Water Sustainability: Evaluation of Alternative Water Supply Methods in Greek and European Islands

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Abstract
Water is a very valuable natural resource absolutely necessary for life. Lately water resources are facing high pressure from continuously increasing demand. Besides, various areas face water shortage due to decrease of precipitation, irrational use, losses and mainly very high rates of tourism, especially in areas with water shortage and/or very limited water availability. Various water supply methods are applied in different cases in order to satisfy water demand, such as dams, desalination units, reuse of wastewater treatment plants effluents and water transport. Each of these methods has different environmental and social impacts. The objective of the work is to present the progress of our on-going research work concerning the identification of the parameters defining water sustainability and the evaluation of these alternative water supply methods. To that effect, the various alternative water supply methods are analysed in terms of technical and economic as well as feasibility characteristics taking also into account their properly defined and measured sustainability according to a set of indicators that has been suggested in the literature to assess it. A multicriteria optimisation model is developed for the quantitative assessment of the various water supply methods.
Keywords: water sustainability, multicriteria analysis, water supply methods

1. Introduction

The water shortage problem is nowadays one of the most serious problems being faced on a global scale. The water shortage problem is more intensive in the island regions mainly because of their geomorphological characteristics. Coming to our country, in some of the Aegean islands, belonging to the Cyclades or Dodecanese Complexes, the water demand in general exceeds the available supplies and the problem is tackled by various methods, e.g. the construction of new infrastructure projects such as desalination plants, new water storage installations such as dams, ground water reservoirs, (both presuming that there is enough precipitation) or other methods such as water transfer. Lately, in order to increase the water supplies as much as possible in a sustainable way, there is an increasing interest in considering new, more innovative methods such as the water reclamation and reuse from waste water treatment plants. This is an interesting option for at least two specific and distinct reasons: the water savings and, in some cases, the reduction of the waste treatment cost.

2. Rationale and Background of the Work

Water-related projects as the ones mentioned above can no longer be assessed only from a purely technical view, ignoring all their other aspects (namely environmental, land use, social and economic concerns). Water sustainability parameters suggested in the literature are the required infrastructure, the society, the environmental quality, economics and finance, human health and welfare, as well as technology (Cheng et al 201). In line with these guidelines, Mays (2006) introduces seven requirements to ensure the sustainability of water resource systems. They are basic water needs to maintain human health; minimum standard of water quality; basic water needs to maintain ecosystem health; long-term renewability of available water resources; accessible data on water resources for all parties; institutional schemes to resolve water conflict; and democratic water-related decision making.

3. Characteristics and Comparative Evaluation of Alternative Water Resources

The water resources of the islands are rather limited, mainly due to their geomorphology, climate, and low precipitation. The water needs are in many cases covered by water transfer with boats, a very expensive and unsustainable water supply. On the other hand, mainly due to the intensive tourism activities, a significant number of waste water treatment plants have been constructed during the last two decades covering almost 48% of the area population. The largest islands have waste water treatment plants that could be considered for recycling. For example for the island of Naxos that there are significant irrigation needs, this option should be seriously considered (with an estimated budget of 880,000 Euros). In general, a detailed study should be elaborated for each specific case to identify the islands where such an investment should be implemented. The evaluation of the alternative water supplies is an interesting and complex

issue that involves the economic, technical and environmental / sustainability dimension of the water. Furthermore, availability constraints as well as the social acceptance of these water supplies need also to be considered. This comparative evaluation is required for a long-term and sustainable water resources management planning and, in general, in any case that decisions need to be taken on relevant infrastructure projects. The most common projects for water supply are the desalination plants, dams, ground reservoirs, water transport by boats and recently the water reuse from WWTPs. The most significant characteristics of various water supply methods is shown in Table 1 (Kouzoupis et al, 2009). In addition, some information concerning water costs from various methods is shown in Table 2 (Gikas et al 2009).

4. Multicriteria Analysis and Optimisation

As it becomes clear from the above discussion, there are various different alternative choices for the solution of water supply problems in areas with limited water availability and the comparative evaluation of the various water supply methods projects needs to be done separately for each specific case. Therefore, optimisation is the only reliable process.

Since sustainability, social, technical, security of supply, economic considerations need to be included in the optimisation reflecting the different characteristics, an optimisation method that will be able to accommodate all these characteristics needs to be employed. Therefore, there are two main issues to be faced: how to measure what is known as intangibles, and how to combine their measurements to produce an overall preference or ranking; and then, how to use it to make a decision with the best available mathematics. The identification of the set of alternatives as well as the identification of the set of criteria by which alternatives are to be compared are crucial tasks. Thus, in terms of its implementation, the MCDM requires the definition of the alternatives under consideration, the goal to be optimised, the evaluation criteria that will be the basis of the evaluation, the weight of each of the criteria in the goal and the assignment of marks for each of the alternatives in the aforementioned criteria. In the present work the alternative water supply methods that are considered are: dam, desalination (with conventional and renewable energy sources), ground reservoirs, reuse of water from WWTP and water transfer. The evaluation criteria that are taken into account are: economics, environmental, security of supply, social acceptance, operation and maintenance and technology. There are various methods for the determination of criteria relative weights. The method that has been used in the present work is the Advanced Hierarchical Process (AHP), being based in the pairwise comparison between the various criteria (Table 3).

5. Conclusions

In the present work (part of our on-going research) the comparative evaluation of various water supply projects is described. Multicriteria Analysis has been employed and the main criteria and their weights calculation have been presented. The completion of the work will result in the development of a very significant and useful decision making tool to assist investors and authorities for the best sustainable water supply projects selection.

Table 1. Water supply comparative evaluation

	Desalination	Dam	Ground Reservoir	Water reuse / reclamation	Water Transport
Existing technical experience	Very good	Very good	Good	In a starting point	Good
Infrastructure required	Low	Complex	complex	Medium	Zero
Energy use	High	Only in the construction	Only in the construction	Low	Transportation fuel required
Social acceptance	Good	Medium	good	Negative	No
Environ. Sustainability	High energy consumption, brine	Questionable	Very good	Very good	Negative
Cost	Rather high	High	High	Not very high	Very high
Siting flexibility	Relatively easy	Difficult	Difficult	Not required	-

Table 2. Cost of water from different supply sources

Volumetric capacity (m^3/d)	**Cost in Euros per cubic meter (€/m^3)**	
	Desal.	**İmport**
100–1000	1.50–3.50	5.00–10.00
1000–2500	1.00–2.00	5.00–10.00
2500–5000	0.75–1.25	4.00–10.00
Reclamation (following wastewater treatment)		
Case 1 (for irrigation)	Case 2 (domestic uses)	
0.25–0.35/0.75–1.35	0.35–0.52/0.80–1.50	
0.15–0.20/0.60–0.75	0.22–0.30/0.70–0.85	
0.15–0.18/0.65–0.75	0.22–0.27/0.75–0.85	

Table 3. Weights of criteria based on the AHP

	C1	C2	C3	C4	C5	C6	WEIGHTS %
Economic and finance (C1)	1.00	0.50	0.33	4.00	1.00	0.33	12.5
Environmental impacts (C2)	2.00	1.00	0.25	2.00	4.00	0.20	16.5
Security of supply (C3)	3.00	4.00	1.00	3.00	5.00	3.00	33.1
Social acceptance (C4)	0.25	0.50	0.33	1.00	3.00	2.00	12.4
Operation/maintenance (C5)	1.00	0.25	0.20	0.33	1.00	1.00	6.6
Technology (C6)	3.00	5.00	0.33	0.50	1.00	1.00	18.9

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