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A Hybrid Multicriteria 0/1 Programming Methodology for Prioritizing the Measures of River Basin Management Plans †

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Abstract: The Programmes of Measures (PoMs) are included in the River Basin Management Plans (RBMPs). They comprise the outputs on the analysis of pressures, impacts and status of the water bodies, by designating those actions that need to be employed for the amelioration of the water quality status. In this research a methodology based on the coupling of hybrid multicriteria methods, namely outranking, in which 6 criteria and 37 alternatives are integrated, with a 0/1 linear programming in which the cost of the measures is induced as a constraint, is proposed for the prioritization of the supplementary PoMs that are included in the RBMP of Central Macedonia, Greece. The results of the research demonstrated the usefulness of the methodology when financial constraints do not permit the implementation of the whole set of measures.

Keywords: multicriteria methods; fuzzy sets and logic; 0-1 programming; programme of measures; River Basin Management Plans; Central Macedonia Water District

1. Introduction

The aim of the Water Framework Directive (WFD) is to prevent deterioration of the aquatic environment and to achieve good status of all water bodies by 2015 [1,2]. For that purpose, a framework for sustainable water management through the development of River Basin Management Plans (RBMPs) at the scale of designated water districts has been created in order for adequate knowledge of the pressures, impacts and status of the water bodies to be established. The WFD planning process is designed to deliver this knowledge base to take well informed decisions about the pressures and impacts on the environment and thereafter to propose through the Programmes of Measures (PoMs) specific measures for ameliorating the water quality. The PoMs, which are organized in basic and supplementary measures, focus on achieving the environmental objectives of the Directive and include the actions that Member States plan to take for that purpose.

According to data of 2015 [3,4] the most common measures reported by Member States are (i) construction or upgrade of urban waste water treatment (ii) reduction of nutrient pollution in agriculture;(iii) improving river continuity and other hydromorphological measures;(iv) research, improvement of knowledge base reducing uncertainty; and (v) drinking water protection measures. Moreover, data retrieved by the European Environmental Agency [3] indicate that at the end of 2016 at EU level, only 23% of and 29% of the proposed specific basic and supplementary measures respectively, were reported as completed. The same source reveals that 11% and 17% of the proposed basic and supplementary measures have not started. The main issue for the non- implementation process of both type of measures lies behind funding and financial obstacles.

The use of economic tools and principles for the achievement of the Directive's ecological objectives is one of its most novel and interesting aspects [4]. Particularly, Annex III (b) of the WFD states that the economic analysis shall 'make judgments about the most cost-effective combination of measures in respect of water uses to be included in the programme of measures under Article 11 based on estimates of the potential costs of such measures'. The literature proposes various methods for the aforementioned economic assessment, such as the cost recovery ratio for the irrigation sector [5] and the cost-effectiveness analysis (CEA) [6–8].

The selection of the most-cost-effective combination of measures is not a solely economic issue, i.e., measures with the lower cost are the most appropriate, but also includes subjects related to the water resources and the environment, such as water bodies' quality status, socioeconomic and environmental impacts, synergies among the measures, and effectiveness of the measures against the environmental targets. Moreover, there are arguments which put emphasis on the bias of the cost effectiveness method towards large scale actions [9] and on the mono-disciplinary (predominately neoclassical) perspective instead of the multicriteria synthesis [10]. In addition, in cases where it is needed to evaluate multiple conflicting criteria for environmental and resource management in the decision-making process, multicriteria analysis (MCA) could provide scientifically sound solutions [11,12]. MCA has also been used to explore non-market monetary values of water quality changes in the context of the WFD, and particularly a specific MCA method, namely the Analytical Hierarchy Process (AHP), was proposed to investigate whether the water quality improvements were measured using a water quality ladder [13].

The main MCA methods could be classified as: (1) Value measurement approach (e.g., Utility theory); (2) Satisfying approach, especially the distance methods (e.g., compromise programming, goal programming) and (3) Outranking methods (e.g., Electre family, Promethee) [14]. The later focus on the application of pairwise comparison of alternatives to discrete choice problems. The outranking methods differ from the value function methods on the fact that there is no underlying aggregative value function. The output of an analysis is not a value of each alternative, but an outranking relation on the set of alternatives.

This research aims at proposing a multicriteria method that integrates a fuzzy set approach, namely outranking based method (first phase), and a 0/1 linear programming approach (second phase) for prioritizing the measures included in the PoMs of RBMPs by considering the availability of national funds for the implementation process. The application field of the proposed methodology is the Water District of Central Macedonia, Greece. The specific area includes both transboundary and national water bodies with different water uses and water demands.

2. Materials and Methods

2.1. Case Study Area

The Water District of Central Macedonia (WD GR10), Greece, includes four River Basins, namely Axios, with an area of 3327 km^2, Gallikos, with an area of 1051 km^2, Chalkidiki, with an area of 5546 km^2 and Athos, with an area of 239 km^2. According to 2011 census data, the permanent population of the WD GR10 is 1,420,321 inhabitants, with the employment structure to be allocated as 16.9%, 26.5% and 56.6% to the primary, secondary and tertiary sector respectively [15]. The water uses are classified in water supply, irrigation, livestock, industry and mining, with the total annual demand on water for all uses to be about 1593 hm^3 (approximately 22.4% of the water demands are covered from a neighboring Water District) [15]. Although a small percentage of labor force is engaged in the primary sector, the irrigation demands on water are tremendous and equal to 1361 hm^3 (85%), while the water volumes for the industry and water supply are 41 hm^3 (3%) and 177 hm^3 (11%) respectively. As for the anthropogenic pressures, the analysis of the data derived from the RBMP of WD GR10 [16], demonstrated that the pressures come from urban wastewater, industry, livestock, landfill sites—uncontrolled waste dumping sites, mines and quarries, aquaculture and agriculture.

For the confrontation of the aforementioned pressures in the WDGR10, the PoMs consist of 76 measures, 39 basic and 37 supplementary measures. The supplementary measures on which the proposed methodology is implemented are presented in Table 1. Based on the WFD nomenclature, the SM02-10 and SM03-10 belong to the category "Administrative Measures", i.e., these measures have limited cost, SM04-10 to SM04-30 to the category "Environmental agreements after negotiations", with these measures to have zero cost, SM05-30 to SM05-50 to the category "Emission Limits Values", measures with moderate cost, SM07-10 and SM07-20 to the category "Recreation and Restoration of wetlands areas", i.e., measures with significant cost, SM08-10 to SM08-40 to the category "Monitoring abstractions", i.e., relatively small cost, SM11-10 to SM11-80 to the category "Construction projects", i.e., measures with significant cost, SM15-10 to SM15-40 are classified as "Educational Measures", i.e., measures with small cost, SM16-10 to SM16-30 are classified as "Research, development and demonstration Projects (best practices)", i.e., measures with adequate cost, while SM17-10 to SM17-100 belong to the category "Other measures", with these measures to have variant but relatively small cost. The more general term "alternative" can be used also instead of "measure" which is used in the multicriteria theory.

Table 1. List of supplementary measures of the RBMP of Central Macedonia River Basin District.

alt.	Code	Description	Cost (*10^3€)
X_1	SM02-10	Increase of reporting frequency of the environmental licensing of companies operating in areas where there are strong pressures	0
X_2	SM03-10	Reform of water providers accounting systems	405
X_3	SM04-10	Agreements with industries that consume large water quantities or generate pollution in WB for adopting codes of good practices	0
X_4	SM04-20	Promotion of agreements with owners of tourist accommodation establishments	0
X_5	SM04-30	Promotion of producers' participation in the Agricultural Production Integrated Management Systems	0
X_6	SM05-30	Hydrogeological-hydrochemical survey to GWB with high concentrations of chemical substances, due to natural background	2095
X_7	SM05-40	Special protection measures in areas with GW bodies where geothermal and mineral waters exist	0
X_8	SM05-50	Rehabilitation of Thessaloniki Gulf by mechanical means	240
X_9	SM07-10	Measures from the approved recovery plan of the National Park for the lakes Koroneia-Volvi and Macedonian Tembi	120,361
X_{10}	SM07-20	Integrated Coastal Monitoring of Environmental Problems in Sea Region and the Ways of their Solution (ICME)	1070
X_{11}	SM08-10	Setting out terms for the protection of the granular system Ormylia after the completion of Chavrias dam	0
X_{12}	SM08-20	Installation of a functional valve in artesian wells	0
X_{13}	SM08-30	Definition of principle restriction zones for drilling new wells in coastal GW bodies where seawater intrusion is observed	0
X_{14}	SM08-40	Definition and delimitation of areas of GWB that have poor quality due to seawater intrusion or exhibit local seawater intrusion	1295
X_{15}	SM11-10	Chavria's dam and networks of Chavria's dam	65,000
X_{16}	SM11-20	Petrenia Dam in the area Gomati and storage, treatment and distribution projects	46,265
X_{17}	SM11-30	Landfill Site expansion in the area of Cassandra	6704
X_{18}	SM11-40	Landfill Site Development in the NW part of the Regional Unit of Thessaloniki	7347
X_{19}	SM11-50	Landfill Site Restoration in the Municipality of Kilkis	4761
X_{20}	SM11-60	Landfill Site / Residue at the 4th Management Unit in Chalkidiki	14,856
X_{21}	SM11-70	Completion of maturation processes of Fanos dam at Paionia (KotzaDere)	2700
X_{22}	SM11-80	Construction of the main sewer of Thessaloniki	24,200
X_{23}	SM15-10	Enhancing the Environmental Education Centre of the Regional Units	150
X_{24}	SM15-20	Management of riparian habitats and visitors, knowledge spreading and public awareness raising in protected areas	867
X_{25}	SM15-30	Educational Actions to promote the prudent and rational utilization of water resources.	90
X_{26}	SM15-40	Consulting services to farmers for the improvement of practices of means and supplies for the protection of the environment.	30
X_{27}	SM16-10	Preparation of research studies for the artificial recharge of GW bodies with treated effluents from WWTP and Industrial WWTP	1036
X_{28}	SM16-20	Integrated Green Cities (INGREENCI)	646

X_{29}	SM16-30	Actions for protection of coastal habitats and important avifauna species in NATURA 2000 areas (Epanomi&Aggelohori lagoons)	1639
X_{30}	SM17-10	Further investigation of exceedances in chemical substances that are recorded in lake Koronia.	145
X_{31}	SM17-30	Further investigation of exceedances in chemicals substances that are recorded in lake Volvi	145
X_{32}	SM17-40	Mitigating the Vulnerability of Water Resources in the context of climate change	167
X_{33}	SM17-50	ENVI/Local Communities in Environmental Action	231
X_{34}	SM17-70	Sampling and analysis of water inside and outside the port of Thessaloniki	370
X_{35}	SM17-80	Further investigation regarding measurements and causes of exceedances in chemical substances in the Gulf of Thessaloniki	200
X_{36}	SM17-90	Masterplan for the Gulf of Thessaloniki	15
X_{37}	SM17-100	Evaluation of the dual-use of the united canal Aliakmonas -Axios concerning the water supply in the regional area of Thessaloniki.	15

2.2.Multicriteria Outranking Method Based on Fuzzy Sets and Logic

The outranking methods in multicriteria decision analysis are based on binary comparisons (outranking relations), and rather recently the handling of outranking methods by using fuzzy sets and logic was conducted [16–19]. Hence, the strict preference (P) and indifference (I) are defined as fuzzy concepts in order to express the granularity of the preference. In addition, the strict preference and indifference can be defined as a function of outranking relation (S), which is a fuzzy binary relation [16,17]. By adopting fuzzy outranking methods, firstly the indifference region and the granularity during the monocriterion comparison between two alternatives can be expressed. This is achieved by using proper thresholds. Secondly, the aggregation of the monocriterion scores can be done with the use of fuzzy aggregators and thus, an interpreted structure rather than an arbitrary algebraic norm can be established to achieve the multicriteria synthesis. In addition, during the multicriteria synthesis, the veto principle can be incorporated to prevent the selection of non-commensurate alternatives [18].

The statement *aSb* means "*α* is not worse than *b*" (i.e., *α* is at least as good as *b*). The statement $\alpha S_j b$ does not mean that *α* is better than *b* with respect to criterion *j*. It means only that either the score $a_j - b_j$ is positive or at least that the difference is no considerably negative to suggest a preference favour of *b* with respect to criterion *j*. The *S* monocriterion relation can be defined axiomatically as a special case of fuzzy set [18,19]. Let the monocriterion comparison of two alternatives *α*, *b* with respect to criterion *j*. Then the moncriterion outranking relation can be defined as follow (Equation (1)) [16]:

$$S_j(a,b) = \frac{p_j - \min\{b - a_j, p_j\}}{p_j - \min\{b - a_j, q_j\}} \quad (1)$$

where p_j, q_j state the preference and indifference thresholds, respectively, and $(p_j, q_j \geq 0)$. The p_j, q_j thresholds express the fuzziness of the monocriterion comparison.

In this work, the weighted sum aggregator is used to modulate the concordance measure regarding all criteria (respect of the majority principle). The six criteria, such as (i) efficiency of the measure (*Cr. 1*) (ii) significance of the measure (area and water quality improvement) (*Cr. 2*);(iii) implementation cost (*Cr. 3*);(iv) potential socioeconomic and environmental impacts (*Cr. 4*);(v) risk of implementation due to climate change (*Cr. 5*) and (vi) synergies among the measures (*Cr. 6*), as well as their weights, Table 2, were retrieved by the RBMP of WD GR10 [15].

An overall outranking relation of the type *αHb* holds if and only if the coalition of attributes or criteria in agreement with this proposition is strong enough (*respect of the majority*), and if there is no significant coalition disagreement (*respect of minorities*) against it. Particularly, by adopting the moncriterion outranking relation $S_j$which is applied in the Electre III method, by using the min intersection (which is the intersection of the crisp logic) and the classical complement, the overall outranking relation between two alternatives a and b is equal to:

$$S(\alpha, b) = \min\{(C_s(\alpha, b), (1 - D_s(\alpha, b))\} \quad (2)$$

In which: $C_s(\alpha,b)$ is the value of the concordance principle which begins by asking to what degree each criterion (or attribute or voter) agrees with the statement $H \in S$ for the pair of alternatives (*α*,*b*). These answers are aggregated to obtain an overall index $C_s(\alpha,b)$ measuring the overall agreement with the proposition *αSb* (over all criteria–right of majority). The resulting index $C_s(\alpha,b)$ is a weighted comprehensive concordance relation. $D_s(\alpha,b)$ is the value of the discordance principle and measures the degree according to which at least one criterion where the alternative *α*has a significant smaller evaluation compared with the score of the alternative *b*. This low evaluation could either reduce or cancel all the overall multicriteria evaluation [19].

Finally, the goal of the proposed multicriteria analysis (first phase) is to achieve a multicriteria ordering between the alternatives, i.e., the 37 supplementary measures. Let *A* be the set of all alternatives. To simplify the decision process the use of scoring function on *A* for the *S* relation can be used for the overall outranking relations (Equation (3))[18,19]. Hence, the net flow scoring function was adopted, since it incorporates both the sense of dominance and domination [19]:

$$\upsilon(\alpha, A, S) = 1/|A| \sum_{b \in A} \left[S(\alpha, b) - S(b, \alpha) \right] \quad (3)$$

where, *A* states the set of all alternatives, $\upsilon(\alpha, A, S)$ states the scoring function of the alternative *α* with respect to the outranking relation *S*, *S*(*α*,*b*) states the outranking relation which indicates that the alternative *α* is not worse than the alternative *b*, *b* represents another alternative which is included to the set of all the alternatives, *A*.

2.3. 0/1 Programming Formulation

The 0/1 linear programming method is used to devise a final set of alternatives (final solution) that potentially improve the water quality status, while the objective function is modulated based on the fuzzy outranking multicriteria analysis [18]. Let the set of alternatives *i*=1(1) N be the alternative α_i. Then the binary decision variables are in the form:

$$X_i = \begin{cases} 1 \ \text{if} \ \alpha_i \ \text{is selected} \\ 0 \ \text{if} \ \alpha_i \ \text{is not selected} \end{cases} \quad (4)$$

As objective function, the comprehensive global criterion is developed corresponding to each of the *N* alternatives by the aims of the scoring function of Equation (3):

$$\max\left\{ \sum_{i=1}^{N} \upsilon(\alpha_i, A, S) X_{ij} \right\} \quad (5)$$

Hence, the multicriteria analysis is exploited, in the 0/1 programming, since it modulates the objective function. However, the combinations of alternatives that will be compatible with the budget's constraint should be also considered. This restriction is expressed in terms of the decision variables X_i as follows:

$$\sum_{i=1}^{N} C_i X_i \le B_{available} \quad \text{(Budgets' constraint)} \quad (6)$$

in which C_i states the cost (€) which corresponds to alternative *i* and $B_{available}$ states the available amount of money.

3. Results and Discussion

The proposed binary outranking relation was initially determined for each criterion and for each pair of alternatives. The thresholds, which as aforementioned express the grey region in the monocriterion binary comparison, are taken from the literature [16] (example of multicriteria filtering by preference). The overall (overall criteria) concordance and non-discordance measures were calculated and finally the overall outranking relation was calculated based on Equation (2) (concordance and non-discordance principle). This process is repeated for each pair of different alternatives and hence a matrix 37 × 37 was produced with the elements of the main diagonal to be empty. To exploit these binary comparisons, the scoring function for each alternative is determined based on the *net flow* concept (Equation (3)). Sequentially, the objective functionaims at maximizing the sum of the scoring function from the selected alternatives (Equation (5)). Several scenarios can be developed considering the funds that will be applied for the implementation of the proposed measures. Here, due to limited space, three Scenarios based on the available budget are considered and demonstrated: (1) 10^6€ for Scenario 1, 10 × 10^6 € for Scenario2 and 150 × 10^6 € for Scenario 3. The final selection for each scenario is presented in Table 2.

Table 2. Estimation of the score of alternatives (*Cr.1* to *Cr.6*), values of their scoring function, and the final solution for proposed scenarios regarding the available budget.

Alt.	*Cr. 1*	*Cr. 2*	*Cr.3*	*Cr.4*	*Cr.5*	*Cr. 6*	Scoring Function	Cost (*10^3€)	Scenario 1	Scenario2	Scenario 3
X_1	1	0.2	*1*	0.11	*0.75*	0.19	−0.086	0	0	0	0
X_2	0.89	1	*0.66*	0.22	*1*	0.39	0.088	405	0	1	1
X_3	0.66	0.24	*1*	0.44	*1*	0.1	−0.306	0	0	0	0
X_4	0.78	0.28	*1*	0.44	*1*	0.16	0.021	0	1	1	1
X_5	0.55	1	*1*	0.44	*1*	0.52	0.175	0	1	1	1
X_6	0.66	0.73	*0.33*	0.44	*0.75*	0.23	0.132	2095	0	1	1
X_7	0.55	0.5	*1*	0.44	*0.75*	0.03	−0.093	0	0	0	0
X_8	0.89	0.04	*0.66*	0.44	*0.75*	0.16	−0.041	240	0	0	0
X9	0.77	0.17	*0.33*	0.78	*0.83*	0.19	0.146	120,361	0	0	1
X_{10}	0.66	0.04	*0.33*	0.78	*0.75*	0.45	0.131	1070	0	1	1
X_{11}	0.66	0.02	*1*	0.33	*0.67*	0.13	−0.792	0	0	0	0
X_{12}	0.89	0.1	*1*	0.33	*1*	0.1	−0.170	0	0	0	0
X_{13}	0.89	0.25	*1*	0.33	*0.66*	0.29	−0.026	0	0	0	0
X_{14}	0.55	0.25	*0.33*	0.33	*0.83*	0.48	−0.201	1295	0	0	0
X_{15}	0.66	0.09	*0.33*	0.56	*0.83*	0.06	−0.504	65,000	0	0	0
X_{16}	0.55	0.09	*0.33*	0.56	*0.83*	0.06	−0.630	46,265	0	0	0
X_{17}	0.66	0.04	*0.33*	0.56	*0.75*	0.03	−0.563	6704	0	0	0
X_{18}	0.66	0.07	*0.33*	0.56	*0.75*	0.03	−0.548	7347	0	0	0
X_{19}	0.66	0.12	*0.33*	0.56	*0.75*	0.03	−0.509	4761	0	0	0
X_{20}	0.66	0.09	*0.33*	0.56	*0.75*	0.03	−0.542	14,856	0	0	0
X_{21}	0.66	0.12	*0.33*	0.56	*0.83*	0.19	−0.384	2700	0	0	0
X_{22}	0.77	0.04	*0.33*	0.56	*0.75*	0.32	−0.102	24,200	0	0	0
X_{23}	0.66	1	*0.66*	0.56	*1*	0.97	0.465	150	1	1	1
X_{24}	0.77	0.76	*0.66*	0.56	*1*	0.32	0.384	867	1	1	1
X_{25}	0.66	1	*1*	0.56	*1*	1	0.485	90	1	1	1
X_{26}	0.77	1	*1*	0.56	*1*	0.9	0.593	30	1	1	1
X_{27}	0.55	0.6	*0.33*	0.56	*0.83*	0.19	0.021	1036	0	1	1
X_{28}	0.55	0.3	*0.66*	0.56	*0.83*	0.39	−0.024	646	0	0	0
X_{29}	0.77	0.06	*0.33*	0.56	*0.67*	0.23	−0.214	1639	0	0	0
X_{30}	0.66	0.1	*0.66*	1	*1*	0.23	0.191	145	0	1	1
X_{31}	0.66	0.11	*0.66*	1	*1*	0.13	0.161	145	0	1	1
X_{32}	0.78	1	*0.66*	1	*1*	0.84	0.868	167	1	1	1
X_{33}	0.66	0.76	*0.66*	1	*1*	0.32	0.541	231	1	1	1
X_{34}	0.89	0.04	*0.66*	1	*0.75*	0.55	0.440	370	0	1	1
X_{35}	0.66	0.04	*0.66*	1	*0.75*	0.55	0.278	200	1	1	1
X_{36}	0.89	0.08	*1*	1	*0.75*	0.68	0.515	15	1	1	1
X_{37}	0.77	0	*1*	1	*1*	0.03	0.101	15	1	1	1

In case of the Scenario 1, the selection process of the proposed methodology demonstrated that among the 23 measures that their implementation cost is less than 10^6 €, Table 1, only 11 fulfill the criteria and are designated for the next phase, while in the Scenario2, among the 36 measures with cost less than 10 × 10^6 €, 18 of them are selected for their implementation. In both cases, the measures that are not qualified for their employment, apart from the budget constraint (Equation (6)), have a negative scoring function. The reason behind the allocation of negative scores in certain alternatives is that the different level among the criteria scores plays an important role in the scoring function. In SM02-10 for example, the variance of scores between the sets of *Cr.1*and *Cr.3*, which have attributed in the higher ranking of scores, and the *Cr.2*, *Cr.4* and *Cr.6* whose score is lower than 0.2 powers the final scoring function.

An interesting point is that the criterion of veto is excluded from the criterion of "implementation cost", *Cr.3*, and the criterion of "risk of implementation due to climate change", *Cr.5*, since the budgets' constraint (during the second phase of 0/1 programming) put emphasis on the cost. In addition, the use of veto in the *Cr.5* will exclude the water quality improvement measures. In case of Scenario 2, all the alternatives with scoring function greater than zero are selected apart from alternative SM07-10 because of its high cost.

It is worth noting that the alternatives which are classified as "Monitoring abstractions and "Construction projects" are excluded because of the low score of either the *Cr.2* i.e., "significance of the measure" criterion (e.g., because of the small area affected) or *Cr.4*, i.e., "potential socioeconomic and environmental impacts". Indeed, it seems more reasonable, in this strategic and integrated scale evaluation, to select alternatives which affect positively a large area or in other words, measures which tend to have a generic implementation. However, in the case that at least one or two construction measures should be selected, additional constraints (during the 0/1 programming) must be added. For instance, regarding the case study under consideration, if at least one construction project must be selected, it holds (Table 2, Scenario 3):

$$\sum_{i=15}^{22} X_i = 1 \tag{7}$$

In this case and by following Scenario 2, the SM11-70 is additionally selected due to its cost together with the value of the scoring function within the optimization process.

Another interesting point of view is that the implementation of the scoring function in the outranking relations gives more general and comprehensive evaluation than the Promethee method since the used method incorporates the non-discordance principle. However, it should be clarified that the selection of the alternatives is not based on the multicriteria ordering itself, since, in practice, several alternatives modulate the final solution. Therefore, the final solution is controlled by taking into account the multicriteria evaluation and other technological constraints. In contrast with other applications [18], in this work the unique constraint arises from the available budget. It should be mentioned that additional constraints should be added such as the geographical dispersion of the constructions project, and the satisfaction of the water demand.

4. Conclusions

Budgeting availability and constraints play a crucial role in capital investment. The same rule exists even in cases of national funds that are oriented towards the fulfillment of environmental commitments to EU Directives. For that purpose, the development of methodologies that couple economic criteria with environmental and social objectives, such as the one proposed in this research where multicriteria methods are coupled with 0/1 programming for issues derived from the WFD, are essential for providing sets of solutions that not only secure but also improve the environment and the socio-economic state under specific financial ranges.

The proposed methodology consists of two phases. In the first phase a fuzzy outranking method is implemented and during the second phase a 0/1 programming is used in order to modulate the final set of alternatives. By using the outranking methods, we lead to commensurate and more integrated alternatives which are combatable with the budgets' constraint, since the final selection is achieved with the use of 0/1 programming.

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