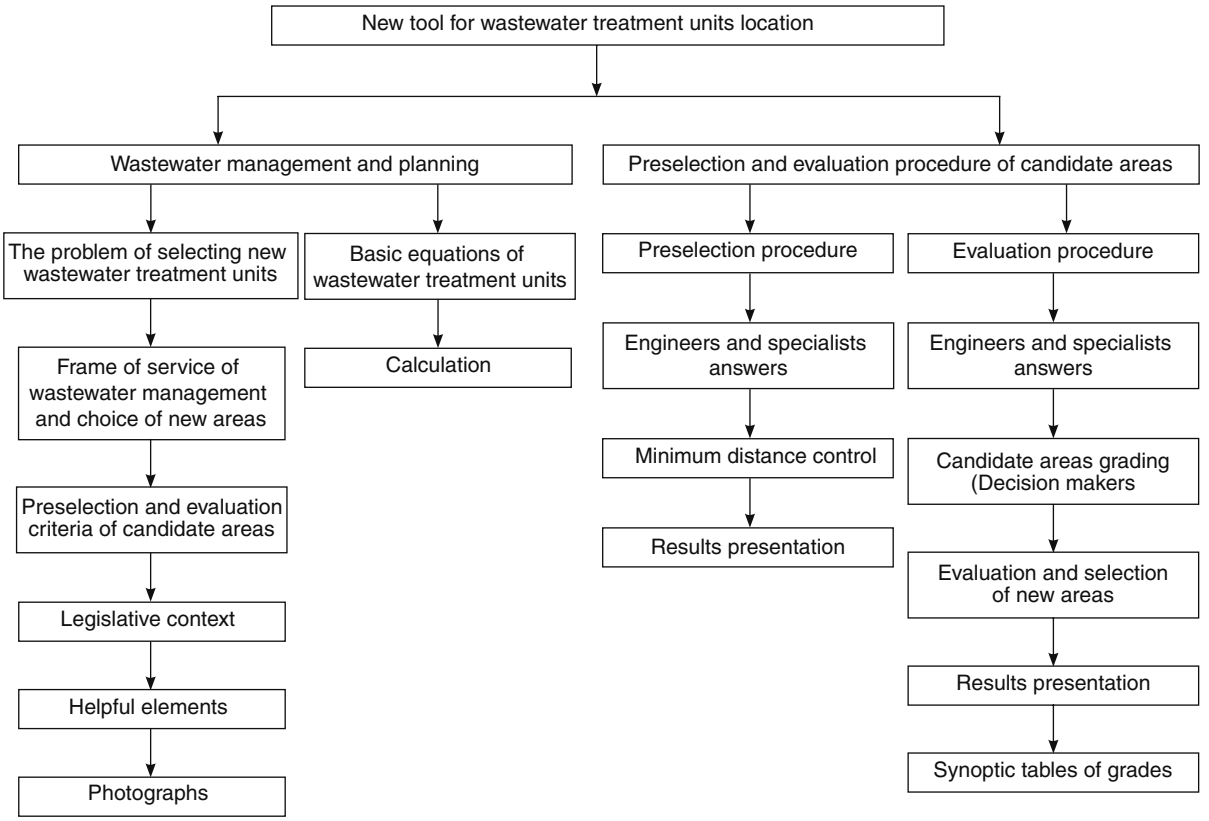

Fig. 1. Modeling course and main components of the suggested tool.

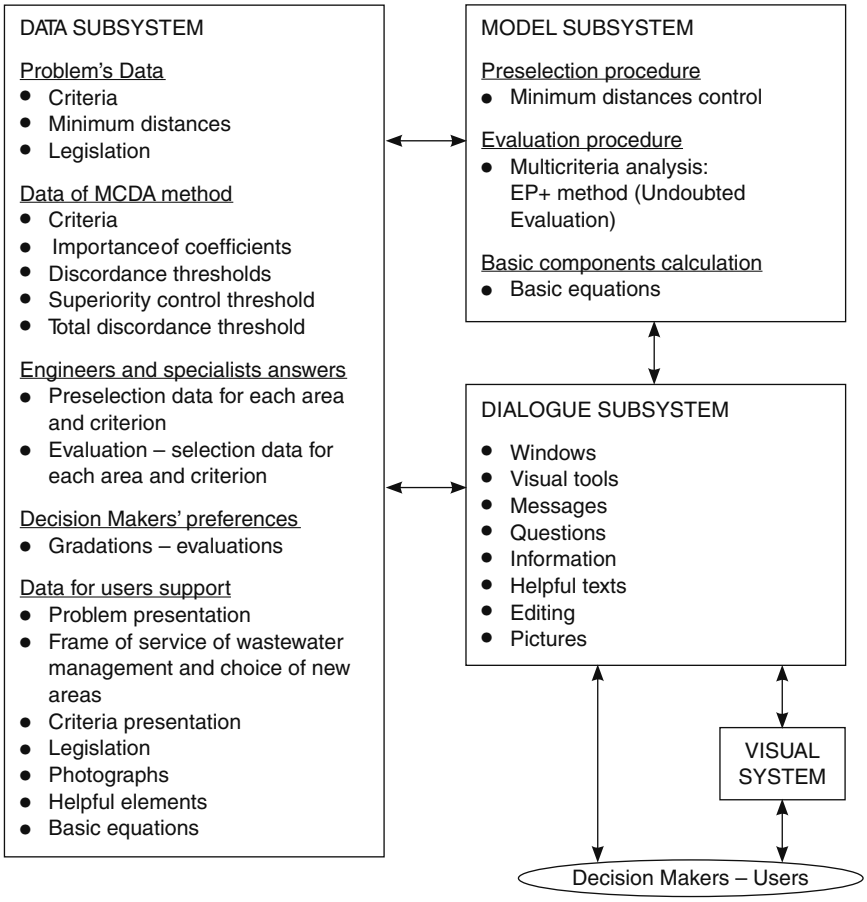

Fig. 2. The components of the suggested tool.

(i.e. electives, appointive advisors), helping decision-makers to understand experts' knowledge

- An independent processor of decision-makers' judgments thereby giving a rational selection procedure.

Specifically, the tool includes the following steps:

- *Preselection*: It realizes the preselection of candidate areas, using a simple procedure of questions–answers between computer and experts and a list of technical specifications.
- *Grades width definition*: It composes an objective selection frame for the preselected areas, using a new procedure of evaluation questions. In this way, it defines the limits of freedom of graders (decision-makers).
- *Decision-makers training*: It helps the decision-makers to understand the wastewater treatment problem, what they are grading and why they have certain limits in grading.
- *Grades registration and data protection*: It calls the responsible decision-makers to grade the candidate areas and ensures the necessary confidentiality, using different passwords.
- *Multi-criteria analysis and decision-making*: It classifies candidate locations based on the Undoubted Evaluation method and suggests the selection of the candidate areas, according to the criteria that have been defined.

- *Control step*: It gives the interested person the option of a comparative evaluation of any two areas, referring analytically to the advantages and the disadvantages of one over the other.
- *Verification step*: It introduces tables with the grades of the candidate areas.
- *Other tool's uses*: The proposed tool is useful in the hands of qualified local authorities, because it includes:
  - a calculator of the basic equations for wastewater treatment units planning
  - a library of wastewater subjects
  - the Greek and European legislation of wastewater
  - an index of preselection and evaluation criteria
  - a legal and technical adviser of authority establishment for wastewater management and choice of new wastewater treatment units.

The preselection, selection and evaluation procedures of candidate areas are briefly introduced in Fig. 3. Furthermore, the main forms of proposed tool are represented in Figs 4–11.

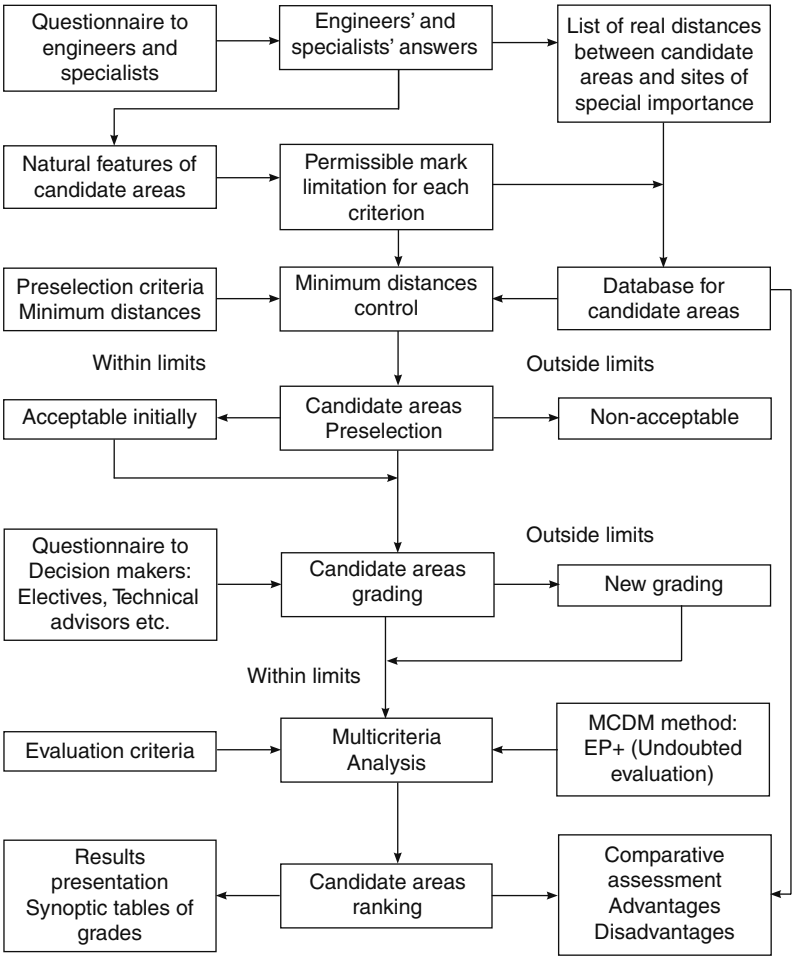

Fig. 3. The preselection, selection and evaluation process for the candidate areas.

Fig. 4. Presentation of proposed tool.

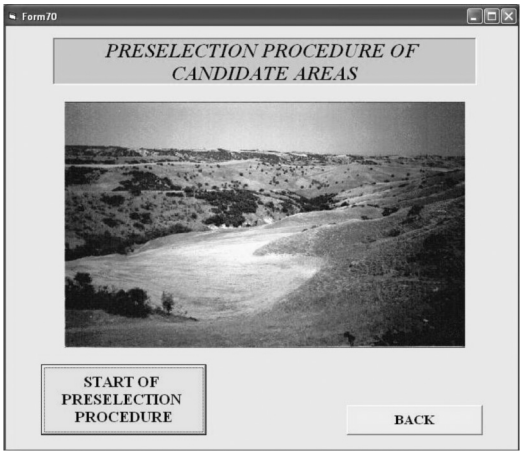

Fig. 6. Presentation of proposed tool.

3. Multi-criteria analysis

Site selection of wastewater treatment unit is a step-by-step process, in which environmental, financial and technical criteria must be applied successively. Therefore, the evaluation of candidate areas can be achieved using multiple criteria decision-making methods, because of the number and the non-uniformity of evaluation criteria. The proposed tool uses the multi-criteria method EP+ "Undoubted Evaluation" [1, 6] so as to ensure a rational procedure. The suggested method is mainly based on the foundations of the ELECTRE I [7] and PROMETHEE II [8] methods. Specifically, it is a combination and an extension of them and consequently preserves intact several fundamental principles of these methods. The entire modeling procedure of this method is presented in Fig. 12.

The main elements of the EP+ are as follows:

- *Set of activities A*: The candidate areas (alternatives) that are defined by responsible authorities, researchers and decision-makers.

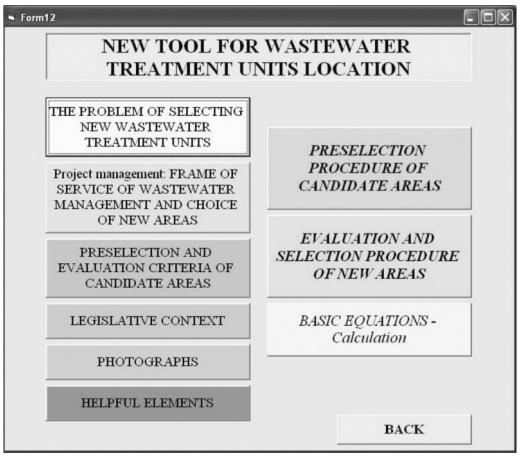

Fig. 5. Presentation of proposed tool.

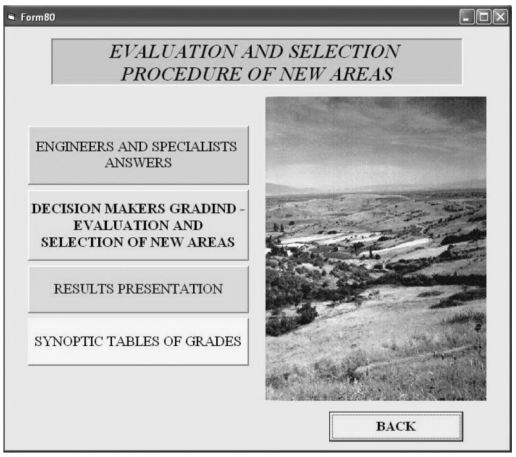

Fig. 7. Presentation of proposed tool.

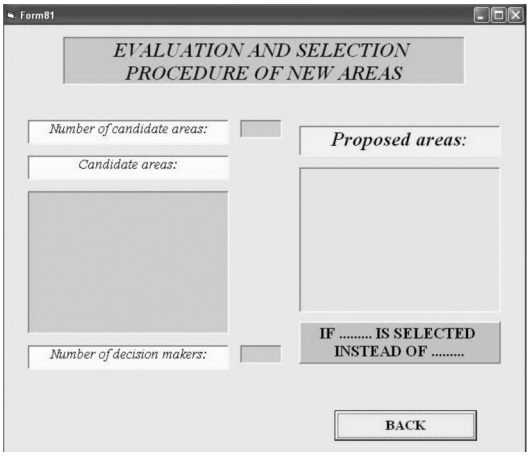

Fig. 8. Presentation of proposed tool.

- *Consequent family of criteria F*: The evaluation criteria (g_1, g_2, …, g_n) that fulfill the three basic conditions – monotony, exhaustion and non-redundancy (minimal) [9].
- *Table of multi-criteria evaluation $g_i(a_i)$*: The grades of decision-makers for each area and criterion, respectively. The quantitative performances of candidate areas should be normalized and therefore the six general criteria of the PROMETHEE method [8] or any other mathematically proven technique could be used.

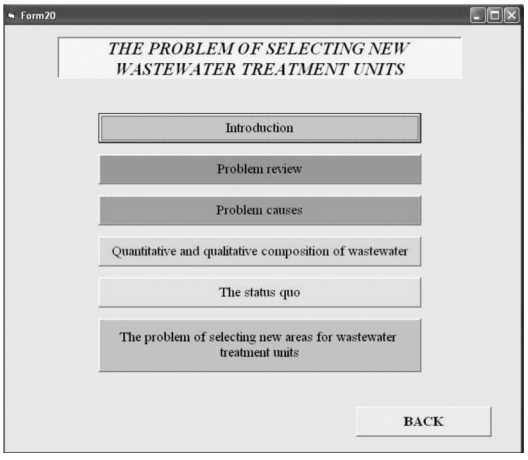

Fig. 9. Presentation of proposed tool.

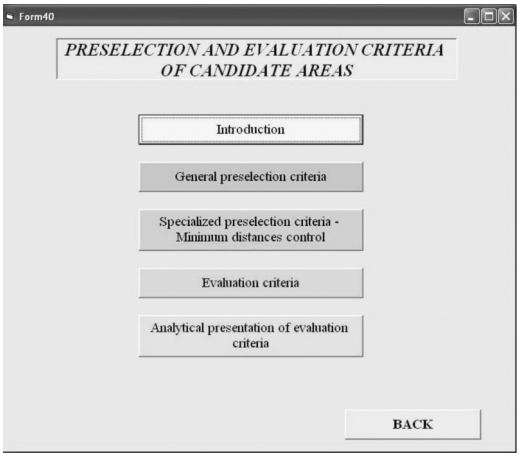

Fig. 10. Presentation of proposed tool.

- *Important coefficients of criteria p_1, p_2, …, p_n*: Normally positive weights of criteria

$$\sum p_i = 1 \Leftrightarrow p_1 + p_2 + \cdots + p_n = 1$$

- *"Undoubted Evaluation" indicator*: For each pair of candidate areas (a,b) is defined:

$$V_C(a,b) = \sum\{p_i[g(a) - g(b)]\}$$
$$\forall i \; where \; g_i(a) > g_i(b)$$

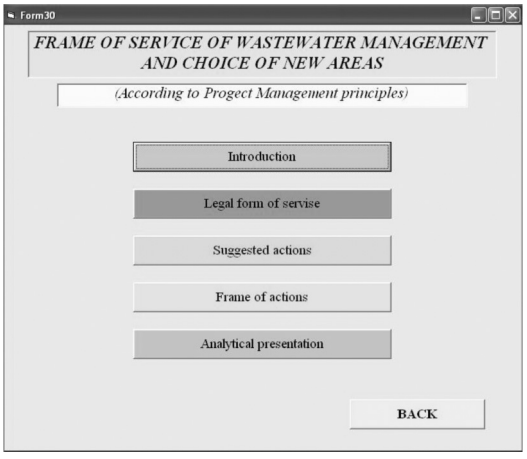

Fig. 11. Presentation of proposed tool.

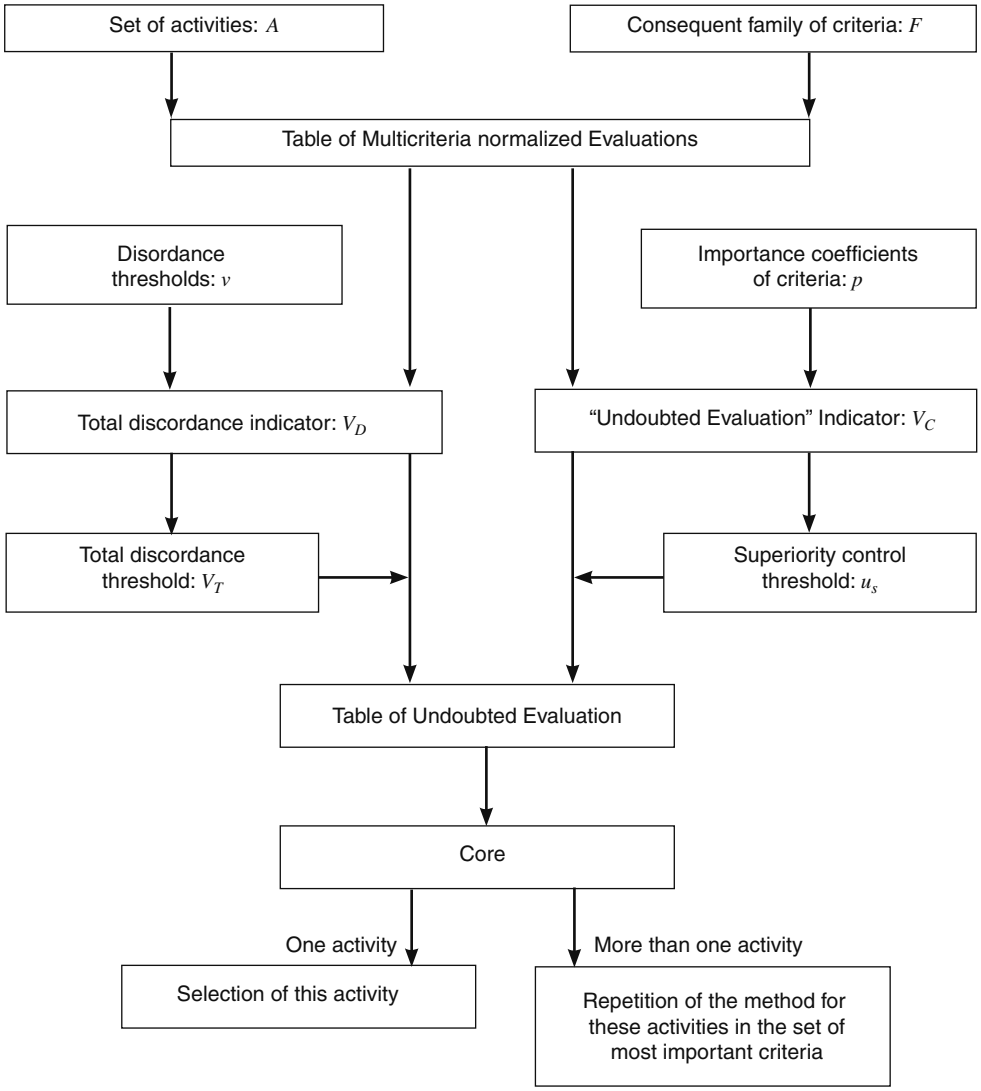

Fig. 12. The MCDA algorithm of EP+ method (Undoubted Evaluation).

- *Superiority control threshold* (u_s): A dimensionless number ($u_s > 0$) is chosen (by modeler) to control the superiority between two areas.
- *Discordance thresholds* $v_1, v_2, \ldots, v_n$: N numbers are chosen (by modeler) to control the large differences between the grades of areas.
- *Total discordance indicator*: For each pair of candidate areas (a,b) is defined

$$V_D(a, b) = \sum p_i \quad \forall j \text{ where } g_j(b) - g_j(a)\, v_j$$

when $g_j(b)$, v_j *discordance threshold*

- *Total discordance threshold* V_T: A dimensionless number is chosen (by modeler) to check

Table 1
Suggested evaluation criteria of candidate areas

	Weight
General criteria	
• Area surface	3
• Area availability	3
• Ownership status	2
• Area cost	2
• Potentials of area use in future	1
Land-planning criteria	
• Distance from residential, tourist and developing areas	3
• Distance from areas of historic, archaeological, architectural or paleontological importance	2
• Distance from areas of natural scenic beauty or natural protection and habitats of protected species or wetlands	2
• Distance from municipal parks, sports centers and areas with recreation sites	3
• Distance from hospitals, medical centers and military bases	3
• Distance from water supply resources, natural or artificial lakes and rivers	3
• Distance from flood zone areas and areas rich in water surface	2
• Distance from unstable areas and areas with subsidence zones or expansive soils	2
Geomorphological criteria	
• Exclusion zone	2
• Visual isolation	3
• Scenic environment	1
• Convenience in the construction of foundation projects	3
• Access to the area	3
• Existing road network	1
• Traffic effects	1
• Ground inclination	1
Hydrogeological criteria	
• Depth of water table	1
• Soil media	1
• Wells' density in solitary rural areas	2
• Monitoring of groundwater	1
Specialized criteria	
• Expansion Potential	1
• Distance from final receiver	2
• Distance from site of sludge disposal	2
• Energy conservation requirements	1
• Centrobaric position (in case that many settlements use the same wastewater treatment unit)	3

the total of the large differences among the grades of candidate areas. The sum of weights of significant criteria is suggested as a total discordance threshold.

- *Table of Undoubted Evaluation*: The set of Undoubted Evaluation relations for each pair of candidate areas (a,b), that is

$$aS_V b \Leftrightarrow V_C(a,b) - V_C(b,a) > u_s$$

and the condition of total discordance is satisfied.

- *Core*: A subset P of F for which the two following properties are true [10]

$$\forall b \in (F-P) \exists a \in P \text{ for which } aS_v b$$
$$\forall a \in P \text{ and } a' \in P \; a \$_V a' \text{ and } a' \$_V a$$

So, the core includes the best areas of set F that the decision-makers must examine.

- *Subset of significant evaluation criteria*: The set of evaluation criteria for which the importance coefficients are bigger than a value given by modeler.

4. Suggested evaluation criteria

As mentioned before, site selection of wastewater treatment unit is a step-by-step process, in which environmental, financial and technical criteria (general, specialized, land-planning, geomorphological and hydrogeological) must be applied successively. These criteria are reconsidered, completed and represented so as to take into consideration in defining a new site of wastewater treatment unit.

Furthermore, the importance (weight) of each criterion has been defined having in mind a large number of reports from the international bibliography [11–17]. Nevertheless, these weights are always matters of discussion and can be modified by the researchers and the decision-makers under the condition that new values will be defined before the beginning of the evaluation procedure. This is necessary in order to secure a rational and bias-free selection procedure.

All these elements (evaluation criteria and their weights) are tabulated and presented in Table 1, so as to apply in multiple criteria decision system procedures or independently.

5. Application of proposed tool

The proposed tool is planned to apply in the coastal settlements of Municipality of Down Olympus of Prefecture, Larissa, in collaboration with the Department of Infrastructure Engineering of ATEI, Larissa. Specifically, in a first step, candidate sites of wastewater treatment units will be recognized having in mind the minimal distances of candidate sites from areas of particular importance. Then, the evaluation criteria for the candidate places will be analysed and the basic elements of the EP+ method (superiority control threshold, discordance thresholds and total discordance threshold) will be determined. The process will be completed with the marking of candidate sites and the determination of core with the better places.

However, a variation of the proposed tool was applied on a pilot scale [18] for the selection of new landfill in West Thessaly, Greece. Specifically, the suggested tool was applied successfully in landfill location using similar criteria suitable for landfill site selection [1].

6. Conclusion

The proposed tool seeks the rational selection of new sites of wastewater treatment units aiming for a wider community participation and acceptance. Initially, it acts as an intermediary between experts and decision-makers, helping decision-makers' training by experts. In addition, it acts as an independent processor of decision-makers' judgments and gives a reliable result using a new multiple criteria decision method (EP+). In this way, it utilizes the experts' knowledge and takes into account local authority and public opinion, averting the violation of prospective agreements. The pilot application of

this tool has shown that it can help significantly researchers and local authorities with wastewater treatment unit location.

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