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Using the fuzzy Analytic Hierarchy Process for selecting wastewater facilities at prefecture level

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Abstract: Although decision makers involved in environmental management issues usually agree on the necessity of interventions, conflicts emerge when interventions are specified and touch upon citizens' reality in their local societies. In this context, a rationalization of the decision-making process is clearly needed in order to deal with conflicting objectives and divergent interests. We propose a multicriteria approach based on the Analytic Hierarchy Process (AHP) for selecting wastewater facilities at prefecture level. On the one hand we take for granted that there is consensus on the structure of hierarchy, i.e. the treatment processes and the criteria used for their evaluation. Evaluation of alternative treatment processes is performed with respect to the number, size, treatment method, and facilities location, and the evaluation criteria are based on the land planning, the environmental and techno-economic considerations, such as construction and operating costs. On the other hand, we propose the fuzzy extension of AHP for dealing with the vagueness of decision makers' judgments. Since decision makers are not normally able to provide a quantitative evaluation of the alternatives but only a qualitative one, the pairwise comparisons are expressed in fuzzy terms. We use this method in a case study, we discuss its application in real world situations, and we conclude that this approach is a viable evaluation device and a good communication tool between analysts and decision-makers.

Key words: AHP, fuzzy sets, triangular fuzzy numbers, multicriteria analysis, wastewater treatment process selection

1. INTRODUCTION

In order to avoid the serious effects of wastewaters in the environment, current legislation requires an appropriate wastewater treatment, which permits the accomplishment of quality objectives in receiving waters after the effluents discharge (CEC 1991, Angelakis and Tchobanoglous 1995, Garcia et al. 2001, Metcalf & Eddy 2003). Direct result of these requirements has been the rapid increase of wastewater treatment plants during the last two decades in many countries, including Greece.

In order to comply with the EU legislation, the effort in Greece, up to now, was focused on the construction of treatment plants in the major cities of each prefecture. However, in many cases important environmental problems emerge in non-sewered rural areas with small population equivalent (p.e.) number where no treatment exists (Hoffmann et al., 2000, Adenso-Diaz et al., 2005). Particular interest present settlements or agglomerations with less than 2000 p.e. that already have or they are about to have sewerage, and those that are not included to the EU legislation but should be taken into account due to sustainability considerations (Balkema et al., 2002).

The planning of full-scale interventions at prefecture level is very complex, given the number of treatment methods, restrictions in their implementation (Angelakis and Tchobanoglous 1995, Gratziou 2003), receivers dilution capability, the existing plants and conduits' networks, and the cost of constructing conduits to connect an agglomeration with the treatment plants. Moreover, decision making must take into consideration not only quantitative but qualitative criteria as well (Angelakis and Tchobanoglous 1995, Balkema et al. 2002, Gratziou 2003, Metcalf & Eddy 2003).

In this paper the fuzzy extension of the Analytic Hierarchy Process (AHP) is performed to evaluate alternative wastewater treatment processes with the use of economic, environmental, and social criteria. As briefly explained in Section 2, this work is part of a GIS based decision support system for the planning of wastewater facilities at prefecture level.

2. LOCATION AND ALLOCATION OF THE WASTEWATERS TREATMENT PLANTS

The proposed multicriteria evaluation is the third of a three steps procedure for the planning of wastewater facilities at prefecture level. In the first step, the candidate agglomerations for wastewaters treatment, the receivers for the final discharge of the effluents, and space availability are specified by spatial analyses using GIS tools. In this way alternative treatment processes are evaluated according to their performance on serving the same amount of p.e., and their ability to achieve the same treatment level as it is defined by receivers' sensitiveness (Angelakis and Tchobanoglous 1995, Gratziou 2003, Metcalf & Eddy 2003).

In the second step centralized or decentralized treatment options are considered. Since the cost of the required conduits becomes very large as their length grows, decentralized treatment becomes more attractive solution. A pole is defined as a single agglomeration or as an aggregation of agglomerations. The implementation of a plant for handling with the wastewaters in each pole is considered to be a feasible scenario. For a catchment area where N agglomerations are settled, the number of possible poles varies between 1 (fully centralized treatment) and N (a treatment plant for each agglomeration). To minimize the total cost of conduits, a minisum algorithm is applied for finding the agglomeration from which the distances from all the others to a pole is minimal. This agglomeration is poles' absolute median, and the plant is located to its neighborhood.

Finally, since every pole is considered to be a feasible scenario for the implementation of a plant, in any possible case multicriteria analysis is performed for selecting the most preferable treatment process for handling poles' wastewaters. The final choice is taken in favor of the scenario, i.e., number of treatment facilities, with the lowest budget, determined by the cost for constructing the facilities and the needed conduits (Adenso-Diaz et al., 2005).

3. MULTICRITERIA APPROACH FOR THE WASTEWATERS TREATMENT PLANTS SELECTION

3.1 The Analytic Hierarchy Process

Developed by T. L. Saaty, the AHP is a multicriteria method for dealing with complex decision-making problems in which many competing alternatives (projects, actions, scenarios) exist (Saaty 1995, Saaty 2005). The alternatives are ranked using several quantitative and/or qualitative criteria, depending on how they contribute in achieving an overall goal. AHP is based on a hierarchical structuring of the elements that are involved in a decision problem. The hierarchy incorporates the knowledge, the experience and the intuition of the decision-maker for the specific problem.

$$
\begin{array}{c|cccc}
K & A_1 & A_2 & \cdots & A_n \\
\hline
A_1 & 1 & a_{12} & \ldots & a_{1n} \\
A_2 & 1/a_{12} & 1 & \ldots & a_{2n} \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
A_n & 1/a_{1n} & 1/a_{2n} & \ldots & 1
\end{array}
$$

Figure 1. Pairwise comparisons matrix A of alternatives P_i with respect to criterion K.

The evaluation of the hierarchy is based on pairwise comparisons. The decision-maker compares two alternatives A_i and A_j using a criterion and assigns a numerical value to their relative weight. The result of the comparison is expressed in a fundamental scale of values ranging from 1 (A_i, A_j contribute equally to the objective) to 9 (the evidence favoring A_i over A_j is of the highest possible order of affirmation). Given that the n elements of a level are evaluated in pairs using an element of the immediately higher level, an $n \times n$ comparison matrix is obtained (Fig. 1).

The decision-maker's judgments may not be consistent with one another. A comparison matrix is consistent if and only if $a_{ij} \times a_{jk} = a_{ik}$ for all i, j, k. AHP measures the inconsistency of judgments by calculating the consistency index CI of the matrix. The consistency index CI is in turn divided by the average random consistency index RI to obtain the consistency ratio CR.

The RI index is a constant value for an $n \times n$ matrix, which has resulted from a computer simulation of $n \times n$ matrices with random values from the 1-9 scale and for which $a_{ij} = 1/a_{ji}$. If CR is less than 5% for a 3×3 matrix, 9% for a 4×4 matrix, and 10% for larger matrices, then the matrix is consistent (Saaty, 1995).

Table 1. Fuzzy scale of preferences

Linguistic Variables	***Crisp AHP Scale***	***Fuzzy AHP Scale***	
		TFS	***Reciprocal TFS***
Equally Preferred (EqP)	*1*	*(1, 1, 1)*	*(1, 1, 1)*
Equally to Moderately Preferred (Eq-MP)	*2*	*(1, 2, 3)*	*(1/3, 1/2, 1)*
Moderately Preferred (MP)	*3*	*(2, 3, 4)*	*(1/4, 1/3, 1/2)*
Moderately to Strongly Preferred (M-SP)	*4*	*(3, 4, 5)*	*(1/5, 1/4, 1/3)*
Strongly Preferred (SP)	*5*	*(4, 5, 6)*	*(1/6, 1/5, 1/4)*
Strongly to Very Strongly Preferred (S-VSP)	*6*	*(5, 6, 7)*	*(1/7, 1/6, 1/5)*
Very Strongly Preferred (VSP)	*7*	*(6, 7, 8)*	*(1/8, 1/7, 1/6)*
Very Strongly to Extremely Preferred (VS-ExP)	*8*	*(7, 8, 9)*	*(1/9, 1/8, 1/7)*
Extremely Preferred (ExP)	*9*	*(8, 9, 9)*	*(1/9, 1/9, 1/8)*

3.2 Fuzzy Extension of the AHP (FAHP)

In the fuzzy extension of the AHP the weights of the nine level fundamental scale of judgments are expressed via the triangular fuzzy numbers (TFN) in order to represent the relative importance among the hierarchy's criteria (Zhu et al. 1999). A TFN is fully characterized by a triple of real numbers (ℓ, m, u), where parameter m gives the maximal grade of the membership function $\mu(x)$, and parameters ℓ and u are the lower and upper bounds which limit the field of the possible evaluation. From a number of scales that have been proposed in literature, we use the one that seems to correspond better to the original preferences scale of the crisp AHP (Table 1) (Zhu et al. 1999, Lamata 2004).

$$\mu(x) = \begin{cases} (x-\ell)/(m-\ell) & x \in [\ell, m] \\ (u-x)/(u-m) & x \in [m, u] \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

Priorities estimation is accomplished using the extent analysis method for estimating the synthetic degree value (Chang, 1996). However, to avoid meaningless results provoked by the direct unrevised application of the real numbers operators, requisite constraints are taken into consideration. In the original version of the method the final ranking of the alternatives is obtained using the so called possibility theory to measure the possibility of dominance of each alternative over the others (Klir 1997, Enea and Piazza 2004). Possibility theory is strongly criticized as defuzzification method, since it assigns quite often zero weights in the hierarchies' criteria and subcriteria (Enea and Piazza, 2004). In order to avoid questionable results and to reduce the loss of information that takes place during the defuzzification process, the overall priorities of the alternatives are obtained in fuzzy terms. Finally, their rankings are reached after normalization of the Best Nonfuzzy Performance (BNP) value, which is estimated using the centre of gravity method according to Equation 2 (Hsieh et al. 2004).

$$BNP_i = (\ell_i + m_i + u_i)/3 \tag{2}$$

4. THE STRUCTURE OF THE HIERARCHY

Treatment processes selection involves the evaluation of various factors that must be considered to meet objectives as they are defined by the local authorities (Abu-Taleb 2000). It is already mentioned that multicriteria selection is a part of a GIS based decision support system. The role of the GIS is crucial given that treatment process feasibility (considering topography, hydrology and other restrictions), land availability, and environmental constraints define the alternatives for evaluation. On the other hand, the notion of agglomerations pole enables alternatives evaluation that are referring to the same influent characteristics and flow variations.

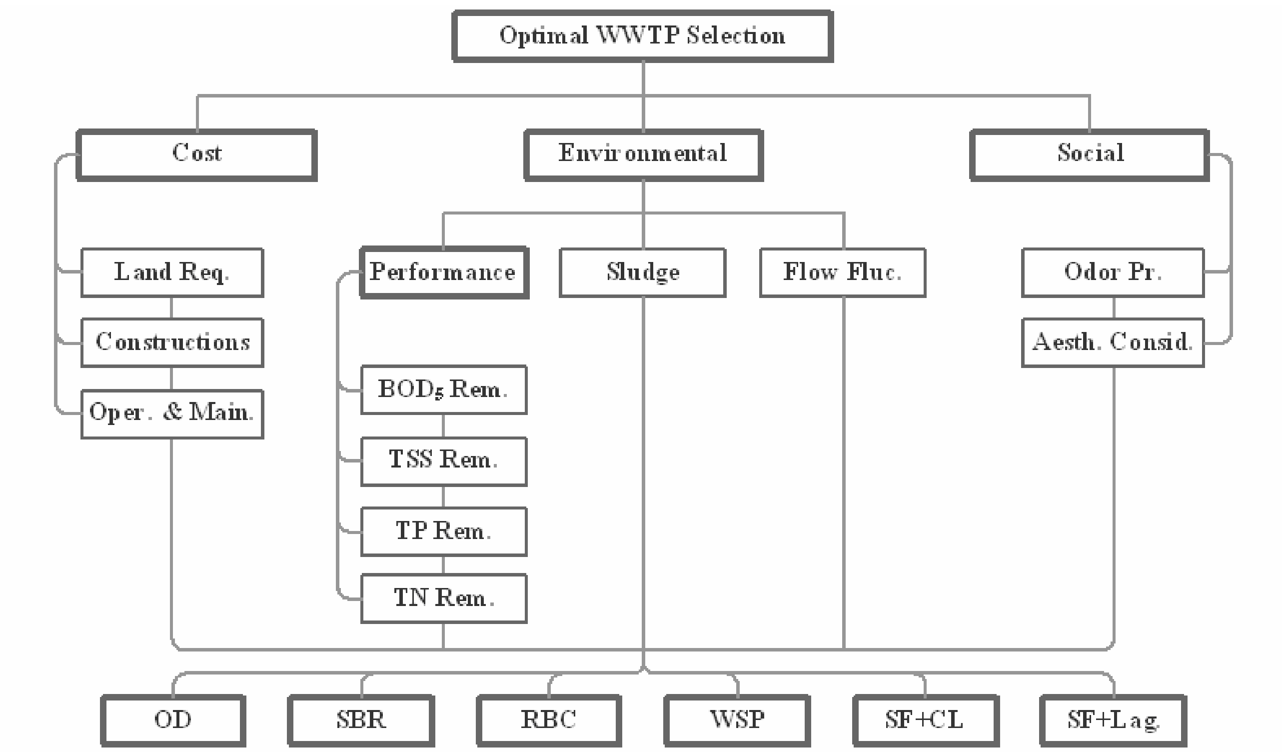

Figure 2. The evaluation hierarchy

In our model, Constrained Fuzzy Analytic Hierarchy Process is used for selecting the most preferable wastewater handling technology in a pole. This is achieved with the use of a four level hierarchy by which Compact Sequential Batch Reactor (SBR), Oxidation Ditch (OD), Rotating Biological Contactor (RBC), Waste Stabilization Ponds (WSP), Horizontal Flow Subsurface Constructed Wetlands with Lagoon (SF+Lag) and Horizontal Subsurface Flow Constructed Wetlands with Chlorination (SF+CL) are evaluated with the use of three sets of criteria (Fig 2) (Balkema et al. 2002).

1. *Cost Criterion* (Cost) is analyzed into the next three subcriteria:

a) *Land Requirements* (Land Req): Cost of land may vary considerably, from pole to pole, as it is depending by its use, its productivity, potential alternative uses and its production capacity. The above reflect on how the specific criterion is prioritized in the hierarchy. For example in highly development tourist coastal areas where land availability is restricted, land requirements subcriterion is getting higher priority compared to rural areas of small productivity. Each one of the alternative treatment processes is evaluated according to the land that will be required for its realization in the examined pole. This is achieved using estimations that allow the reduction to the served p.e. (m^2/p.e.). It is noticed that natural systems require more land compared to the conventional ones.

b) *Construction Cost* (Constr): Usually construction cost includes those for civil and mechanical works, such as buildings, engineering designs and supervision of on-site infrastructure. In the most decentralized options where the amount of the served population is small, the construction cost for the natural systems is smaller. In more centralized options conventional systems are getting higher priorities due to economies of scale. Alternatives evaluation is taken place converting the cost to the served p.e. (€/p.e.).

c) *Operations and Maintenance Cost* (Ope+Main): This subcriterion is formed in general by the personnel, energy, chemicals and maintenance costs. Since the central government funds the construction of the plants, while the local authorities undertake the operational and maintenance costs, the priority of this criterion should be examined in accordance with the prefectures contribution to the gross national product. In other words this criterion is getting higher priority when the model is applied to richer communities and vice versa.

Our model is supported by a database which is supplied with the cost estimations for a range of population equivalent (Mara and Pearson 1998, Gratziou 2002, Tsagarakis et al. 2003).

2. *Environmental Criteria* (Environ).

a) *Performance* (Perform): Alternatives are evaluated according to the quality of the effluents, which is defined by the lower, typical and higher observed performance estimated by the percentage removal of biochemical oxygen demand (BOD Rem), solids in suspension (SS Rem), nitrogen (TN Rem) phosphorous (TP Rem).

b) *Sludge Production* (Sludge Pr): Alternatives are evaluated taking into consideration the amount of the sludge produced by each treatment process.

c) *Flow Fluctuations* (FlowFluc): The response ability of each one of the alternative treatment processes to hydraulic flow fluctuations is evaluated using the fuzzy scale of judgments presented above.

The required data for alternatives evaluation with respect to the environmental criteria have been obtained from references (Hammer 1989, Angelakis and Tchobanoglous 1995, Reed et al. 1995, EPA 1998, Mara and Pearson 1998, Vymazal et al. 1998, EPA 2000i, EPA 2000ii, Kadlec et al. 2000, Metcalf & Eddy 2003).

3. *Social Criteria* (Social). Treatment plants are described as undesirable facilities and when they are located near to inhabited agglomerations give rise to neighborhood opposition. In order to take into account these effects, the next social criteria are also included in the hierarchy:

a) *Odour Problems* (OdourProb): Odours have been rated as the foremost concern of the public relative to the implementation of wastewater treatment facilities (Metcalf & Eddy, 2003). Odour control has become a major consideration in the wastewater treatment facilities design, especially with respect to the public acceptance of these facilities. Many projects have been rejected because of the concern over the potential for odours. In the present paper the evaluation of the alternatives is performed qualitatively. Data from on-site olfactometers measures or determinations of the threshold odour number for each one of the alternatives seems to provide more objectively weights and can be used as well, though persons do not respond in the same way to an odour (Metcalf & Eddy, 2003).

b) *Aesthetic Considerations* (AesthCons): Alternatives are qualitatively evaluated concerning the downgrading of the natural environment, the deterioration of the residents pride and the investment discouragement (Metcalf & Eddy, 2003).

Other researchers use the social cost to measure the impact from the realization of treatment plants next to inhabited agglomerations. Negotiations with the affected citizens are often accompanied by some type of compensation (construction of a new road, improvements in the local schools, and so on), which can always be translated into economic cost. Data from previous compensations paid from the authorities and their reduction to the served p.e. can also be used here. For the final calculations the definition of a social radius around the proposed settlement of the plant is appropriate in order to specify the beneficiaries (Balkema et al. 2002, Adenso-Diaz et al. 2005).

Table 2. Second, third and four level criteria priorities estimation

2nd Level Criteria	***Normalized Eigenvectors***			***Composite Relative Priorities***		
	ℓ	m	u	ℓ	m	u
Cost Criteria	*0.387*	*0.540*	*0.634*	*0.387*	*0.540*	*0.634*
Environmental Criteria	*0.192*	*0.297*	*0.443*	*0.192*	*0.297*	*0.443*
Social Criteria	*0.117*	*0.163*	*0.260*	*0.117*	*0.163*	*0.260*
3rd Level Criteria	***Normalized Eigenvectors***			***Composite Relative Priorities***		
	ℓ	m	u	ℓ	m	u
Land Requirements	*0.085*	*0.109*	*0.149*	*0.033*	*0.059*	*0.095*
Construction Cost	*0.444*	*0.582*	*0.667*	*0.172*	*0.314*	*0.422*
Operation & Maintenance Cost	*0.222*	*0.309*	*0.444*	*0.086*	*0.167*	*0.282*
Performance	*0.584*	*0.661*	*0.714*	*0.112*	*0.196*	*0.317*
Sludge Production	*0.143*	*0.208*	*0.281*	*0.027*	*0.062*	*0.125*
Flow Fluctuations	*0.097*	*0.131*	*0.200*	*0.019*	*0.039*	*0.089*
Odour Problems	*0.667*	*0.750*	*0.800*	*0.078*	*0.123*	*0.208*
Aesthetic Considerations	*0.200*	*0.250*	*0.333*	*0.023*	*0.041*	*0.087*
4th Level Criteria (Performance Criteria)	***Normalized Eigenvectors***			***Composite Relative Priorities***		
	ℓ	m	u	ℓ	m	u
BOD5 Removal	*0.235*	*0.333*	*0.407*	*0.026*	*0.065*	*0.129*
SS Removal	*0.235*	*0.333*	*0.407*	*0.026*	*0.065*	*0.129*
P Removal	*0.125*	*0.167*	*0.250*	*0.014*	*0.033*	*0.079*
N Removal	*0.125*	*0.167*	*0.250*	*0.014*	*0.033*	*0.079*

5. MODEL APPLICATION

The presented model is applied in Evros prefecture and more specifically at the municipality of New Vissa. Two catchment's areas are identified by spatial analyses. In the first one agglomerations of Vissa (3190 p.e.), Kavilli (1650 p.e.) and Sterna (990 p.e.) are settled and in the second Kastanies (1430 p.e.) and Rizia (1870 p.e.). Multicriteria evaluation of the alternative treatment processes is applied in the second case in order to select the best treatment plant for serving a total of 3300 p.e.

According to the AHP methodology, second level criteria are evaluated via pairwise comparisons with respect to the overall goal (selection of the best treatment process), while third and fourth level criteria are evaluated for their relative importance to the criterion or subcriterion they belong. The evaluations are expressed using the fuzzy scale of preferences (Table 1) and then the composite relative priorities are calculated (Table 2). Finally, the alternatives are compared according to their performance in each one of the selection criteria using common scales for the quantitative parameters, and AHP scale of weights for the qualitative criteria. As regards to the quantitative criteria priorities of the alternatives from pairwise comparisons derived using the ratio of their performance considering the examined criterion. For example, for two alternatives A_i, A_j if we consider that their performance under a specific quantitative criterion is $w_i = (l_i, m_i, u_i)$ and $w_j = (l_j, m_j, u_j)$ respectively, then the measure of their relative importance is expressed as $\alpha_{ij} = w_i/w_j = (l_i/u_j, m_i/m_j, u_i/l_j)$. Priorities vectors S_i (synthetic degree value) are calculated using the following equations:

$$S_i = \begin{cases} S_{li} = min\left[\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right] / \sum_{k=1}^{n}\left[\left(\prod_{j=1}^{n} a_{kj}\right)^{1/n}\right] \\ S_{mi} = \left[\left(\prod_{j=1}^{n} m_{ij}\right)^{1/n}\right] / \sum_{k=1}^{n}\left[\left(\prod_{j=1}^{n} m_{kj}\right)^{1/n}\right] \\ S_{ui} = max\left[\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right] / \sum_{k=1}^{n}\left[\left(\prod_{j=1}^{n} a_{kj}\right)^{1/n}\right] \end{cases} \quad (3)$$

subject to

$$a_{kj} \in \left[l_{kj}, u_{kj}\right], \forall j \succ k$$

$$a_{kj} = 1/a_{kj}, \forall j \prec k$$

$$a_{jj} = 1$$

The fuzzy impact score of alternatives is obtained by adding the synthetic degrees values S_i weighed by the corresponding fuzzy composite relative priorities of the parent node criterion (Table 3). Then the final ranking is estimated using Equation 2 (Table 4).

The final ranking of the alternative processes shows that natural systems in general derive higher priority than the conventional ones. Specifically, Waste Stabilization Ponds and the two options of Horizontal Flow Subsurface Contracted Wetlands are ranked in the first positions deriving priorities of 18.8%, 18.3% and 18.0% respectively. The only conventional treatment option that seems to compete the natural processes is the Sequential Batch Reactor which is ranked fourth with a total priority of 17.1%. The other two examined processes, Oxidation Ditch and Rotating Biological Reactor are ranked last deriving priorities of 15% and 12.9% respectively. Land applicability in the examined area will define the final selection (Table 4).

FAHP can be successfully used by a certain group of interest or can be applied through a group decision process. In the second case it is possible serious debates to arise during the weights assignment process. For example, the prefecture authorities who fund the facilities consider their cost of higher importance. The opposite is obtained when the municipality authorities assign weights, since operations and maintenance costs as well as social criteria are considered as more significant. When a compromise is not reached, priorities can be derived by calculating the geometric mean of the participants proposed weights.

6. CONCLUSIONS

Multicriteria analysis is a powerful approach to decision making problems, especially to the wastewater treatment plant selection, in which economic, technical and social criteria must be taken into consideration in order to achieve an optimal evaluation of the alternatives. We have proposed a generic approach based on the Fuzzy Analytic Hierarchy Process multicriteria method for selecting wastewater treatment process. This approach has been proved to be a workable and flexible tool that offers good communication between engineers and decision-makers. In comparison with the original method, the triangular fuzzy numbers used in the fuzzy extension of the Analytic Hierarchy

Process reflect in a more proper way decision makers' intuition and experience when they assign weights during the pairwise comparisons phase. The proposed model can be used for agglomerations up to 10000 p.e., using each time the appropriate costs estimations. Finally, constraints (geological, temperature etc) obtained via GIS based tools could reduce the number of

Table 3. Synthetic degree values for the alternative treatment processes

Treatment Process Selection Criteria	***S.B.R.***						***O.D.***					
	Normalized Eigenvectors			***Composite Relative Priorities***			***Normalized Eigenvectors***			***Composite Relative Priorities***		
	ℓ	m	u	ℓ	m	u	ℓ	m	u	ℓ	m	u
Land Requir.	*0.129*	*0.355*	*0.661*	*0.004*	*0.021*	*0.063*	*0.145*	*0.355*	*0.661*	*0.005*	*0.021*	*0.063*
Constructions	*0.170*	*0.199*	*0.228*	*0.029*	*0.063*	*0.096*	*0.093*	*0.111*	*0.129*	*0.016*	*0.035*	*0.054*
Oper. & Maint.	*0.121*	*0.127*	*0.133*	*0.010*	*0.021*	*0.037*	*0.114*	*0.120*	*0.125*	*0.010*	*0.020*	*0.035*
BOD5 Removal	*0.170*	*0.188*	*0.209*	*0.004*	*0.012*	*0.027*	*0.172*	*0.186*	*0.209*	*0.005*	*0.012*	*0.027*
SS Removal	*0.146*	*0.179*	*0.223*	*0.004*	*0.012*	*0.029*	*0.146*	*0.179*	*0.223*	*0.004*	*0.012*	*0.029*
P Removal	*0.016*	*0.059*	*0.144*	*0.000*	*0.002*	*0.011*	*0.146*	*0.179*	*0.223*	*0.002*	*0.006*	*0.018*
N Removal	*0.207*	*0.247*	*0.286*	*0.003*	*0.008*	*0.023*	*0.207*	*0.247*	*0.286*	*0.003*	*0.008*	*0.023*
Sludge Production	*0.041*	*0.052*	*0.069*	*0.001*	*0.003*	*0.009*	*0.041*	*0.052*	*0.067*	*0.001*	*0.003*	*0.008*
Flow Fluctuations	*0.053*	*0.071*	*0.101*	*0.001*	*0.003*	*0.009*	*0.053*	*0.071*	*0.083*	*0.001*	*0.003*	*0.007*
Odor Problems	*0.172*	*0.263*	*0.341*	*0.013*	*0.032*	*0.071*	*0.182*	*0.263*	*0.341*	*0.014*	*0.032*	*0.071*
Aesthetic Consider.	*0.069*	*0.090*	*0.128*	*0.002*	*0.004*	*0.011*	*0.069*	*0.090*	*0.128*	*0.002*	*0.004*	*0.011*
FINAL PRIORITIES				***0.072***	***0.181***	***0.386***				***0.062***	***0.156***	***0.346***

Treatment Process Selection Criteria	***R.B.C.***						***W.S.P.***					
	Normalized Eigenvectors			***Composite Relative Priorities***			***Normalized Eigenvectors***			***Composite Relative Priorities***		
	ℓ	m	u	ℓ	m	u	ℓ	m	u	ℓ	m	u
Land Requir.	*0.031*	*0.101*	*0.199*	*0.001*	*0.006*	*0.019*	*0.014*	*0.059*	*0.137*	*0.000*	*0.003*	*0.013*
Constructions	*0.112*	*0.133*	*0.154*	*0.019*	*0.042*	*0.065*	*0.163*	*0.202*	*0.279*	*0.028*	*0.063*	*0.118*
Oper. & Maint.	*0.143*	*0.150*	*0.156*	*0.012*	*0.025*	*0.044*	*0.211*	*0.225*	*0.278*	*0.018*	*0.037*	*0.078*
BOD5 Removal	*0.120*	*0.144*	*0.174*	*0.003*	*0.009*	*0.022*	*0.154*	*0.176*	*0.237*	*0.004*	*0.012*	*0.031*
SS Removal	*0.144*	*0.172*	*0.210*	*0.004*	*0.011*	*0.027*	*0.050*	*0.108*	*0.190*	*0.001*	*0.007*	*0.025*
P Removal	*0.016*	*0.059*	*0.144*	*0.000*	*0.002*	*0.011*	*0.143*	*0.296*	*0.557*	*0.002*	*0.010*	*0.044*
N Removal	*0.025*	*0.040*	*0.057*	*0.000*	*0.001*	*0.004*	*0.184*	*0.220*	*0.287*	*0.003*	*0.007*	*0.023*
Sludge Production	*0.061*	*0.094*	*0.134*	*0.002*	*0.006*	*0.017*	*0.184*	*0.237*	*0.331*	*0.005*	*0.015*	*0.041*
Flow Fluctuations	*0.073*	*0.120*	*0.185*	*0.001*	*0.005*	*0.016*	*0.184*	*0.244*	*0.354*	*0.003*	*0.010*	*0.031*
Odor Problems	*0.113*	*0.177*	*0.282*	*0.009*	*0.022*	*0.059*	*0.046*	*0.062*	*0.125*	*0.004*	*0.008*	*0.026*
Aesthetic Consider.	*0.069*	*0.090*	*0.128*	*0.002*	*0.004*	*0.011*	*0.094*	*0.164*	*0.282*	*0.002*	*0.007*	*0.024*
FINAL PRIORITIES				***0.054***	***0.132***	***0.296***				***0.071***	***0.178***	***0.454***

Treatment Process Selection Criteria	***S.F.+L.***						***S.F.+CL.***					
	Normalized Eigenvectors			***Composite Relative Priorities***			***Normalized Eigenvectors***			***Composite Relative Priorities***		
	ℓ	m	u	ℓ	m	u	ℓ	m	u	ℓ	m	u
Land Requir.	*0.019*	*0.059*	*0.151*	*0.001*	*0.003*	*0.014*	*0.121*	*0.152*	*0.189*	*0.004*	*0.009*	*0.018*
Constructions	*0.164*	*0.203*	*0.246*	*0.028*	*0.064*	*0.104*	*0.156*	*0.167*	*0.178*	*0.027*	*0.052*	*0.075*
Oper. & Maint.	*0.199*	*0.212*	*0.228*	*0.017*	*0.035*	*0.064*	*0.123*	*0.153*	*0.180*	*0.011*	*0.026*	*0.051*
BOD5 Removal	*0.123*	*0.153*	*0.180*	*0.003*	*0.010*	*0.023*	*0.148*	*0.181*	*0.223*	*0.004*	*0.012*	*0.029*
SS Removal	*0.148*	*0.181*	*0.220*	*0.004*	*0.012*	*0.028*	*0.102*	*0.263*	*0.510*	*0.003*	*0.017*	*0.066*
P Removal	*0.102*	*0.263*	*0.437*	*0.001*	*0.009*	*0.035*	*0.102*	*0.263*	*0.510*	*0.001*	*0.009*	*0.040*
N Removal	*0.097*	*0.123*	*0.167*	*0.001*	*0.004*	*0.013*	*0.097*	*0.123*	*0.163*	*0.001*	*0.004*	*0.013*

Sludge Production	*0.226*	*0.299*	*0.330*	*0.006*	*0.018*	*0.041*	*0.223*	*0.266*	*0.292*	*0.006*	*0.016*	*0.036*
Flow Fluctuations	*0.203*	*0.262*	*0.307*	*0.004*	*0.010*	*0.027*	*0.175*	*0.233*	*0.266*	*0.003*	*0.009*	*0.024*
Odor Problems	*0.082*	*0.117*	*0.186*	*0.006*	*0.014*	*0.039*	*0.082*	*0.117*	*0.192*	*0.006*	*0.014*	*0.040*
Aesthetic Consider.	*0.201*	*0.283*	*0.330*	*0.005*	*0.012*	*0.029*	*0.201*	*0.283*	*0.355*	*0.005*	*0.012*	*0.031*
FINAL PRIORITIES				***0.077***	***0.192***	***0.417***				***0.071***	***0.180***	***0.423***

the candidate solutions, while the presented poles' methodology determines the optimal location for the selected treatment plant.

Table 4. Estimation of alternatives crisp priorities

S.B.R.		***O.D.***		***R.B.C.***	
Weight Vector	*0.213*	*Weight Vector*	*0.188*	*Weight Vector*	*0.161*
Overall Priority	*0.171*	*Overall Priority*	*0.150*	*Overall Priority*	*0.129*
RANK	***4th***	***RANK***	***5th***	***RANK***	***6th***
W.S.P.		***S.F.+L.***		***S.F.+CL.***	
Weight Vector	*0.234*	*Weight Vector*	*0.229*	*Weight Vector*	*0.225*
Overall Priority	*0.188*	*Overall Priority*	*0.183*	*Overall Priority*	*0.180*
RANK	***1st***	***RANK***	***2nd***	***RANK***	***3rd***

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