Research article

Application of Analytical Hierarchical Process Method to Select a Technology Option in Rural Settings

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Received 29 October 2013 Accepted 1 March 2014 (*Corresponding Author)

Abstract Selection of an appropriate technology in rural settings in developing countries contributes to the effective use of the scarce resources of the community and the sustainability of the system using that technology. Literature review shows that appropriate selected technologies suit difficult conditions of poor people, lessen their financial burdens, increase productivity and create wealth. This paper also introduces the application of Analytical Hierarchical Process (AHP) method in making decision on technology in rural settings. The eight-step process of AHP method is demonstrated with an illustration example of rural water supply investment based on the alternatives, criteria and priorities as judged. This new model, an application of mathematical methodology in social choice, would correct the shortcomings of other decision rules and improve the quality of decision-making process of a community in their initiatives to improve their livelihoods.

Keywords rural development, technology selection, analytical hierarchical process

INTRODUCTION

Nowadays about three quarters of 780 million people are drinking unsafe water and two thirds of this number are living in Africa and Asia (UNICEF, 2012). In order to achieve the Millennium Development Goal for Water Supply and Sanitation of the United Nations, more efforts need to be made to provide safe water to rural communities in these two continents. Fortunately, this mission is likely to be realized, at least in terms of technology as nowadays there are many water technology options, both traditional and modern. A collection of most recent water treatment technologies include solar water disinfection, coagulants/flocculants, ultraviolet treatment, reverse osmosis, ultra filtration, nanofiltration, to name some (Dalberg, 2013). Beside those advanced technologies, people can use traditional water treatment methods such as boiling water, chlorination, sand filters and ceramic filters. For each technology application, there is a corresponding type of water supply. Current popular types include piped water distribution, hand-pump well, rainwater guttering system which can be used in rural areas (Mekong Delta Water Project). Before selection of technology and water distribution type, it is important to know what community wants. How to relate the community's wants or criteria to technology options for optimal selection requires a quantitative decision model. This paper introduces the application of Analytical Hierarchical Process (AHP) technique for this purpose because the requirements for its application are met with available options and predictable criteria. With many choices presented, communities have great opportunities to make informed decision in a suitable water supply model to improve their health and even further, increase farming and irrigation productivity hence raise their income. Analytical Hierarchical Process (AHP) technique is presented as a quantitative decision technique in many operations research books and journal papers. The key to this method is pairwise comparison between alternatives in respect to each criteria and these comparisons are organized in the structural form of tree branches. The final goal is to calculate a weighted score total for each alternative and select the most optimal alternative. Saaty (1990) introduced clear basic guidelines for this calculation. Following him, some scholars proposed an extended AHN method, or fuzzy AHN technique (Abdel-Kader and Dugdale, 2001, Ertugrul Karsak and Tolga, 2001, Ordoobadi, 2012). The extended AHP method supplemented the short comings of failing to discuss uncertainties or risks in determining values for each alternative. Applications of AHN techniques can be found in much literature on investment selection, portfolio plans, technology choice, vendor or provider selection.

OBJECTIVE

The purpose of this paper is to introduce the application of Analytical Hierarchical Process (AHP) method in a decision on water technology in rural settings. This is a multi-criteria decision-making process which requires eight steps, as described in the next sections. A rural water technology is recommended as a result of applying this method given judgment values provided by top experts.

The limitation of this presented calculation is that its outputs are only accurate in case pairwise comparison is perfectly consistent. In practice, pairwise comparison is not perfectly consistent. Actually, consistency ratio should be calculated in any AHP matrices, whose calculation is explained in the work of Saaty (Saaty, 1990). The scope of this paper does not include the inconsistency ratio.

METHODOLOGY

Basic AHP methods are explained in the work of Nydick and Hill (1992). He showed calculation tables to describe step by step to reach to the final aggregated score for each supplier. Saaty (1990) listed AHP method steps as follows: 1 - identify potential alternatives; 2 - identify and classify selection criteria; 3 - Identify criteria/alternatives interdependence; 4 - Construct AHP Model; 5 - Perform pairwise comparisons to determine criteria priorities; 6 - Perform pairwise comparison to determine alternative priorities with respect to each criterion; 7 - Determine overall priority for each alternative; 8 - Select the technology alternative with the highest priority.

To illustrate this paper with a simple example, a list of three key criteria normally used for rural water supply technology selection, extracted from literature, is used. Next, from reading technical assessment on community-level water supply, three emerging rural water technology alternatives are selected based on the recommendations by water experts (Dalberg, 2013). They are solar water disinfection, coagulant/flocculants treatment and reverse osmosis. After the criteria and alternatives have been identified, top experts in rural water supply have been contacted for giving judgment values to the alternatives and criteria. This qualitative approach is called "jury of executive opinion" where the opinions of a small group of high-level managers are good enough for decision (Render, Stair, & Hanna, 2009). From personal working relationship, a UNICEF top water engineer and a former team leader of Mekong Delta Project Rural Water Project have been asked to answer the questionnaire using the survey website www.surveymonkey.com. Both of them worked as top experts in an Australia-funded water project in Mekong Delta. The team leader, who is a water engineer with more than 30 years of experience in rural water supply has responded. In the questionnaire, the respondent is asked to judge the importance level of each water technology and each criteria. The questionnaire uses 5-point Likert scale: 1 = very unimportant; 2 = unimportant; 3 = neutral; 4 = important; 5 = very important for criteria importance weights and 1 = very poor; 2 = poor; 3 = average; 4 = good; 5 = very good for other questions.

ILLUSTRATION EXAMPLE AND RESULTS

Let's consider the following case. Suppose that a social enterprise wants to select an appropriate technology option to supply water to a community in rural Mekong Delta. This example excludes water provision at the individual household level hence eliminate technologies for this level including chlorination, sand filters, ceramic filters. A preliminary technical assessment filters out three technologies suitable to local conditions are solar water disinfection, coagulant/flocculants treatment and reverse osmosis. The overall objective is to identify the best technology which has the highest evaluation score. Note that comparison values in the tables below are given by a top expert in rural water supply.

Step 1: Identified potential alternatives are solar water disinfection, coagulant/flocculants treatment and reverse osmosis).

Step 2, 3& 4: Criteria/alternative interdependence and AHP Model are established (Fig. 1).

Step 5: Criteria pairwise comparisons performed to determine criteria priorities (Tables 1, 2).

Let’s sum up all the elements in each column to generate Column Total (Table 1). Then divide each value by its column sum. For example, the sum of all the elements in the column of item a – Low cost is 6.25. The value of the pairwise comparison between quality and itself is 1. To normalize this value, we divide 1 by the column total of 6.25 to result in 0.16 (Table 2). The last column of Table 3 shows the priority weight of each criterion, which is calculated by averaging all the values of the same row. For example, the criterion of item a - low cost is 0.16. The row average value is not different from the value previously normalized by column because the expert judgment is perfectly consistent.

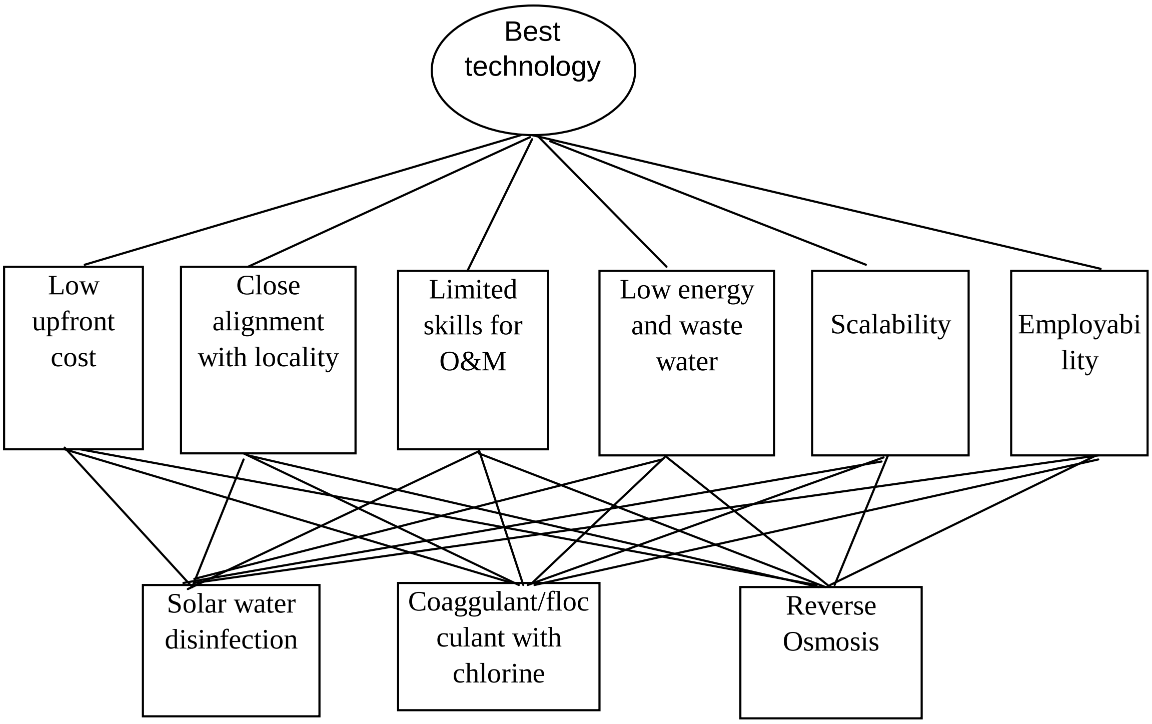

Fig. 1 The AHP model for technology selection

Table 1 Pairwise comparison of criteria - original matrix

	a	b	c	d	e	f
a. Low cost	1	4/5	4/4	4/4	4/4	4/4
b. Alignment with locality	5/4	1	5/4	5/4	5/4	5/4
c. Limited O&M skills	4/4	4/5	1	4/4	4/4	4/4
d. Low energy and waste water	4/4	4/5	4/4	1	4/4	4/4
e. Scalability	4/4	4/5	4/4	4/4	1	4/4
f. Employability	4/4	4/5	4/4	4/4	4/4	1
COLUMN TOTALS	6.25	5.0	6.3	6.3	6.3	6.3

Read: take the example of the 2nd row. The pairwise comparison between alignment with locality (item b) and low cost (item a) is 5/4. It means that the expert judged 5 points for alignment with locality versus 4 points for low cost.

Table 2 Pairwise comparison of criteria - adjusted matrix

	a	b	c	d	e	f	Priorities (Row average)
a. Low cost	0.16	0.16	0.16	0.16	0.16	0.16	0.16
b. Alignment with locality	0.20	0.20	0.20	0.20	0.20	0.20	0.20
c. Limited O&M skills	0.16	0.16	0.16	0.16	0.16	0.16	0.16
d. Low energy and waster water	0.16	0.16	0.16	0.16	0.16	0.16	0.16
e. Scalability	0.16	0.16	0.16	0.16	0.16	0.16	0.16
f. Employability	0.16	0.16	0.16	0.16	0.16	0.16	0.16
						TOTAL	1.00

Step 6: Pairwise comparison to determine alternative priorities with respect to each criterion. After we make comparison between criteria, we continue with pairwise alternative comparison. Table 3a and Table 3b show the results of priority weights after we have taken Step 5 above. For example, after column value normalization and row average, the priority weight for solar water disinfection option relative to other option is 0.396 in respect to Low cost (Table 3a).

Table 3a Supplier pairwise comparison in respect to cost, alignment to locality, O&M skills

	Cost			Alignment to locality			Limited O&M skills		
	A	B	C	A	B	C	A	B	C
A. Solar disinfection	1	5/3	1/3	1	1	4	1	5/3	5
B. Coagulant/flocculants plus chlorine	3/5	1	3	1	1	4	3/5	1	3
C. Reverse Osmosis	1/5	1/3	1	1/4	1/4	1	1/5	1/3	1
Weight	0.396	0.453	0.151	0.444	0.444	0.111	0.556	0.333	0.111

Read: Take the example of the judgment value of 1/5 between C and A in the 3rd row. It means that C is 5 times less preferable than A in respect to Cost.

Table 3b Supplier pairwise comparison in respect to low energy/waste water, scalability and employability

	Low energy and water waste			Scalability			Employability		
	A	B	C	A	B	C	A	B	C
A. Solar disinfection	1	5/3	5	1	3/4	3	1	1/2	2/3
B. Coagulant/flocculants plus chlorine	3/5	1	3	4/3	1	4	2	1	4/3
C. Reverse Osmosis	1/5	1/3	1	1/3	1/4	1	3/2	3/4	1
Weight	0.556	0.333	0.111	0.375	0.500	0.125	0.222	0.444	0.333

Table 4 Computation of overall weights

Option	Low cost	Alignment with locality	Limited O&M skills	Low energy and water waste	Scalability	Employability	Overall Weights (row total)
	0.160	0.200	0.160	0.160	0.160	0.160	
A	(0.396)(0.160)	(0.444)(0.2)	(0.556)(0.16)	(0.556)(0.16)	(0.375)(0.16)	(0.222)(0.16)	0.426
B	(0.453)(0.160)	(0.444)(0.2)	(0.333)(0.16)	(0.333)(0.16)	(0.5)(0.16)	(0.444)(0.16)	0.419
C	(0.151)(0.160)	(0.111)(0.2)	(0.111)(0.16)	(0.111)(0.16)	(0.125)(0.16)	(0.333)(0.16)	0.155

Step 7: Determine overall priority for each alternative.

After we have known the priority for each criteria and alternative, we generate the overall priority weight by making a product of these two priorities and sum all the values of the same row (Table 5). For example, Option A gets an overall priority weight of 0.426.

Table 5 Overall priority weight ranking

Alternative	Overall priority weight
A – Solar disinfection	0.426
B – Coagulant/flocculants plus chlorine	0.419
C – Reverse Osmosis	0.155

Step 8: Select the technology alternative with the highest priority: the final step is to sort the overall weights by descending order and select the alternative with the highest weight (Table 5).

The above calculated result from AHP method yields the highest overall priority weight for solar disinfection for rural water technology (overall priority weight of 0.426). This is because the expert assessed that this alternative receives the highest values for three out of six assessment criteria, i.e. alignment to local conditions, limited requirements for O&M skills, low energy and waste water, with the largest importance weight loaded on the alignment to local conditions.

In the Mekong Delta Water Project (2002-2008) all piped water schemes in communes use flocculant/coagulant technology. Several reasons can be given. Traditionally, local preliminary technical assessment engineers did not include emerging technologies like solar disinfection or reverse osmosis, in the feasibility study phase. It was because of limited capacity of local rural water centers, their ignorance of other better technologies and project time constraint, to name some. Besides, local partners are inclined to prefer a familiar technology like flocculant/coagulant technology with chlorine rather than take time to study the feasibility of a new technology which requires much time and expertise. As a result, beneficiary communities in the project are introduced with familiar coagulant technology whereas our computations show solar disinfection is better.

CONCLUSION

The AHP method is recommended for use as a multi-criteria selection model by any community committee composed of members of diverse expertise, background and possibly interests. For example, an engineer may prefer operations feasibility while a community representative favours affordability and employability. The remaining issue is how to reach this consensus among these members. Future studies need to introduce a method by which committee members can come up with a consensus. Group preference decision technique is one method of this kind. Besides, the conditions for applying this model include prior identification of suggested choices and ability of committee members in determining criteria relevant to the proposed investment, which would be a challenge in rural areas. It is strongly suggested that social enterprises use this selection approach as quantitative management. In a context where stakeholders need to know justifications of any choice made by the social enterprise in option selection, the results of this approach would show clear and scientific evidence to convince them. The limitations of this approach include a short list of alternatives meaning that if the number of alternatives and criteria is too large, it is too complex to calculate priority weights manually. In this case, it is suggested to use a specializing software Expert Choice. It is possible to properly apply the AHP method in selecting water technology because of some reasons. Firstly, the nature of a water project requires preliminary technical investigation for available water sources, normally done as part of feasibility study. As a result, a short list of technology alternatives would be proposed. It should be avoided that a project presents too many alternatives without prior technical screening step and consequently community select an option which subsequently turns out to be technically unfeasible. Secondly, the list of evaluation criteria can be enriched by consulting community members. Thirdly, for community-level water schemes, different views from engineers, community development consultants, planning experts, etc should be considered in making decisions. The AHP is a suitable and fair process to synergize these diverse but important points of view. Lastly, with emerging advanced technologies in water treatment and distribution, a community should be wise to take advantage of a technology which can help enhance farming productivity hence reduce poverty. Future studies should explore how some technologies can create employment for local people.

ACKNOWLEDGEMENTS

I owe a debt of gratitude to Mr. Ray Miles, the former Australian Team Leader at the Mekong Delta Rural Water Supply and Sanitation Project for his expertise inputs to this paper. Without them, I would have been unable to produce this study with the judgment values for the matrices.

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