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ORIGINAL CONTRIBUTION

Comparison of Analytic Hierarchy Process (AHP) and Fuzzy Analytic Hierarchy Process (f-AHP) for the Sustainability Assessment of a Water Supply Project

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Abstract Ensuring sustainability in community-based water supply schemes involves major hurdles in identifying and prioritizing the key aspects with a comprehensive decision-making process. In this study, the concept of sustainability has been assessed for an intra-state water supply scheme using analytic hierarchy process and fuzzy analytic hierarchy process by systematically prioritizing various design and operational aspects. It has been adopted a three-level classification of the key attributes such as 5 dimensions, 15 sub-criteria and 50 indicators. The environmental dimension (41%) is found to have the highest importance in the measurement of sustainability of this project, followed by the social (22%), governance (20%), economical (8%) and infrastructure (6.8%) dimensions. Among the sub-criteria, quality at the source demands highest priority followed by cost-effectiveness. Among the indicators, water testing frequency carries the maximum weightage, followed by public participation and consultation. The results indicate the influence of scale and functioning stage of the project on prioritizing and decision-making. The study also recommends the scope of improving the social and governance factors together (in terms of transparency, flexibility and serviceability) by increased public involvement. The results from the study can serve as a valuable guideline for planning and implementation of similar projects for sustainable development.

Keywords AHP · Fuzzy AHP · Sustainability · Water management · Water governance

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Abbreviations

MCDM	Multi-criteria decision-making
PROMETHEE	Preference Ranking Organization METHod for Enrichment of Evaluations
ELECTRE	Elimination Et ChoixTraduisant la REalite
CP	Compromise programming
EXPROM	EXtension of the PROMethee
TOPSIS	Technique for order preference by similarity to ideal solution
SAW	Simple additive weighting
NAIADE	Novel approach to imprecise assessment and decision environments
AHP	Analytic hierarchy process
f-AHP	Fuzzy analytic hierarchy process
HF-CRITIC	Hesitant fuzzy criteria importance through intercriteria correlation
HF-MAUT	Hesitant fuzzy multi-attribute utility theory

Introduction

Community-based water supply schemes constitute an indispensable component of the global initiatives on integrated water management schemes promoted to ensure water sustainability. In practice, the water supply schemes are progressively being challenged with increasing plea for water, rising number of customers and their anticipations, requirements to maintain pure water quality and security of health of the people involved, environmental issues, economic issues and so on [1]. While confronting the definition of sustainability as "the ability to meet the present needs without compromising for the future", most of the water supply projects are limited in their scope of expansion by the regional considerations which are very specific and vary from place to place [2, 3]. In addition, the assessment of sustainability of a water supply scheme also linked to the purpose, that is to say, the preferences and demands will change according to the end user's calls. In any case, assessing the sustainability of a socially significant, financially momentous and environmentally sensitive project is a prime necessity for the sanctioning authorities though it encounters many perplexing challenges.

While assessing the sustainability, the temperament and preference of various dimensions need to be properly recognized in order to obtain a reliable plan of action as the output. Though the term sustainability commonly relies on the main three pillars such as economic feasibility, environmental adaptability and social acceptability, the implementation of many government-owned, public-directed projects necessitates consideration of additional dimensions as well. Based on the recommendations from United Nations Commission on Sustainable Development (UNCSD), many people have attempted to make a systematic framework for sustainability assessment by defining various indicators and metrics with due consensus on formulating strategies, leading towards the development of policies. Even though it is safe to assume that the financial commitment can be assured by the government while sanctioning the project, still there is lack of transparency and hierarchy in monitoring and addressing the managerial and technical aspects during the implementation and functioning of the projects. When these issues are not timely addressed in community-based projects with public participation, it is observed that the public opinion, serviceability and, in turn, the mutual responsibility slacken due to the mere negligence in addressing such simple, yet underrated components of social dimensions. Therefore, it is important to include additional elements representing the equitable access to the governance and infrastructure maintenance services.

There are many scientific approaches and analytical tools currently being implemented to evaluate the sustainability of a water-related project. Most commonly used among them include cost–benefit analysis (CBA), integrated assessment (IA), triple bottom line (TBL), life cycle assessment (LCA) and multi-criteria decision-making (MCDM). MCDM offers a unique solution by introducing the inclusivity of highly distinct elements (both qualitative and quantitative) into the decision-making process in various fields of engineering [4] unlike the CBA and LCA methods which consider only a single dimension. MCDM is considered superior to IA and TBL as they can consider more than three dimensions [5–10]. It is also observed that among these options, the MCDM has been frequently used in the past for various water resources projects [11–14].

The analytical hierarchy process (AHP) is a widely used tool for decision-making process as it is based on the hypothesis that complex problems can be hierarchically structured and analysed in a simple and comprehensive manner [15–17]. Although AHP is the popular choice for many, the method has been criticized for their want of exact numerical values to express the magnitude of the stakeholders' preferences [18–22]. The exact pair-wise comparisons are not so easy to determine, and thus, uncertainties arising from the various dimensions/factors should be carefully taken into account for wise interpretation. In this aspect, recent studies have been focusing on adopting the fuzzy set theory to the classical AHP to deal with uncertainty problems [23–25]. Mosadeghi et al. [22] compared AHP and f-AHP for spatial multi-criteria decision-making for urban land use planning alternatives and reported that both methods play a crucial role for consideration of intersectional area for development. A qualitative comparison between AHP and f-AHP has been carried out for the prioritization of watersheds by Meshram et al. [26], and they reported that f-AHP approach is a practical and convenient method to show potential zones for implementation of effective management techniques especially when data availability is low. A summary of the various dimensions or factors considered for analysis in the above studies is provided in Table 1.

Based on the contemporary literature review, though there is a common opinion on the sustainability aspects, there were no evidences of any comprehensive guidelines for the identification of sustainability criteria for community-based water supply schemes. Bhandari and Grant [27] have analysed the sustainability of drinking water supply system in Nepal by evaluating the causes of disparities in the willingness to pay by the users in the rural villages and local market centres. Based on the survey analysis in the rural areas of Pakistan, Haq et al. [28] observed that quality assurance of drinking water supply schemes can be enacted by enhancing the level of public participation and ownership. As seen from the most relevant references, it is to be understood that the issues of inconveniences and accessibility may vary from place to place; however, the enhancement of institutional capacity and flexibility seem to be more essential in achieving the sustainability in water supply projects.

Based on the available information, it is felt that the application for f-AHP in water resources domain is quite limited, and hence, there is a need to explore the comparison of AHP and f-AHP from the perspective of water sustainability. One critical issue while dealing with any such sensitive project is the lack of integrity in creating adequate representations of all basic dimensions. In this study, it has been attempted to

Table 1 Various factors considered for sustainability assessment of water resources projects

Model/Method	Factors/Dimensions	References
PROMETHEE-2, EXPROM-2, ELECTRE-3, ELECTRE-4, CP	Economic, Environmental and Social	Srinivasa Raju et al. (2000)
Analytical and qualitative approach	Economic, Environmental, Social, Health and hygiene, Cultural, Functional and Technical	Hellstrom et al. (2000)
Qualitative analysis	Economic, Environmental, Social, and Institutional	DiSano (2002)
Analytical approach	Economic, Environmental, Social, Technical and Cultural	Balkema et al. (2002)
Analytical approach	Economic, Environmental, Social and Technical	Ashley et al. (2003)
TOPSIS, SAW and CP	Economic, Environmental and Social	Yilmaz and Harmancioglu (2010)
Qualitative analysis	Economic, Environmental and Social	de Cruz et al. (2013)
Analytical approach	Economic, Environmental, Social, Technical and Governance	Marques et al. (2015)
AHP, NAIADE	Economic, Social and Technical	Sikder and Salehin (2015)
HF-CRITIC, HF-MAUT	Economic, Environmental, Health Risk, Social and Technical	Narayanamoorthy et al. (2019)
AHP	Economic, Environmental, Social, Technical, Governance and Institutional	Boukhari et al. (2018)
Combination of Adaptive AHP, TOPSIS and Entropy	Economic, Environmental, Planning, Social and Technical	Birgani and Yazdandoost (2018)

address this particular issue by adopting a three-level classification, with 5 dimensions, 15 sub-criteria and 50 indicators. This would facilitate the identification of the critical parameters for a water supply project even at the micro-level.

Methodology

The present study considers an integrated outlook at the various issues faced by the aged and operational water supply projects commissioned by the Tamil Nadu Water Supply and Drainage board (TWAD board) under the municipal administration and water supply department of Government of Tamil Nadu, India. It is needless to state that the TWAD board has been very instrumental in materializing many of the flagged projects such that water harvesting, groundwater exploration and recharging, sanitation projects and low-cost water treatment projects. The board has completed many major water supply schemes under the categories of rural, urban and combined water systems, each of them covering hundreds of kilometres of pipelines with thousands of direct beneficiaries. It certainly involves huge risk on the water resources, water sharing, water quality, etc. to name a few. In this aspect, it has been considered a basic case study of combined water supply scheme being implemented in any one of the central districts of the state having severed scarcity of water. The initial steps involved inventory development based on the available sources and collecting experts' opinion about the viability as well as effectiveness of the water supply scheme. It is believed that this approach will lay a general foundation to compare with the progress having in other parts of the state.

The analytical methodology of the chosen processes (AHP and f-AHP) is briefly discussed here in order to ascertain the background of parameter selection for the model. The AHP makes the following four assumptions. First assumption is about the reciprocity, i.e. when the two factors are paired and compared, the value of preference should satisfy the reciprocal condition. Second assumption is about the homogeneity, i.e. the importance is represented by a bounded scale within a limited range. Third point is on dependency, i.e. elements at a level should be dependent on those at an upper level. The fourth and the final assumption is about the expectations, i.e. this assumes that the purpose of decision-making is completely included in the corresponding level.

Analytic Hierarchy Process (AHP)

As mentioned above, the AHP is a procedure for multi-criteria decision-making proposed by Saaty [29] based on the subjective judgements of people. The first phase is to identify the key elements (dimensions, criteria and indicators) in order to achieve the goal of water sustainability and then frame the hierarchical structure. Based on the information shared on the public domain, it has been identified the key dimensions for the study as economic, environmental, governance, institutional and social. The pair-wise comparison matrix was formed based on the inputs provided by the experts in the field of water resources and environmental engineering. The details of the dimensions, the various criteria under each dimension and the indicators for each criterion are provided in Table 2.

The second phase is preparation of the pair-wise comparison matrix to evaluate the importance of each of them.

Table 2 Dimensions, criteria and indicators adopted for the current study

Scheme	Dimensions	Sub-criteria	Indicators
Water supply	*1.* Social	*1.1.* Accessibility **(A)**	*1.1.1.* Accessibility of drinking water services
			1.1.2. Accessibility to sanitation services
			1.1.3. Economic service accessibility
		1.2. Satisfaction **(B)**	*1.2.1.* Quality of service
			1.2.2. Aesthetics
			1.2.3. Readiness for feedback
		1.3. Empowerment **(C)**	*1.3.1.* Willingness to adopt
			1.3.2. Knowledge sharing
			1.3.3. Initiative in problem solving
	2. Environmental	*2.1.* Optimum use **(D)**	*2.1.1.* Efficient use of water
			2.1.2. Energy use
			2.1.3. Material use
		2.2. Quality at source **(E)**	*2.2.1.* Water testing frequency
			2.2.2. Identification of point and non-point sources
			2.2.3. Self-purification capacity
			2.2.4. Reduced exposure to surface contamination
		2.3. Quality at end use **(F)**	*2.3.1.* Quality of pipeline materials
			2.3.2. Quality of storage tanks
			2.3.3. Distance from sewer pipes
			2.3.4. Safety from flood and fire
	3. Economic	*3.1.* Cost effectiveness **(G)**	*3.1.1.* Investment
			3.1.2. Efficiency
			3.1.3. Balanced budget
		3.2. Water policy **(H)**	*3.2.1.* Fixing the slab rate
			3.2.2. Discount of tariff
			3.2.3. Subsidies based on usage
	4. Governance	*4.1*. Transparency **(I)**	*4.1.1.* Availability of information and documents
			4.1.2. Accessible information and written documents
			4.1.3. Public participation and consultation
		4.2. Accountability **(J)**	*4.2.1.* Individual mechanisms of accountability
			4.2.2. Collective mechanisms of accountability
			4.2.3. Accountability in terms of documentation
		4.3. Flexibility **(K)**	*4.3.1.* Provisions for substitution
			4.3.2. Frequency of changing policies
			4.3.3. No. of deviations allowed
	5. Infrastructure	*5.1.* System performance **(L)**	*5.1.1.* Flexibility
			5.1.2. Adaptability
			5.1.3. Reliability
			5.1.4. Auditingfrequency
		5.2. Risk of damage **(M)**	*5.2.1.* Failure identification
			5.2.2. Network yield
			5.2.3. Detection and repair of leaks
			5.2.4. Safety provision in network
		5.3. Property sharing **(N)**	*5.3.1.* Loss of productive land
			5.3.2. Displacement of properties
			5.3.3. Inconvenience with supporting structure and equipment

Table 2 (continued)

Scheme	Dimensions	Sub-criteria	Indicators
		5.4. Service and maintenance **(O)**	***5.4.1.*** Regular servicing schedule
			5.4.2. Expenses on services
			5.4.3. Cleanliness after servicing
			5.4.4. Service life extension

The pair-wise comparison for AHP was developed based on Saaty [29] numerical scale as shown in Table 3. The pair-wise comparison (Eq. 1) for each dimension, sub-criteria and indicator was prepared based on the inputs obtained from various experts working in the field of water and environmental engineering. Tables A1–A3 (Appendix) provide the pair-wise comparison matrix framed for the dimensions, sub-criteria and indicators used.

$$A = \left[a_{ij}\right] = \begin{bmatrix} 1 \; a_{12} \; a_{13} \; \ldots \; \ldots \; \ldots \; ..a_{1n} \\ \frac{1}{a_{12}} \; 1 \; \ldots \; \ldots \; \ldots \; \ldots \; \ldots \; \ldots \; a_{2n} \\ . \\ . \\ . \\ \frac{1}{a_{1n}} \; \frac{1}{a_{2n}} \; \ldots \; \ldots \; \ldots \; \ldots \; \ldots 1 \end{bmatrix} \tag{1}$$

where A is the decision matrix and a_{ij} are the comparisons between elements i and j for all I, $j \in \{1, 2 \ldots n\}$

After the construction of the decision matrix for each element, the weight of each of the dimensions, criteria and indicators is calculated. The procedure for calculation of the weights for the dimensions is as per the steps given below, and the same is followed for the criteria and indicators also

1. Calculate the sum per column.
2. Divide each of the values in the column by the sum of the values.
3. The dimension's weight is obtained by calculating the average of each of the rows.
4. The dimension's weight is multiplied with each value in the pair-wise comparison matrix of the dimensions and summed up to get the weighted sum.
5. Weighted sum divided by dimensions' weights provides the λ.
6. The maximum value among all the λ values gives the $\lambda_{max.}$

Then, the consistency of the result should be checked. The AHP method then proposes validating the reliability of the result by calculating the consistency ratio (CR), which will enable us to detect defects in the calculation and evaluation. The CR is calculated by Eq. (2).

$$CR = \frac{CI}{RI} \tag{2}$$

RI is the random index, which can be obtained from Table 4. CI is the consistency index, calculated based on Eq. (3).

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

λ_{max} is the principal eigenvalue and n represents the number of rows or columns of the square matrix of judgement. If $CR \leq 0.1$, the matrix is considered sufficiently consistent, otherwise, the assessments may require some revision to reduce inconsistencies. This is performed by reformulation of the pair-wise comparison matrix.

Fuzzy Analytic Hierarchy Process (f-AHP)

A brief introduction to the development of the f-AHP model is provided herewith for the benefit of the readers. Let X is the universe set of the set of objects and y is a fuzzy subset of the universe set. The fuzzy number y is a fuzzy subset of real numbers that has a few important characteristics:

The membership function $u_y(x)$ is continuous from R to [0, 1].

The membership function $u_y(x)$ is normal, that is, there exists the number x_0 so that $u_y(x_0) = 1$. If all of the level sets are convex in classical sense for a fuzzy set y, it means that this fuzzy set y is convex. A triangular fuzzy number y can be represented as (y_l, y_m, y_r). Then, the membership function of the triangular fuzzy number $u_y(x)$ can be expressed in the following form:

$$\boldsymbol{u_y(x)} = \begin{cases} \frac{x - y_l}{y_m - y_l}, & \text{if } \boldsymbol{y_l} \leq x \leq \boldsymbol{y_m} \\ \frac{y_u - x}{y_u - y_m}, & \text{if } \boldsymbol{y_m} \leq x \leq \boldsymbol{y_u} \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

Fuzzy decision-making is used to choose the best alternative among the several ones in the presence of uncertainty. A set of alternatives $A_1, A_2, \ldots, A_n$ depends on some criteria $H_1, H_2, \ldots, H_m$. So, the best alternative is one that fulfils all the criteria.

Fuzzy preferences are actually based on the fuzzy logic and fuzzy sets. In MCDM, fuzzy preferences are written as

Table 3 Saaty numerical scale

Magnitude of importance	Definition
1	Equal importance for both elements
3	Weak preference (element i over element j)
5	Strong preference (i over j)
7	Very strong preference (i over j)
9	Absolute preference (i over j)
2,4,6,8	Intermediate values between two judgements (i over j)
1/3	Weak preference (j over i)
1/5	Strong preference (j over i)
1/7	Very strong preference (j over i)
1/9	Absolute preference (j over i)
1/2,1/4,1/6,1/8	Intermediate values between two judgements (j over i)

Table 4 Random index (RI)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.52	1.54	1.56	1.58	1.59

fuzzy-weighted sums. These weighted sums are the fuzzy numbers. A fuzzy preference is a significant type of fuzzy binary relation and is used to generate the degree of preference between two alternatives when there are certainty and uncertainty preferences. Let A represent a set of alternatives A_1, A_2,… A_n and $n > 1$. A fuzzy preference for the set of alternatives A is a fuzzy relation on A denoted by $R = (r_{ij})_{nxn}$ which has a membership function denoted by u_R: $A \times A$ [0,1]. Here, u_R $(A_i, A_j) = r_{ij}$ represents the degree of preference for alternative A_i over A_j.

The corresponding fuzzy pair-wise comparison for the dimensions, sub-criteria and indicators is provided in Tables A4–A6 (Appendix).

Results and Discussion

The results of the AHP approach can be discussed in terms of two critical parameters. One is the consistency ratio of the matrices framed by the experts to ensure that each of the proposed pair-wise comparison is consistent. The other parameter is the relative weightage for the individual relationships (between the dimensions to the sub-criteria or between the sub-criteria to the indicators).

Comparison of Consistency Ratio

The consistent ratios determined for the matrices of dimensions, sub-criteria and indicators are provided in pictorial format (Figs. 1, 2, 3). In this study, individual single matrices were framed for the dimensions and sub-criteria, and 15 matrices were framed for the indicators. As mentioned earlier, the pair-wise comparison matrix is consistent if the CR ≤ 0.1 as per Saaty [29, 30], but Pauer et al. [31] have reported that a consistency ratio ≤ 0.2 is considered to be acceptable for the matrix to be considered as consistent.

As evident from the results, there is an increase in the assured level of consistency as it was proceed from the indicators to sub-criteria to the dimensions. The highest value of consistency ratio for any indicator was 0.2, which is observed for water policy (*H*). It is important to note that several judgements are to be made in the analysis and the informative value of the analysis is pulled down by considering a lower value of consistency ratio. Hence the authors believe that the same is applicable for the study as has been considered 5 dimensions, 15 sub-criteria and 50 indicators. Therefore, it is observed from Figs. 1, 2 and 3 that the consistency ratios are well within the limit for consistency (CR ≤ 0.2) for all the matrices framed. A sample calculation of the weights and consistency ratio for the dimensions is provided in Appendix B1.

Comparison of Weightages

The next best parameter to compare the strength of significant relation among the three levels of attributes is the weightage. This is particularly unique which is assessing the relative importance of a particular dimension by taking the pair-wise cross-combinations. Based on the results obtained from the AHP and f-AHP process, the weights were compared for the dimensions, sub-criteria and indicators (Figs. 4, 5, 6). From Fig. 4, it is observed that the environmental dimension has been given the highest importance (41.25% as per AHP and 41.17% as per f-AHP) by the experts in the measurement of sustainability of a water supply project, followed by the social dimension. This is followed by governance, economical and infrastructure. This shows that the environmental impacts play a very crucial role for a state like Tamil Nadu as it a clearly visible output. However, the critical behaviour lies in the fairly equal importance given to the social and governance dimensions, indicating the changing trends in the social reformation which is shifting from the financial dependency towards more participative and inclusive development. This necessitates an increased expectation of valuing the opinions of the local people while planning, implementation and maintenance of such projects.

Infrastructure has been issued the least weightage of 6.6% (AHP) since establishment of the water supply system is relatively easier when compared to combating the environmental risks and impacts. In another perspective, it can be observed that the planners and policy-makers should facilitate more hassle-free governance and transparent supply chain while executing the rural water supply projects. As far as the comparison of AHP and f-AHP is concerned, both of them have given similar weights for all the chosen dimensions with a marginal variation. This is because triangular function has been considered for the calculation of the weights and it can be concluded that f-AHP with triangular functions does not show much variation compared to AHP for a water supply project.

While comparing the weightage of the sub-criteria (Fig. 5), quality at source (sub criteria 2.2) carries the maximum weightage (17.38% by AHP and 18.30% by f-AHP) followed by cost-effectiveness (sub-criteria 3.1) (15.26% by AHP and 14.40% by f-AHP) and optimum use of water (sub-criteria 2.1) (12.73% by AHP and 12.92% by f-AHP). Quality at source and optimum use of water fall under the environment dimension, while the cost-effectiveness appears under economical dimension. The least weightage (2.83% by AHP and 2.97% by f-AHP) has been awarded for risk of damage (sub-criteria 5.2) (infrastructure dimension). This is because the infrastructure dimension has been provided the least weightage by the experts and it is appropriate that the least weightage has been awarded for the sub-criteria under that category. Quality at the source plays a vital role in the well-being of the society and indirectly aids in maintaining a clean and pollution-free environment.

In the social dimension, accessibility to water supply carries more weightage when compared to satisfaction and empowerment. In the environmental dimension, quality at source is given more importance compared to optimal usage and quality at end use. In the economic dimension, cost-effectiveness is given more weightage compared to water pricing policy. In the governance dimension, all the sub-criteria carry equal weightage. Thus, transparency, accountability and flexibility should be treated on equal terms for the sustenance of the water supply project. In the infrastructure dimension, property sharing carries more weightage

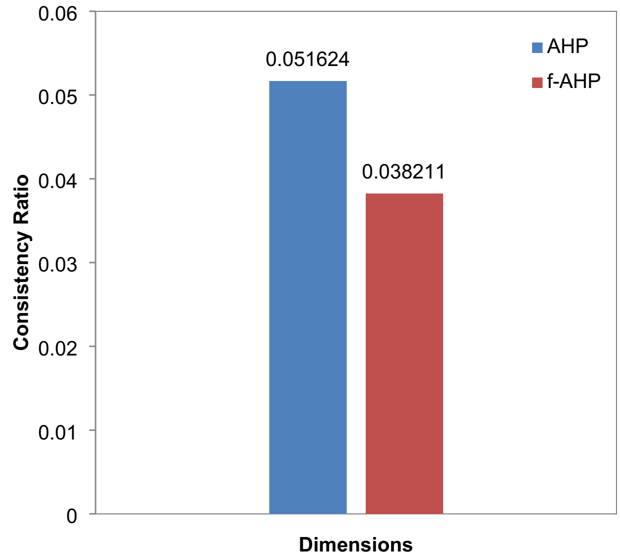


Fig. 1 Consistency ratios obtained using AHP and f-AHP for the pairwise comparison matrix of dimensions

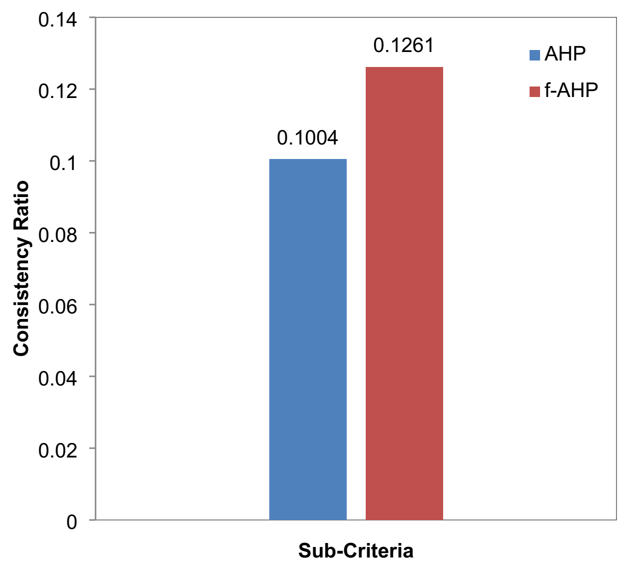


Fig. 2 Consistency ratios obtained using AHP and f-AHP for the pairwise comparison matrix of sub-criteria

followed by system performance, maintenance schedule and risk of damage. Based on this comprehensive analysis, it is anticipated that the policy-makers and managers should give more importance to those aspects or sub-criteria which has obtained maximum weightage under each dimension, while planning for a water supply project scheme.

Among the indicators (Fig. 6), the indicator 2.1.1 (Water testing frequency) carries the maximum weightage, followed by 4.1.3 (Public participation and consultation), 4.2.1 (Individual mechanisms of accountability), 3.1.2 (Efficiency), 2.3.3 (Distance from sewer pipes), 1.3.1 (Willingness to

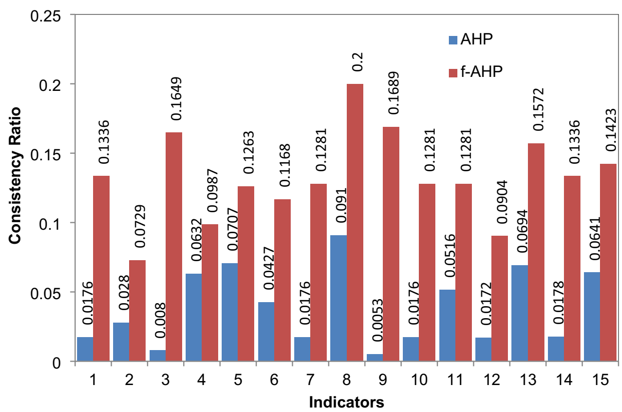


Fig. 3 Consistency ratios obtained using AHP and f-AHP for the pairwise comparison matrix of indicators

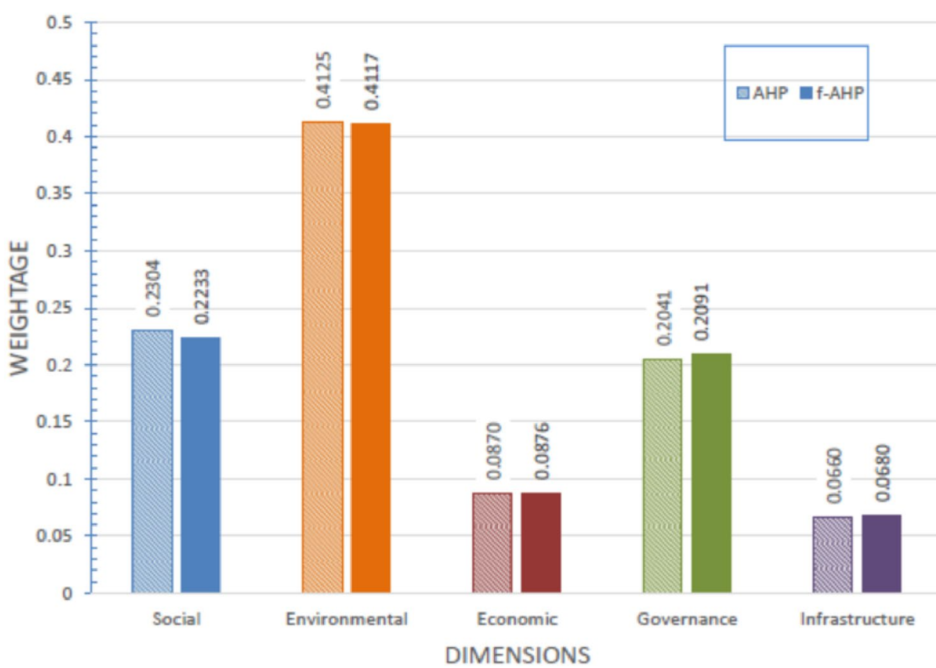
adopt). The above-mentioned indicators fall under the sub-criteria of optimum use (Sub-criteria 2.1), transparency (Sub-criteria 4.1), accountability (Sub-criteria 4.2), cost-effectiveness (Sub-criteria 3.1), quality at end use (Sub-criteria 2.3), empowerment (Sub-criteria 1.3). These sub-criteria need to be given focus to push the water supply projects to sustainability in the state of Tamil Nadu, India. It is also interesting to note that Sub-criteria 2.1 and 2.3 fall under the environment dimension, 4.1 and 4.2 fall under the governance, 3.1 under economic and 1.3 under social dimensions.

As evident from the relative weight distribution among the indicators, all the higher weighing attributes indicate the social and governance aspects where the direct involvement of the public is critical. As it has been seen the weight propagation to the higher levels of decision-making resembles an additive inference, all the highlighted indicators under each sub-criteria need to be clearly identified while assigning the managerial tasks. This analysis clearly demonstrates the need of categorically evaluating the preferences in terms of acquired weights while disseminating the resources such money, power and materials during the execution of a water conservation project. Nonetheless, this exercise too proves the underlined coalition of sustainability indicators involved in the impact assessment by giving a more comprehensive and pragmatic approach with fuzzy-adopted AHP model.

Salient Features of Comparison

The modelling exercises involving ranking and optimization have some limitations in bringing out innovative steps on the chosen methodology. However, as the complexity and the intended application of the problem scenario varies, the methodology and solution algorithm get automatically extended. Especially in case of criticality (risk) assessment, such a scenario can possibly provide significantly varying conclusions. However, in the present case, intention is to evaluate the performance of AHP and f-AHP methods for evaluating the priorities for a water supply project covering majority of the state of Tamil Nadu. As the scale and operational phase of the project are quite extensive, it has been observed that many of the minor details were getting nullified which otherwise would have been a serious cause of concern for a smaller scale of the project. Hence, the present study attempted to explore such hidden effects

Fig. 4 Comparison between AHP and f-AHP weights for the dimensions



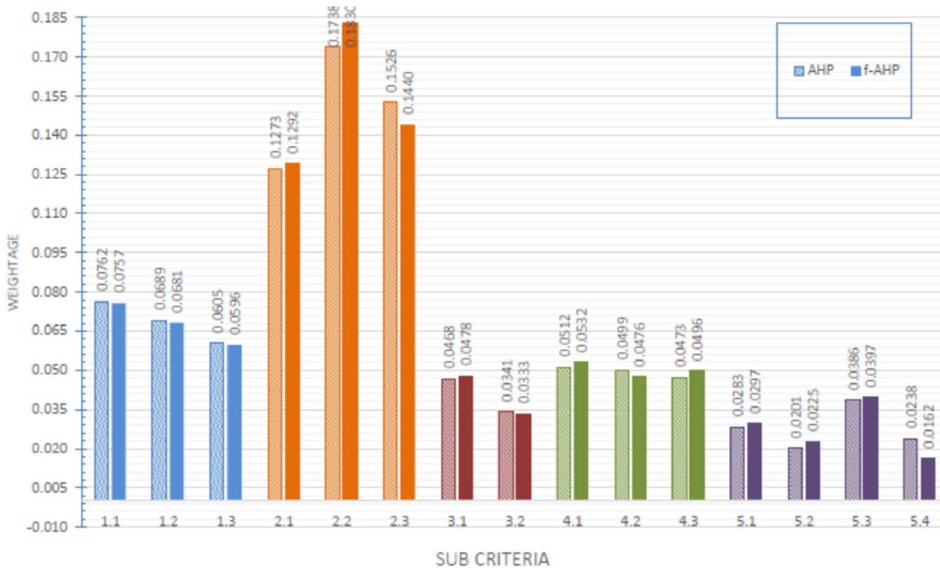


Fig. 5 Comparison between AHP and f-AHP weights for the sub-criteria

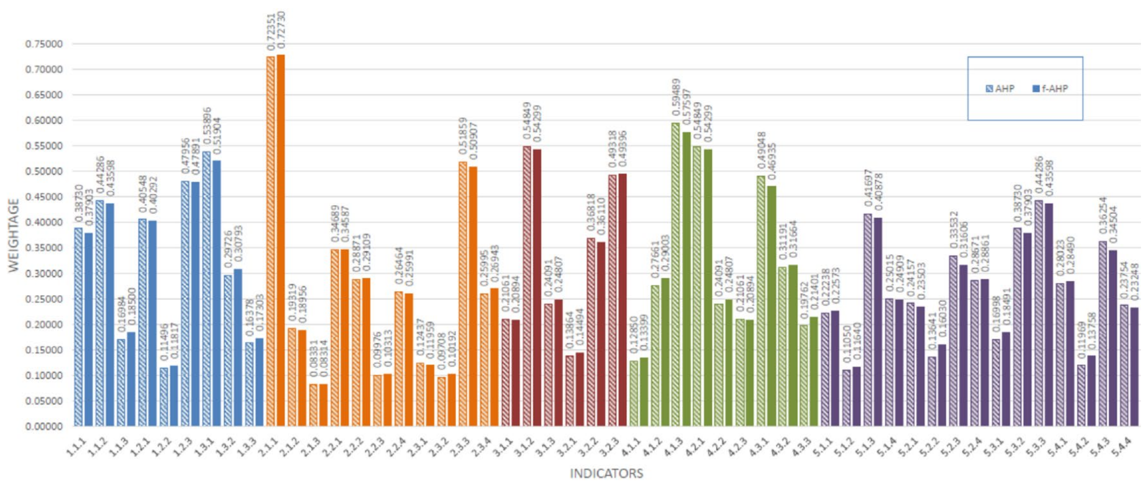


Fig. 6 Comparison between AHP and f-AHP weights for the indicators

on prioritizing the parameters at various levels (as have been taken three levels). The results from this study can be justified based on the pertaining assumptions taken for the intended scenario as mentioned in the Methodology section, which imply that the generic nature of the results is subjected to the scale and operational phase of the project under consideration.

Conclusion

In this study, AHP and f-AHP-based decision-making processes were compared for assessing the sustainability of a water supply project. The major dimensions (social, environmental, economic, governance and institutional) were resolved into 15 sub-criteria and 50 indicators to make the model framework. Based on the analysis, the environmental dimension (41%) has been given the highest importance in the measurement of sustainability of this project, followed by the social (22%), governance (20%), economical (8%) and infrastructure (6.8%) dimensions. Among the sub-criteria, quality at the source was given highest priority followed by cost-effectiveness, optimum use of water. The least weightage was given to risk of damage as it is a subset of infrastructure. The process of prioritizing the parameters has a higher dependency on the qualitative evaluation. However, the methodology is already well established that the chance of bias was nearly eliminated by comparing the consistencies of the results. In order to minimize the vagueness in representing the results, it has been adopted the quantitative comparison of performance of AHP and f-AHP in terms of the consistency ratio as well as the weightages. Hence, the results are free from vagueness and randomness and the conclusions can be relied for practical application within the limits of the inherent assumptions made in Methodology. The study recommends more public involvement in the planning, maintenance and operation of a water supply project where the social and governance factors together can bring about an overall change in the project outcomes. By ensuring the transparency, flexibility and serviceability during the implementation, the degree of satisfaction can be enhanced which, in turn, will ensure more responsible maintenance and follow-up by the public. Based on this study, it has been anticipated that the policy-makers and water supply managers should entail the importance to those elements which has obtained high significance so as to establish a sustainable water supply project scheme for the present as well as the future.

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Declarations

Conflict of interest None.

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