

Sustainable community-based drinking water systems in developing countries: stakeholder perspectives

Muhammad Sagheer Aslam, Mohammad Adil, M. Saeed Mirza and Dominic Frigon

ABSTRACT

Over the past 25 years, stakeholders have become increasingly involved in the development and management of community-based projects. This paper presents the results of a study aimed at establishing stakeholder perspectives and priorities for sustainable community-based drinking water systems (CBDWS). The stakeholders have agreements and biases, which require an improved understanding of the sustainability of CBDWS. Environmental and institutional components of sustainability were noted to be two top priorities among the different groups of stakeholders. Most stakeholders agreed on priorities of clean drinking water sources, properly maintained infrastructure protecting the water quality, and the need for socially aware consumer communities. A complete review of the existing engineering practices and policy development is needed for successful implementation of any sustainable CBDWS.

Key words | analytical hierarchy process (AHP), community, drinking water, stakeholders, sustainable

Muhammad Sagheer Aslam
University of Engineering and Technology,
Peshawar,
Pakistan
and
Department of Civil Engineering,
McGill University,
Montreal,
Canada

Mohammad Adil (corresponding author)
University of Engineering and Technology,
Peshawar,
Pakistan
E-mail: adil@uetpeshawar.edu.pk

M. Saeed Mirza
Dominic Frigon
Department of Civil Engineering,
McGill University,
Montreal,
Canada

INTRODUCTION

Over the past 25 years, the stakeholders, which are identifiable groups or individuals who can affect or can be affected by a system (Freeman & Reed 1983), have become increasingly involved in the development and management of community-based projects and have evolved as one of the fastest growing mechanisms for challenging development assistance over the past two decades (Mansuri & Rao 2004).

It was overwhelmingly agreed at the 1992 Dublin International Conference on Water and the Environment (ICWE) and the 1992 Rio de Janeiro UN Conference on Environmental Development (UNCED) that development and management of water systems should be based on participatory approaches involving stakeholders, including users, planners and policy makers at all levels (WMO-UN 1992). A number of water-related projects were executed in developing countries involving active involvement of stakeholders (SADC 2002; Peter & Nkambule 2012). Engineers are primarily responsible for implementation (design, execution, operation, and

maintenance) of projects, and they are normally trained for a logical set of decisions and actions. They assemble information about all feasible solutions for a clearly stated problem, select the lowest cost solution that fulfills the objective, and implement it (Eschenbach & Eschenbach 1996). However, without a clear understanding of this 'magic elixir' of 'stakeholder involvement' (Eschenbach & Eschenbach 1996), engineers and policy makers cannot develop an effective solution of the associated problems.

The concept of 'participation in social and human development' is not an entirely new phenomenon and it can be traced back to the ancient Greeks (Cohen & Uphoff 1980). However, the participation and participatory approaches have been taking different shapes during different eras. The recent promulgation of the concept of participatory approaches by ICWE and UNCED can be considered involvement of a significant number of stakeholders in water development and management for the well-being of the local community. It

should be noted that the term ‘participatory approach’ in this paper implies ‘stakeholder involvement’, and the two terms are often used interchangeably.

Promulgation of the concept of participatory approaches for community-based systems (CBS) evolved gradually in some developing countries, especially in regions with a shortage of water resources and discriminatory patterns of water allocations, such as South Africa and Zimbabwe (SADC 2002). During the past three decades, community-based management models have become popular throughout Sub-Saharan Africa (Peter & Nkambule 2012). Some examples of active participation of the communities in water management include irrigation management in north-eastern Tanzania, flood management system for the Alexandra community (South Africa), Mlazi river catchment management program (South Africa), and the Mbongolwane wetland projects (South Africa) (SADC 2002). Although CBS are based on participatory approaches involving stakeholders, no studies focusing on stakeholder perspectives and subjectivities about sustainability of community-based drinking water systems (CBDWS) have been found in the literature.

Some efforts to develop a framework for evaluation of sustainability of urban drinking water systems were reported recently (Hellström *et al.* 2000; Fagan *et al.* 2010; Collier *et al.* 2014). Similar efforts were also made for sustainability of one or a few components of rural water supply systems (Lundin & Morrison 2002; Jones & Silva 2009; Nare *et al.* 2011). Unfortunately, these studies either did not consider the stakeholder perspectives (Giné & Pérez-Foguet 2008), or they lacked the involvement of stakeholders (Panthi & Bhattarai 2008; Peter & Nkambule 2012) to define the priorities and subjectivities (or weights) for the various sustainability elements of a CBDWS. A sustainable CBDWS can be defined as a drinking water system capable of delivering safe and sufficient drinking water, based on participation of stakeholders, while (i) maintaining (not eroding) environmentally the renewable capacity of the water resources, and protecting them from contamination, (ii) technically optimizing design with high quality execution and regular maintenance of distribution infrastructure, (iii) developing and operating the system in an economically beneficial and financially self-sufficient manner, (iv) promoting socially equitable access to clean drinking water through

awareness and involvement of communities, and (v) relying institutionally on effective local community organizations and management units. No data were found in the existing literature for comparison with the results of this study. However, the earlier studies provide a good starting point towards development of an evaluation framework, even if they lack the stakeholder context to be fully relevant for field applications. This study is based on a survey conducted principally in Northern Pakistan to obtain stakeholder input to their priorities for the various elements of sustainability of CBDWS involving the hierarchy of five components (technical, environmental, economic, social and institutional), along with factors within each component, and their sub-factors for a sustainable CBDWS.

These elements are self-explanatory and are detailed in Table 1, and are based on a detailed survey of the literature, meetings with stakeholders and detailed discussions and resulting iterations at meetings with a group of researchers.

This paper deals with understanding the stakeholder perspectives and priorities for sustainable CBDWS, aimed at developing an integrated framework for their effective implementation. The results of the stakeholder survey and evaluation of the weights for components of sustainable CBDWS and the related factors are reported in this paper.

STAKEHOLDER SURVEY

Stakeholders were identified and contacted in almost equal proportion for each of five groups of stakeholders, to respond to a survey aimed at determining their relative priorities for a defined set of elements for a sustainable CBDWS. Selection of the respondents was made based on their involvement, experience, and ability and access to make broad contacts. Users were one of the major stakeholders. They were considered under the social stakeholders group as users’ aspects were covered under the social component (see Table 1). However, the users included in this survey were literate to a level where they can understand the survey and respond accordingly. Depending on the convenience of the respondent, he/she was provided with a web-based or a paper-based version of the survey (Aslam 2013). Each respondent was required to make a number of pair-wise comparisons between the five

Table 1 | Elements of a sustainable CBDWS

Component	Factors	Sub-factors
Technical	Design and execution of distribution infrastructure	Design optimization Available pressure at delivery points Protection from external pollution Safety against external threats/disasters
	Maintenance	Physical condition Service interruptions Preventive and remedial maintenance
	Water quality in distribution system	Existence of treatment facilities Efficiency of treatment facilities Water quality at consumer end
Environmental	Source capacity	Present capacity of source Reliability of source over time
	Source quality	Water quality at source Water source protection
Economic	Financing	Funding availability for operations and maintenance Asset value decreases over service life time Reliability and continuity of finances
	Economic impact	Direct benefits to community members Indirect benefits
Social	Social awareness	Awareness of water-related issues Water usage practices
	Social involvement	Population coverage (quantitative) Equity/inclusion (different sectors)
Institutional	Community organizations	Existence of community organizations Effectiveness of community organizations
	Operation and maintenance (O&M) units	Existence of O&M units Skills and training of committee members Transparency in utilization of funds Inventories/records for maintenance

components, and between two to three factors within each component. The analytical hierarchy process (AHP) was used as a tool for ranking the various sustainability components and factors (Saaty 2008). The weights obtained using the AHP algorithm represent a measure of stakeholder subjectivities. Because of time constraints, the sub-factors were not made a part of the main survey; however, online respondents were provided with an option to deal with sub-factors.

The stakeholders were asked to provide the following information: (1) how best they would define themselves as an individual belonging to one of the identified groups, that is, technical, environmental, economic, social or institutional stakeholders; (2) their organizational and social affiliations (serving or representing academia and education, consultancies and the fields of infrastructure execution and management, governmental and non-governmental service

providing agencies, and community institutions, such as community organizations and their various sub-units); and (3) the number of years of experience. The pair consisting of associations of stakeholder groups and their affiliations was tested by conducting a chi-square test of independence to examine the relationship between the identified groups of stakeholders and their reorganized groupings based on their affiliations described above. The pairs, consisting of association between each group of stakeholders and years of experience were tested using the univariate analysis of variance (ANOVA) with years of experience for a quantitative response (Sokal & Rohlf 1994).

Comparison of weights between the stakeholder groups were performed using multivariate analysis of variance (MANOVA) for components and the factors within each technical component. These comparisons were performed

using ANOVA for the factors within other components, as the choice was between only two factors (i.e. only one degree of freedom in the attributions of weights) (Sokal & Rohlf 1994), using the raw weights for each response. Once the overall null-hypothesis of no difference between the groups was rejected ($p < 0.05$), similarity between the groups was tested using contrasts for the components, or using the Duncan pairwise multiple comparison for factors (Sokal & Rohlf 1994).

Results of stakeholder survey

Survey responses

Over 450 individuals (stakeholders) were approached for responding to the survey. The response rate was a little over 50%, with a total of 232 responses, including 55 women (31.5%) and 177 men (68.5%) from the various stakeholder groups – technical (30.6%), environmental (21.6%), social (24.1%), institutional (15.1%), and economic (8.6%) (Figure 1(a)). Despite the effort to contact the respondents in equal proportions, the response rate of technical, environmental, and social stakeholders was higher as compared with institutional and economic stakeholders. The respondents affiliated (Figure 1(b)) with academia (mainly dealing with higher education and research) and educational institutions (such as schools in and around the communities) participated more actively (44.6%), followed by the respondents from consultancies and field of engineering (22.7%), and community organizations/institutions (19.4%). The proportion of respondents from service providing agencies was the lowest (13.4%).

As expected, classification of the respondents with reference to their affiliation (Figure 2) was not independent. There was a significant ($p < 0.05$) association between the stakeholder groups and their organizational affiliations.

There was also a significant association between the various groups of respondents and the number of years of experience (Table 2). Technical, environmental and economic respondents had similar average number of years of experience with the averages ranging from 5.9 to 7.0 years. However, social and institutional respondents had slightly higher experience with averages of 9.3–10.0 years, respectively. Figure 3 presents the

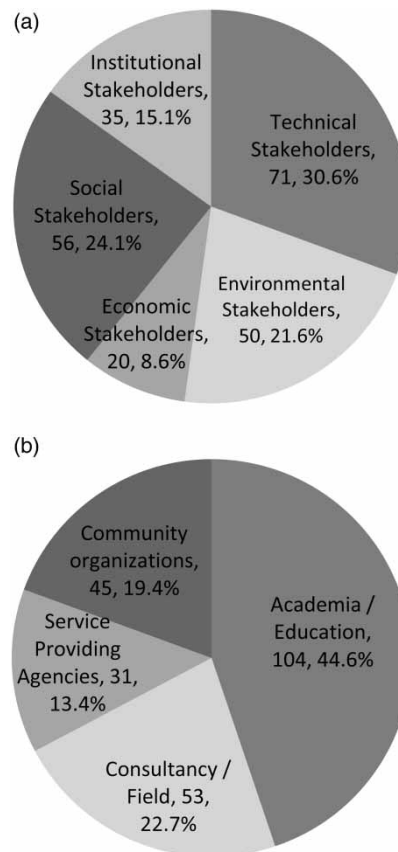


Figure 1 | (a) Number of respondents from the various groups of stakeholders, (b) number of respondents on the basis of their organizational affiliation.

proportion of respondents in each group vs. the number of years of experience. A majority of the respondents in each group belong to the 5–10 years of experience.

Weights assigned to sustainability components

The weights assigned to the sustainability components by the various groups of stakeholders are presented in Figure 4.

When the average weights were compared on the basis of the stakeholder attributes (groups, affiliation, years of experience, and the country of origin), only the 'groups' were statistically significant (Table 2). Two groups of homogeneous weight profiles can be observed: technical and environmental stakeholders expressed preferences similar to each other; social and institutional stakeholders agreed with each other for the average components weight profiles. This implies that the similarity and

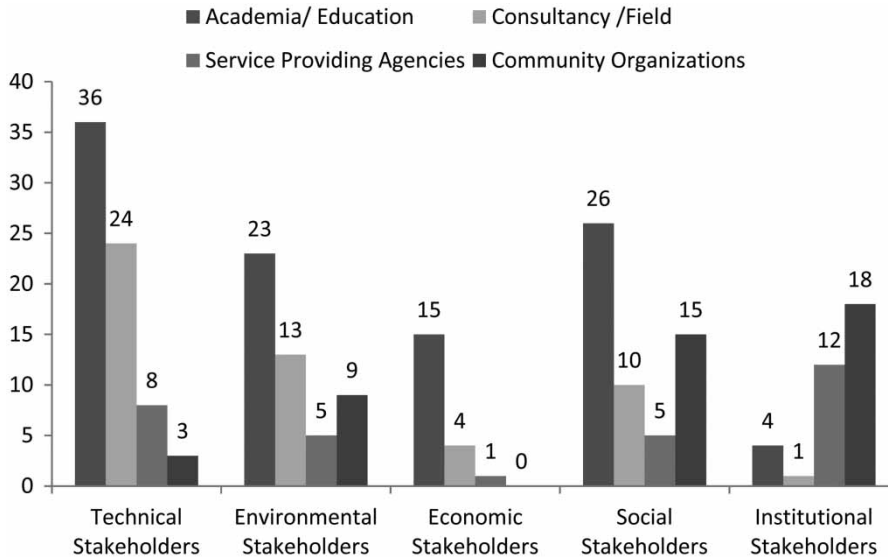


Figure 2 | Number of respondents in each group showing their organizational affiliations.

Table 2 | MANOVA and ANOVA test results for weights of components and factors vs. respondent features

Classification	Df*	Sustainability factors											
		Sustainability components		Technical factors		Environmental factors		Social factors		Economic factors		Institutional factors	
		Wilk's Lambda	p value	Wilk's Lambda	p value	F value	p value	F Value	p value	F value	p value	F value	p value
Defined stakeholder groups	4	0.852	0.017	0.949	0.529	0.44	0.780	0.29	0.885	2.72	0.031	3.21	0.014
Professional affiliations	3	0.942	0.585	0.979	0.870	0.23	0.878	0.45	0.720	1.39	0.247	2.41	0.068
Years of experience	1	0.973	0.312	0.977	0.183	2.19	0.141	0.18	0.669	8.06	0.005	2.68	0.103
Contrast: Technical and Environmental vs. Social and Institutional	1	0.894	< 0.01	NA	NA	NA	NA	NA	NA	1.33	0.251	3.95	0.048

Df* = Degree of freedom.

Bold entries were judged to be statistically significant ($p < 0.05$).

direction of awareness, including educational background and formal training, plays a role in developing consensus in priorities. The results show some clear biases and agreements among the various groups of stakeholders, as follows: the environmental component received the highest average weight from the environmental and technical respondents (26.1 and 25.4%, respectively); social component received the highest average weight from social respondents (24.2%), institutional components received the highest average weights from social and institutional

respondents (25.7 and 24.5%, respectively). Overall, it was observed that all groups of respondents assigned significantly lower ($p < 0.05$) weights to the technical component than to the other components.

Weights for factors

The average weight profile for factors within each sustainability component were examined for differences between stakeholder attributes (Table 2). The average weight

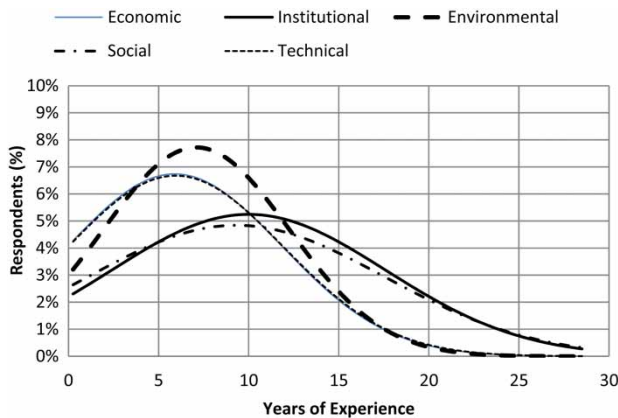


Figure 3 | Number of years of experience for the various groups of stakeholders.

profiles for factors related to technical (Figure 5), environmental (Figure 6) and social components (Figure 7) were not significantly different ($p > 0.05$) from any of the attributes (Table 2). Among the three factors belonging to the technical component (Figure 5), the stakeholders generally assigned an overall average weight of 40% to the factor *Water Quality in Distribution System*, while the factors *Design and Distribution Infrastructure*, and *Maintenance* received almost equal average weights (29 and 31%, respectively). For the factors defining the environmental component (Figure 6), the respondents provided a slightly higher priority to the *Source Water Quality* (average weight 54%) over the *Source Water Capacity* (average

weight 46%). Finally, among the two factors defining the social component (Figure 7), there was a slightly higher average weight for the *Social Awareness* factor (53%) compared with the *Social Involvement* factor (47%).

Analysis of the weight profiles for the factors associated with the economic component showed significant effects ($p < 0.05$) for two stakeholder features: stakeholder groups and years of experience (Table 2). When comparing the relative weights associated with the *Financing Factor* (Figure 8) and the *Economic Factor*, it was observed that the importance of the *Financing Factor* increased on average by 0.76% per year of experience. For the *years of experience* feature, it was found that the technical, environmental and social stakeholders assigned a higher weight to the *Economic Impact Factor*, whereas economic and institutional stakeholders expressed a higher priority for the *Financing Factor* (Figure 8).

The weights for the factors related to the institutional component are shown in Figure 9. The institutional stakeholders, who are related principally to the community institutions, have clearly assigned a higher weight (64.3%) to the *Operation and Maintenance Units Factor*. The technical and environmental stakeholders have also assigned relatively higher weights (53.8 and 52.3%, respectively) to the same factor. The social stakeholders have favoured the socially organized *Community Organizations Factor* with a weight of 57.1%.

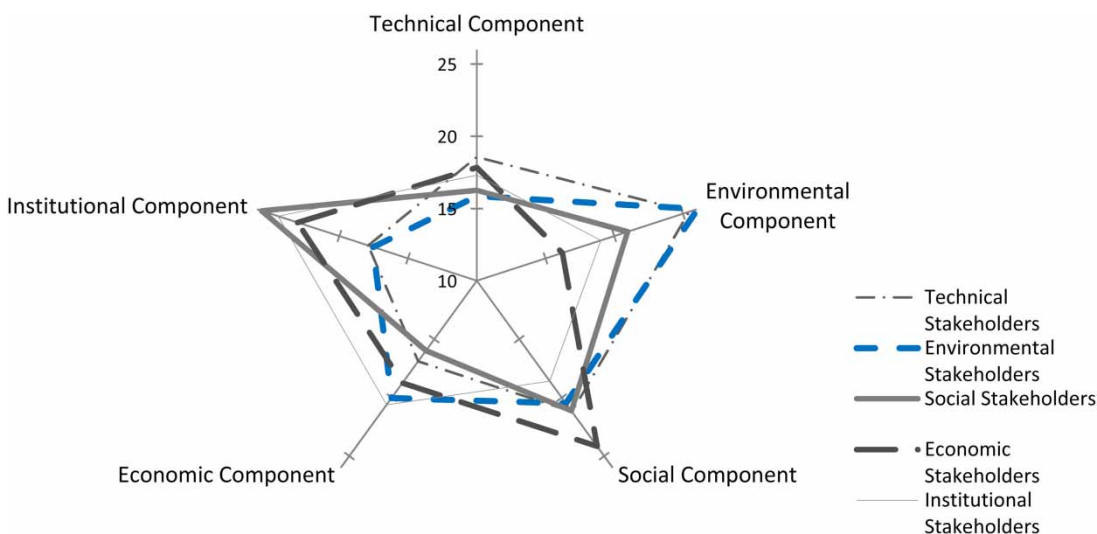


Figure 4 | Average weights assigned to sustainability components, based on survey responses.

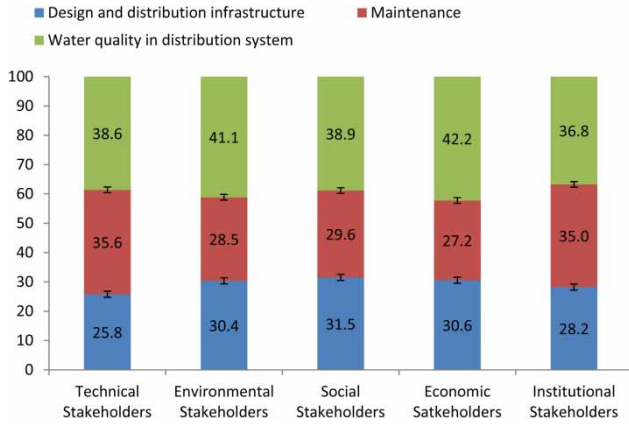


Figure 5 | Average weights for the factors defining the technical component. Error bars indicate standard errors.

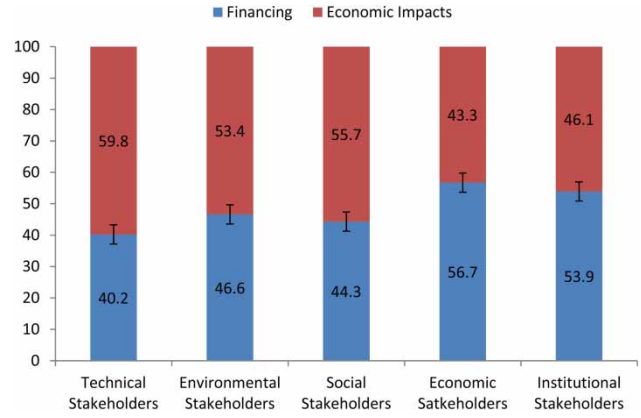


Figure 8 | Variation in weights of factors related to economic components, that is, financing and economic impacts, by the various groups of stakeholders for all component factors. Error bars indicate standard errors.

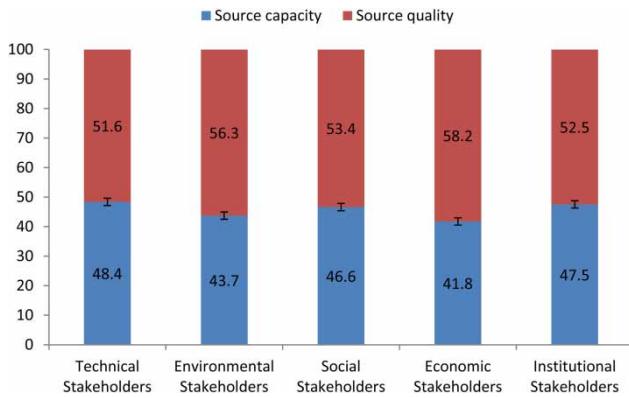


Figure 6 | Average weights for the factors defining the environmental component. Error bars indicate standard errors.

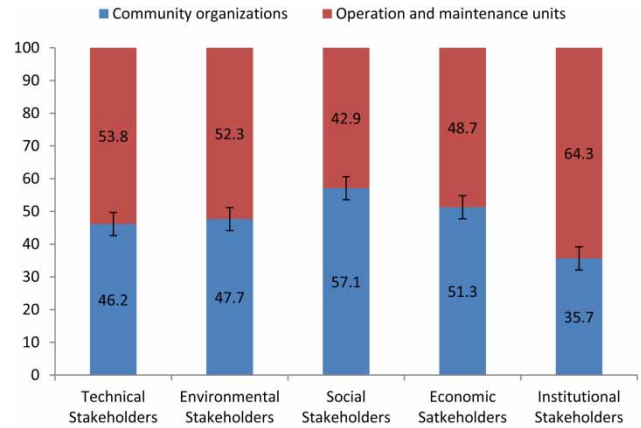


Figure 9 | Average weights for the factors defining the institutional component. Error bars indicate standard errors.

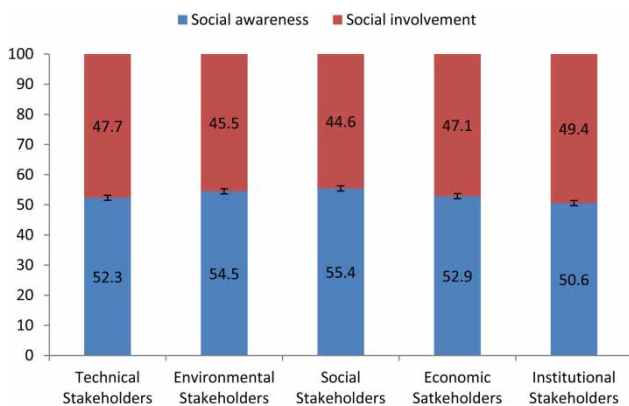


Figure 7 | Average weights for the factors defining the social component. Error bars indicate standard errors.

DISCUSSION

Two clusters of stakeholder groups can be discerned, based on the statistical differences in the average weight profiles assigned to the components: Cluster 1 comprised technical and environmental stakeholders, while Cluster 2 included social, economic, and institutional stakeholders. The summary of the weights assigned to the two clusters of groups are presented in Figure 10. Cluster 1 with a background of engineering sciences assigned a higher priority to the environmental component, while Cluster 2, with a background of social sciences, favored the institutional component as its top priority.

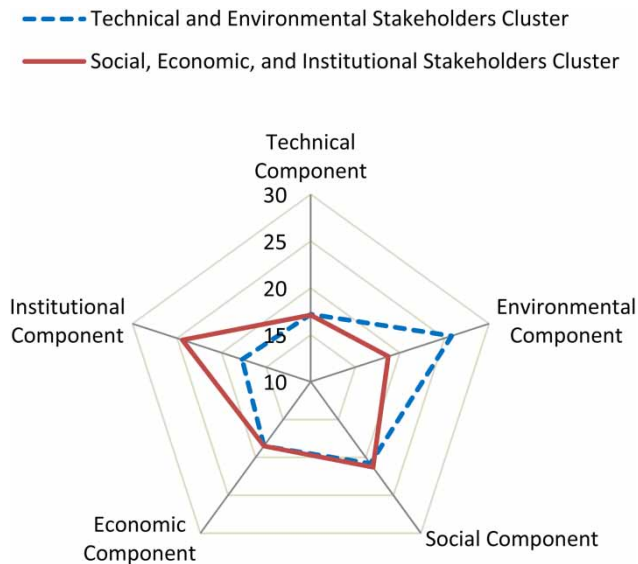


Figure 10 | Comparison of weights for sustainability components between main clusters showing the clusters' priorities.

The environmental and institutional components were the top priorities among the stakeholders. Examining the contrasts and clustering of like-minded stakeholders showed that the environmental component is the top priority among the stakeholders with natural sciences and engineering backgrounds, while the institutional component (related to community institutions) is the top priority for stakeholders with social sciences backgrounds (Figure 10).

A clear trend of assigning higher priorities by the stakeholders to the components can be noticed from the higher weights for some components provided by the group of specific respondents directly related to these components. The environmental component received the highest (26.1%) weight from the environmental respondents; institutional components received maximum (25.7 and 24.5%) weights from social and institutional respondents, respectively, and the technical component was assigned a maximum average weight of (18.6%) from technical respondents.

As mentioned earlier, no studies were found in the literature with data for stakeholder subjectivities and priorities to enable a direct comparison with the results of the present study; however, Panthi & Bhattarai (2008) assigned some weights to the elements of sustainability for evaluation of sixteen rural water supply projects in Nepal. They assigned 50% weight to the technical component,

which was the highest among all five components. The term 'technical component' in their work included technical and environmental factors (reliability, adequacy, depletion, and water quality at source) as used in the present study. Panthi and Bhattarai's work was not based on the analysis of stakeholder input and aimed at fulfilling a consultancy assignment; therefore, a direct comparison with this study is not possible. In spite of some similarities between the combined technical and environmental weights for the components, the weight profiles assigned by the Panthi & Bhattarai (2008) are quite different from the stakeholder subjectivities synthesized in this study, with the exception of the weights for the institutional components which are quite close in both studies. These weights are 20% in the Panthi & Bhattarai (2008) study, and 21% in the present study. More studies are needed in other developing countries in the various regions of the world to verify these trends.

SUMMARY AND CONCLUSIONS

This study has determined the subjectivities of the various groups of stakeholders towards sustainable CBDWS. An examination of the findings showed that stakeholders are more agreeable in their priorities with groups of similar backgrounds than the groups with different backgrounds. These differences can be observed clearly when the combined priorities of stakeholder groups affiliated with engineering sciences and the stakeholder groups affiliated with social sciences are compared. These differences are important to understand for successful implementation of a sustainable CBDWS; otherwise it could seriously affect the system sustainability. Stakeholder involvement is important; however, its mechanism needs to be understood. As discussed earlier, stakeholders have different priorities due to their educational background, experience, and exposure; and these priorities should be given attention for successful implementation of community-based projects. Some of the important conclusions of this study are as follows:

1. Environmental and institutional components are highly important for sustainability of CBDWS. Two major clusters of stakeholders showed a clear bias in this respect. Stakeholders with a background of natural and

engineering sciences assigned a higher priority to the environmental component, while the stakeholders with a background of social sciences and social involvements clearly prioritized the institutional component. Considering the list and hierarchy of the elements of sustainability of CBDWS (Table 1), this shows that sustainable drinking water sources and effective community institutions are important for a sustainable CBDWS. Both must be addressed for successful implementation of CBS.

2. All groups of stakeholders have a consensus on the relative priorities for three factors: (1) design and execution of infrastructure for the technical component (Figure 5), (ii) source quality for the environmental component (Figure 6), and (iii) awareness for the social component (Figure 7). Translating this unanimous agreement among all groups of stakeholders, the most agreed requirements of a sustainable CBDWS leads to the conclusion that clean drinking water sources, properly maintained infrastructure protecting the water quality, and socially aware consumer communities are vital for a sustainable CBDWS. This finding can help to establish policy development and future investments in sustainable CBDWS.
3. Engineering practices often present a solution without considering factors such as the existing level of social awareness, which can be detrimental for sustainability of drinking water systems based on community involvement. Further studies are needed to quantify these factors to incorporate them in engineering design, management practices, and policy decisions.

The conclusions drawn on the basis of this study clearly reflect that CBDWS managed with a significant involvement of all stakeholders require a complete review of existing design and management practices. This will require further studies to suggest and improve specific measures for optimized design, execution and management of CBDWS.

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