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# Drinking water supply service management and sustainable development challenges: case study of Bejaia, Algeria

Samir Hamchaoui, Abderrahmane Boudoukha and Abbas Benzerra

## ABSTRACT

The aim of this study is to develop a methodological tool for the sustainable management of drinking water supply service (DWSS), taking into account local specificities of Algeria. This research is supporting the water utility (Algérienne Des Eaux: ADE) in its challenges to improve the quality of services undertaken for customers. The methodology consists of a construction phase and an evaluation phase. The construction phase is to identify the prior objectives and sub-objectives, as well as criteria and indicators of sustainability associated with them. The evaluation phase is to evaluate the performance of DWSS. The aggregation of indicators and criteria is carried out with the weighted sum method, the weighting is done with the analytical hierarchy process (AHP) method. The application takes place in the DWSS of Bejaia city, Algeria. The evaluation of the objective's performance studied in this paper showed a good level of performance. This tool has allowed the identification of indicators to improve. Targeted decisions can further improve their performance.

**Key words** | AHP method, drinking water supply service, methodological tool, performance indicators, prior objectives, sustainability assessment

**Samir Hamchaoui** (corresponding author)
Department of Hydraulics,
Hadj Lakhdar University of Batna,
05000 Batna,
Algeria
E-mail: *hamchaouisamir@gmail.com*

**Samir Hamchaoui**
**Abbas Benzerra**
Laboratory of Applied Research in Hydraulics and Environment (LRHAE),
Faculty of Technology,
Université de Bejaia,
06000 Bejaia,
Algeria

**Abderrahmane Boudoukha**
Laboratory of Applied Research in Hydraulics,
Hadj Lakhdar University of Batna,
05000 Batna,
Algeria

## INTRODUCTION

Algeria is considered one of the poorest countries in terms of water potential. In 2002, Algiers city underwent an exceptional shortage in terms of meeting the water needs of the population. This situation raised a wide-ranging debate throughout the organization of national and international meetings, focusing on the origins of the sector failures that mainly resulted from precipitated management due to rapid urbanization of cities combined with the rural exodus. In fact, with a preoccupation about drinking water needs' satisfaction, the only concern was, for a long time, to link up the population in the drinking water areas. Accordingly, different projects have been realized, but none with a common thought or with co-ordination. Large budgets have been awarded to equipment realization and investment without integrating future management challenges or following the evolution of service management quality provided to customers. Many aspects, such as protection of water quality, deterioration of water infrastructures, siltation of dams, climate hazards, the real value of water and taking charge of information, have been neglected.

Today, the managers of Algérienne Des Eaux (ADE) (National Industrial and Commercial Public Institution) are facing challenges to take account of government policy directions for sustainable management (Drouiche *et al.* 2012) and translate them into concrete actions for sustainable management of its infrastructure. This seems to be very difficult, yet it is one of the main objectives to reach. This process is still very difficult with the multidimensional aspects of sustainable development associated with a lack of structured methodology and information at different hierarchical levels.

The challenges are undoubtedly difficult in a country like Algeria, which is slow in increasing its capacity to mobilize water resources and develop its economic growth

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(Benzerra *et al.* 2012). Therefore, improvement of the quality of management facilities associated with the urban water services is a prerequisite. Bearing this in mind, the government is beginning to look at advantaging the results and how they can help improve them.

Initially, a partnership has been established including foreign private companies in order to manage and train the staff for drinking water supply service (DWSS) in large cities. This co-operation has been very beneficial but not sufficient, because in terms of these agreements, the ADE can only rely on its skills.

The objective is to propose a methodological tool to monitor the extent of the evolution of management sustainability of Algerian DWSS. The measure of the evolution is a prerequisite to improve the sustainability of DWSS. It is obtained through exploitation of set indicators which are highly recommended by several authors as being useful elements for the development of tools to help in decision-making (Rouxel *et al.* 2008; Alegre *et al.* 2009; Staben *et al.* 2010; Kanakoudis *et al.* 2014).

In this context, several studies have analyzed the issue of assessing the management of drinking water utilities. Some of these researches have led to simpler approaches that organize proposed indicators in a dashboard (Alegre *et al.* 2000; Guérin-Schneider 2001; Kalulu & Hoko 2010).

Other, more complex approaches have developed assessment methods for the sustainable management of water services:

- New approaches have been developed in order to reform the whole management system. The management approach 'New Public Management', adopted by some developing countries, aims to replicate the management methods used by the private sector toward the public sector (Schwartz 2008). The management approach 'Performance Improvement Plans', adopted by some African countries (Mugabi *et al.* 2007), provides strategic planning followed by concrete actions to achieve the desired performance level.
- Other methods apply mathematical models, for example, in the case of the 'Data Envelopment Analysis' model (Thanassoulis 2000). Several works have exploited this technique in order to assess water services' performance. Another model is the 'Quality Index' (Rogers & Louis 2009) which synthesizes a set of measurement in only one indicator of global performance.
- Another approach proposes a change in the design of water supply. An intermittent water supply technique is proposed to rationalize water distribution by an adequate site of valves over the distribution network (Vairavamoorthy *et al.* 2008).
- Other works deal with the analysis of some specific aspects of the drinking water supply. Some are interested in the analysis of non-revenue water, as in the case of the WATERLOSS project (Kanakoudis *et al.* 2013a, b, 2015a), and others in the analysis of water distribution quality (Dietrich *et al.* 2014).

The consulted works provide interesting elements in the construction of the methodology and the choice of simple indicators to measure, adapted to the means available at the Algerians DWSS. The necessary tool needs answers to the two major objectives: structuring the relationships between the organizations to make the management of the services more effective, and allowing the managers to take into account the set of positive and negative points of the services. This tool should be adapted to local specificities and take into account the available information, lack of precise data, types of complaints, analysis of the quality carried out, dysfunction, etc. The adoption of this tool will, in this way, facilitate the ADE managers' involvement in sustainable management and will also improve the service given to the customer.

In this article, the methodology used in the context of a sustainable management of Algerian drinking water systems is presented. Thereafter, a description of the method used to aggregate indicators and assign an overall performance score for each objective will be described.

## METHODOLOGY

The research methodology used in this paper comprises a construction phase and an assessment phase. The research work is inspired by Brugmann's definition (Brugmann 1997) of sustainability assessment: 'Assessing the sustainability of water resources management requires appropriate frameworks of indicators, which can, ideally, describe and communicate current conditions, foster critical thinking about remedial actions required and facilitate the participation of various stakeholders in decision-making processes.'

The construction phase consists of significant consultation with stakeholders and actors having contact with water resources. Its objective is to identify the different prior objectives related to the sustainable management of drinking water service in Algeria. It is particularly difficult and time-consuming, but a necessary step for constructing the objectives that are acknowledged everywhere (Milman & Short 2008). Then the prior objectives are sub-divided into sub-objectives for better determining the meaning of their definition. Each sub-objective is composed of a set of criteria evaluated by performance indicators adapted to the present context management of Algerian DWSS.

The assessment phase starts by the collection of a data base, basically resulting from accompanying measures that are necessary for the calculation of the indicators defined in the previous phase. The values of these indicators are transposed on the performance scales to obtain the performance note of each indicator. During this phase the main difficulty lies mainly in the establishment of these scales.

The performance of the criteria is deduced by weighting and aggregation of the indicators' performance notes. The aggregation of the criteria's performance will provide, as well, the performance of sub-objectives. Finally, the aggregation of the latter will allow the global performance of each objective to be obtained. The developed methodology aims to integrate a support tool to help make decisions. These decisions deal with sustainable management and the implementation of technical and organizational devices of DWSS in Algeria in order to renew the practice of this management.

## System boundaries

In Algeria, as elsewhere in the world, the city consists of a set of various services, of which drinking water supply is considered the most vital. Its management is a major challenge for societies (Varis & Somlyody 1997). It is situated in the intersection between the city and its environment (Pizzol *et al.* 2013). The components of this system interact in a complex manner. Therefore, the adoption of a comprehensive management approach integrating all components of the system is required. This management should take into consideration the constraints, the needs, and the expectations of each element. Several studies on the sustainable management of urban water infrastructures have shown that the choice of system boundaries is crucial for identification of the aspects that are important for promotion of actions towards the objectives of the sustainable development (Lundin & Morrison 2002). In fact, it is necessary to understand the context in which a company like ADE should provide services to its customers. The context defines expectations, constraints, legal and administrative boundaries, interactions, the need and especially the effective use of the company's financial resources (Alegre *et al.* 2000). Various actors concerned with water issues are involved. Making great efforts to communicate and interact with the concerned actors, especially to find a consensus, seems an enormous task. The studied system consists of supply system and its requisites, water supply sources, political and technical organizations managing the system.

## Identification of criteria and indicators of sustainability

Identification of criteria and indicators of sustainability of the Algerian DWSS has been carried out by basic projects related to the problems of water in Algeria, different governmental reports (Social and Economical National Council; Ministry of Water Resource; Millennium Development Goals; Ministry of Environment and Regional Development), and highly technical works dealing with the identification and use of indicators for sustainability (Alegre *et al.* 2000; Guérin-Schneider 2001; Mugabi *et al.* 2007).

Brugmann's definition (Brugmann 1997) has led toward the analysis of drinking water service under its different aspects. This task has required the use of a descriptive approach. It has the role to set out the studied system with regard to its most urgent needs: protection and exploitation of water resources, quality of supplied water, infrastructures' rehabilitation, customer service, and finally

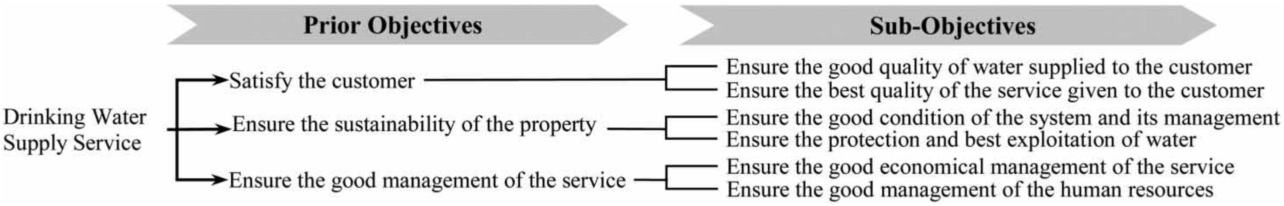


**Figure 1** | Synthesis of retained objectives and sub-objectives.

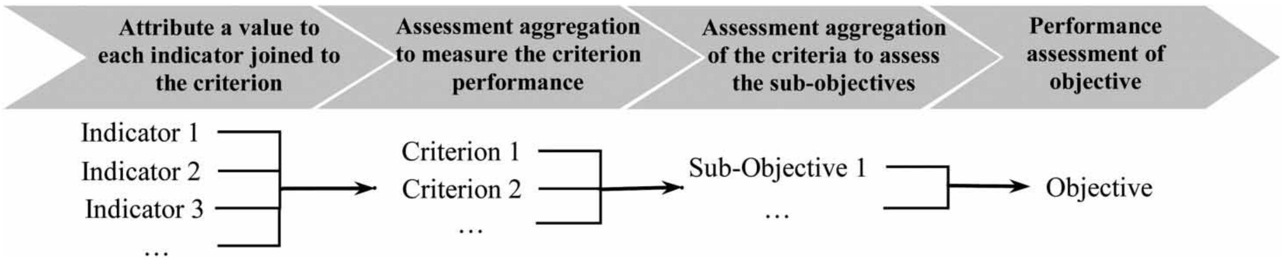


**Figure 2** | Principle of performances' assessment with regard to a particular objective.

the service's financial management and human resources service.

The aspects that contribute to improvement in performance of the drinking water service are various. However, the modes of control for the application of drinking water service demands could appear difficult. This difficulty would go back partly to the lack of competent staff and equipment of measurements necessary for ensuring the control conditions. Therefore, we need a 'small start' as advised by Peter Stahre, author of the foreword of Matos' handbook (Matos *et al.* 2003). The different debates within the work group led us to keep a restricted number of prioritized objectives (Figure 1). Each of the objectives chosen has been selected on the basis of simple, clear definition and a detailed critical analysis.

This work allows association of each objective with a set of sub-objectives that represent the prioritized functional demands for the service managers. Each objective corresponds to one basic function of the drinking water service. For each of the sub-objectives we have then constructed one or several criteria that allow assessment of the level with which the corresponding function is filled.

The proposed model aims, on the whole, at assessing the Algerian DWSS sustainability with regard to its demands. An important number of identified sub-objectives are taken into account. In this paper we study only some criteria. In this article, the prior objective 'Satisfy the customer' has been studied.

## Performance assessment

How to assess the performance of DWSS? Initially, the first step lies in the translation the raw data collected on the system to a performance note, then ascends to the performance of criteria then the performance of sub-objectives, and finally, the performance of the studied prior objective.

The choice lies in an aggregation that brings together the indicators in the criteria, then the criteria for evaluating the objective's performance. This method requires several

**Table 1** | Performance quality

| Performance | Quality |
|---|---|
| $0.00 \leq \text{performance} \leq 0.20$ | Very bad |
| $0.20 < \text{performance} \leq 0.40$ | Bad |
| $0.40 < \text{performance} \leq 0.60$ | Acceptable |
| $0.60 < \text{performance} \leq 0.80$ | Good |
| $0.80 < \text{performance} \leq 1.00$ | Very good |

structured steps (Figure 2) to be followed in a tree hierarchy (Kanakoudis *et al.* 2015b).

The use of this method requires a common assessment scale of the criteria and the sub-objectives. It is necessary beforehand to transform the estimated value of each indicator so as to give it a note on a normalized scale performance.

**Table 2** | Scale of comparison in pairs of the preference of AHP method

| Order of preference | Judgment of the preference |
|---|---|
| 9 | Extremely preferred |
| 7 (8) | Very strongly (very strongly to extremely) preferred |
| 5 (6) | Strongly (strongly to very strongly) preferred |
| 3 (4) | Moderately (moderately to strongly) preferred |
| 1 (2) | Equally (equally to moderately) preferred |

## Performance scale

The performance scale is finite; it is quantitative and scalar between 0 and 1. It is common to all the indicators and criteria. This range of variation is necessary to facilitate a detailed distinction of the assessment of the performance system. This choice agrees with the fact that the adopted performance assessment method is based on the analytical hierarchy process (AHP) method algorithm (Al-Harbi 2001).

To transform the initial measurement of the indicator into a performance note, performance functions have been built using standards, or, failing that, the recommendations

**Table 3** | Random Index (RI) values

| Size of matrix (N) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.53 |

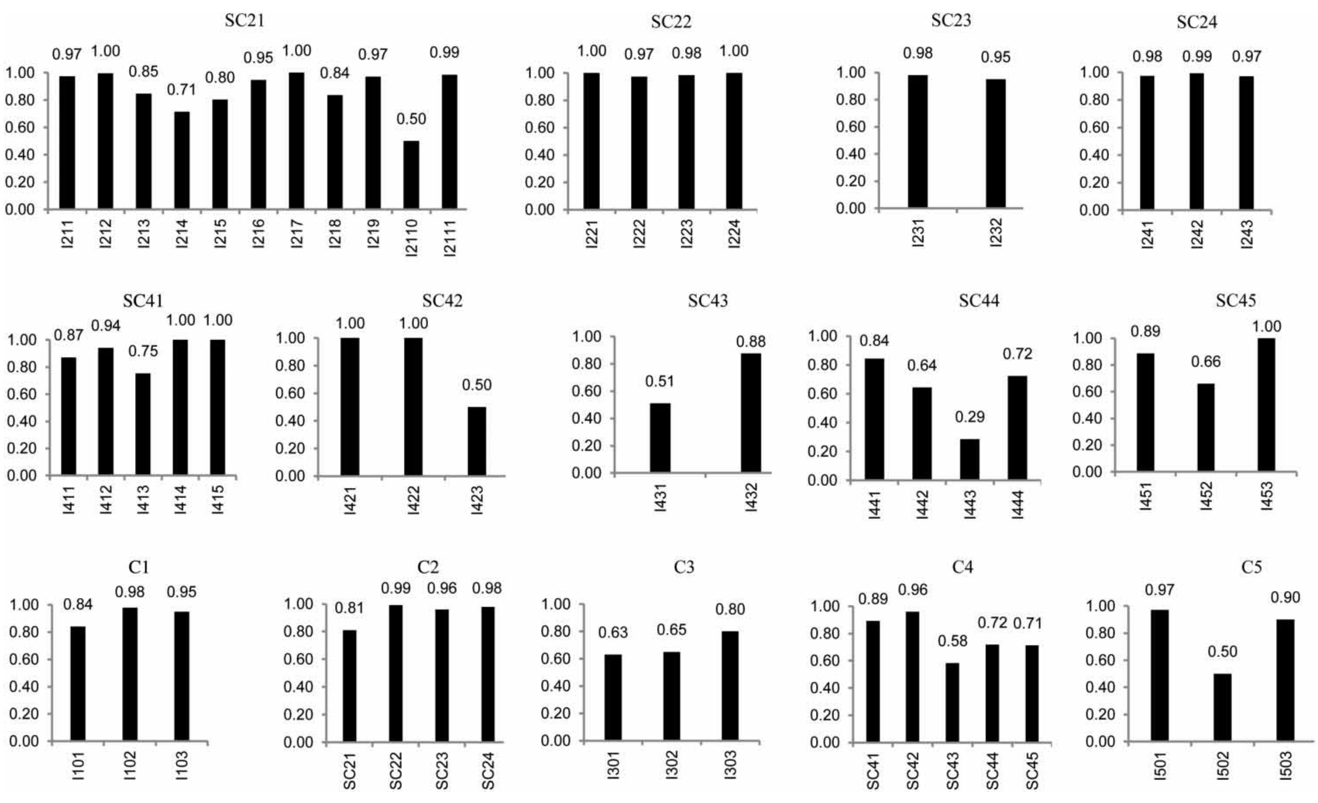


**Figure 3** | Performance of indicators related to the criteria C1, C2, C3, C4, and C5.

of national experts in the field of water. Hereafter, operation of the definition of Coulibaly & Rodriguez (2004) regarding the performance scale was adopted (Table 1).

## Aggregation method

The chosen aggregation method is a complete aggregation founded on the principle of a single criterion of the synthesis. The choice lies in the method of the weighted sum (Coulibaly & Rodriguez 2004) because of its clarity and its simplicity of implementation. The performance of $C_j$ is assessed by the following equation:

$$PC_i = \sum_{j=1}^{n} PI_{ij}.W_{ij} \quad (1)$$

The aggregation step is the same for the sub-objectives; with $n$: number of indicators occurred in the criterion $C_i$; $PC_i$: performance value of criterion $C_i$; $PI_{ij}$: performance value of the indicator $I_j$ of criterion $C_i$; $W_{ij}$: value of weighting coefficient of the indicator $I_j$ of the criterion $C_i$.

## Calculation of weighting coefficient

The calculation of weighting coefficient ($W_{ij}$) consists of applying the AHP method. This method has been used for numerous applications in the domain of multi-criteria decisions about water (Yi et al. 2005; Benzerra et al. 2012; Honkalaskar et al. 2014). This method is considered a global procedure, allowing modeling of a problem for project management decision-making, in order to reduce complexity and find a solution appealing for the concept

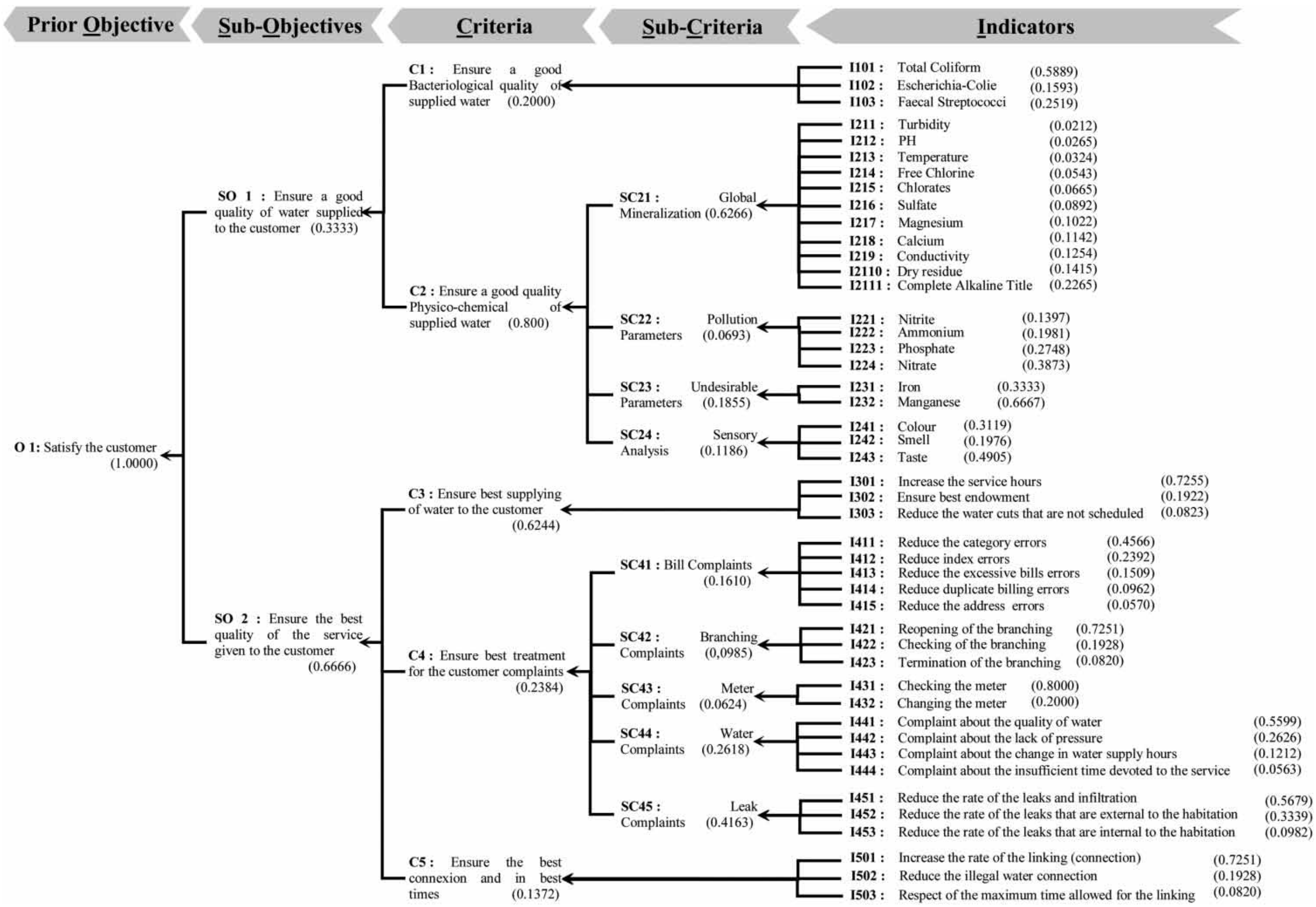


**Figure 4** | Weighted structural hierarchy of the studied prior objective 'Satisfy the customer'.

of comparison in pairs. Its application is based on the following fundamental principles (Al-Harbi 2001):

(1) Define the problem and to determine its objective.
(2) Decompose the complex problem into a structural hierarchy from the different levels.
(3) Construct a set of matrices of the comparison in pairs for each of the levels with one matrix for each element. Table 2 contains the numerical scale used to make the binary comparisons.
(4) Realize (NXN) judgments of all matrices constructed in step 3 (N: size of each matrix).
(5) Calculate the weight of each member of the set of matrices, then calculate the eigenvector (λmax) of each matrix.
(6) Calculate the coherence index:

$$CI = \frac{\lambda \max - N}{N - 1} \quad (2)$$

Then, verify the consistency of judgments using the following report:

$$CR = \frac{CI}{RI} \quad (3)$$

The values of Random Index (RI) are mentioned in Table 3. If $CR \geq 0.10$, the judgment should be revised and improved.

(7) Steps 3 and 6 are carried out at all levels of the hierarchy.

## RESULTS AND DISCUSSION

The methodological tool is applied to the DWSS of Bejaia city. The latter is located about 220 km east of Algiers. It has 181,386 inhabitants covering an area of 12,022 km² (Department of Regional Planning 2010). Nowadays, the water supply is provided by various sources (one natural source; one dam; eight drillings) and is to be reinforced by a sea water desalination station (Drouiche et al. 2011).

The length of the system of drinking water supplies of this city is 161 km for water supply and 281 km for the

**Table 4** | Retained coherence ratios

| | Sub-criterion | | | | | | | | | Criterion | | | | | Sub-objective | | Prior objective |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SC21 | SC22 | SC23 | SC24 | SC41 | SC42 | SC43 | SC44 | SC45 | C1 | C2 | C3 | C4 | C5 | SO1 | SO2 | O1 |
| Size of the matrix (N) | 11 | 4 | 2 | 3 | 5 | 3 | 2 | 4 | 3 | 3 | 4 | 3 | 5 | 3 | 2 | 3 | 2 |
| Eigenvalue (λmax) | 11.903 | 4.135 | 2 | 3.061 | 5.433 | 3.109 | 2 | 4.177 | 3.033 | 3.070 | 4.143 | 3.106 | 5.091 | 3.109 | 2 | 3.027 | 2 |
| Consistency index (CI) | 0.090 | 0.045 | 0 | 0.030 | 0.108 | 0.054 | 0 | 0.059 | 0.016 | 0.035 | 0.048 | 0.053 | 0.023 | 0.054 | 0 | 0.013 | 0 |
| Consistency ratio (CR) | 0.060 | 0.050 | 0 | 0.052 | 0.097 | 0.094 | 0 | 0.065 | 0.028 | 0.061 | 0.053 | 0.092 | 0.020 | 0.094 | 0 | 0.023 | 0 |

distribution with a connection rate equal to 97% at the end of 2010.

'Satisfy the customer' is a prior objective treated in this paper. Only the measurable and available indicators on the site of the study are taken into account. Consequently, data collected by the various public services of Bejaia city, during 2010, are exploited. All the information is sufficiently reliable to use in the development of the methodology. The comparison phase of the preferences in pairs is realized in collaboration with the various managers and engineers (biology, chemistry and water) from the ADE of Bejaia.

Subsequently, the use of performance functions allows the transition to a score between 0 and 1. This operation allows the performance note of each assessment indicator to be obtained (Figure 3).

Aggregation of the performance notes of the indicators using Equation (1) and the value of the corresponding weights (Figure 4) provides the performance of each criterion. In the same way, aggregation of the performances of the criteria has permitted us to set the global performance of each sub-objective, and then the performance of the studied priority.

The coherence of the preferences' judgments attributed to the matrices of the sub-criteria, the criteria, the sub-objectives, and the studied prior objective are acceptable because their coherence ratios are less than 0.10 (Table 4).

The analysis of the results could be done at any level of the studied structural hierarchy. In fact, the obtained performance on the studied objective (0.76) is well qualified (Figure 5). The interpretation of this performance at that hierarchical level could provide managers with an overall performance management overview. However, these analyses at the level of performances of indicators may improve the lower quality performances as well as global performance.

## CONCLUSIONS

This study provides a methodological decision support tool within the framework of the sustainable management of DWSS in Algeria, taking into account the local specificities. The choice of the prior objectives, sub-objectives, criteria and sub-criteria and the indicators required collaboration and significant consultation with stakeholders and actors in relation to water resources. This step is difficult and time-consuming but necessary to build objectives accepted by all.

The proposed research methodology consists of a construction phase and assessment phase. The former aims at identifying the prior objectives related to the sustainable management of DWSS. Then, these objectives are subdivided into sub-objectives. Each sub-objective is defined by a set of assessed criteria in their turn by indicators. The assessment phase starts with data collection. The values are transposed on the performance scale to obtain performance notes of each indicator. Likewise, a performance note is determined for the sub-criteria, criteria, sub-objectives, and the final objective.

Application of the tool was performed in the DWSS of Bejaia city. An assessment was made on the prior objective, i.e., 'Satisfy the customer'. Its performance is situated in the 'good performance' class. This result is the fruit of the labor that arises from the state's support of drinking water issues in Algeria during the last decade. The proposed tool has allowed the identification of some indicators for improvement. Thus, the ADE managers can undertake solutions needed to improve their performances.

The methodology provides interesting elements about the expectations of the DWSS managers. The constructed model is validated a priori. Differences in methodologies encountered in the literature and

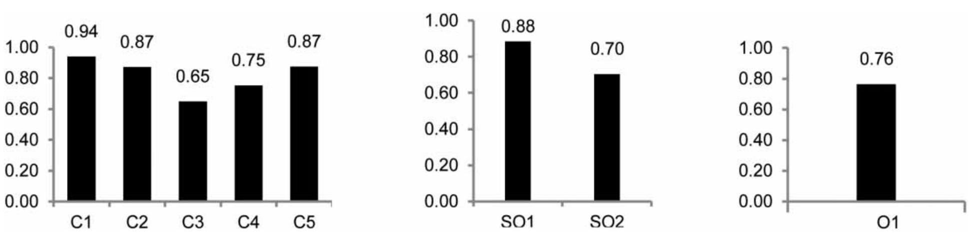


**Figure 5** | Performance of the criteria, sub-objectives, and prior objective.

specificities of our case study do not allow us to compare objectively the results obtained with other existing models. For this kind of model, as far as we are concerned, only feedback with consultations between the different stakeholders related to the drinking water system will strengthen the model's response and allow eventual improvements.

In the future, its extension to other cities is possible. From this perspective, it would be interesting if ADE organized national meetings with the necessary actors and the concerned services. The objective is to emerge with a common panel of indicators, criteria, and objectives accompanied by their performance scales. It is from there that benchmarking steps could be engaged in order to encourage all manager services to better performances.

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