Water treatment technology selection in rural Cambodia

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Abstract

One major problem facing the future provision of safe water throughout Cambodia is the limited information and tools available to analyse the holistic nature of water supply management and the wide range of water treatment technologies available. Implementers may select an inappropriate technology for a given situation and this is one of the main reasons, along with lack of community education and participation, that the failure rate of water projects is so high.

This study has identified the use of a decision support system as a potential solution. A decision support system could come in many forms, two of which, case based reasoning and rule based reasoning have been outlined in this paper.

It is evident that there are advantages and disadvantages to both case based reasoning and rule based reasoning. Rule based reasoning is more suited to long term water treatment planning whereas case based reasoning is suited to small-scale single project decisions. Both methods have the potential to greatly improve the efficiency and effectiveness of projects for the provision of potable water in Cambodia. Furthermore these tools can be adapted to work in any developing country.

Keywords: Decision Support Tool; Water Treatment; Cambodia.

1. Introduction

Currently Cambodia is still recovering from the aftermath of its recent history and is dependent on international aid to ensure development. This is no more apparent than with the need for improved infrastructure. The World Bank reported on the lack of vital infrastructure in Cambodia in 2002, and stressed the need for Cambodia to improve access to clean water sources and sanitation, electricity, transport and communications if it is to rise out of poverty (World Bank, 2002). This report further mentioned that the real sufferers are rural inhabitants, who make up nearly 90% of the population (World Bank, 2002). One of the most important issues is that 56% of the rural population lack access to safe water (World Bank, 2008). This is very low compared to countries with a similar Human Development Index (United Nations, 2010).

One major problem facing the future provision of safe water throughout Cambodia is the limited information and tools available to analyse the holistic nature of water supply management and the wide range of water treatment technologies available (United Nations, 2006). This lack of information is largely due to the subjective nature of the problem coupled with the multiple technology options and complex social, technical, environmental and economic factors that influence the uptake of the technology. It is for this reason that implementers may select an inappropriate technology for a given situation and it is one of the main reasons, along with lack of community education and participation, that the failure rate of water projects is so high (Pahl-Wostl, 2002; Parker, 2007).

2. Engineering Decision Support Tools

It is evident that a number of innovative techniques exist and are used to assist planners analyse complex subjective problems. One example is using rule based reasoning (RBR) with Geographical Information Systems (GIS) to solve spatial problems that involve many factors. This could involve the planning of piped sanitation supplies in cities, or assessing urban sprawl (Longley *et al.*, 2010). Alternatively, a case-based reasoning (CBR) system is a computerised artificial intelligence tool. It attempts to mimic human learning by using past experience, in this case past water projects, to predict the outcome of similar situations in the future (Liao *et al.*, 2000). Case-based reasoning (CBR) has proven to be successful in providing accurate solutions to complex problems by providing a solution based on previous outcomes rather than relying on set rules (Krovvidy, 1993). CBR is becoming increasingly popular within a number of sectors including engineering, law and medicine (Liao *et al.*, 2000). However, these techniques have not yet been fully explored within the water and sanitation aid sector.

3. Materials and Methods

In order to develop the CBR model, the authors conducted nineteen interviews with sixteen industry professionals who have worked extensively within the water treatment sector in Cambodia. This identified the main social, technical, environmental and economic factors that affect the success of various water treatment technologies. Furthermore two case studies were conducted in rural Cambodia to further identify the social factors that influence the uptake of different water treatment technologies. A survey of rural water practitioners was also conducted to determine what technical, environmental and social system factors affect the success of water treatment projects. The results from the interviews, case studies and surveys were then compared to ensure the most significant factors were selected.

3.1. Survey 1: Criteria influencing uptake of Bottled Water

An observational survey was undertaken in collaboration with a local NGO located in Battambang, western Cambodia, in order to determine the social factors that affect the implementation and uptake of bottled water in rural areas. The aim of the survey was to cover all possible stages in a bottled water project and identify the key factors that affect the success or failure of this type of method. It was also important to analyse systems using different water sources. For that purpose, three different rural villages were selected for the survey: two villages had established centralised water treatment systems that treated water and distributed door to door via 20 litre bottles and one village had a newly installed system, however the system had not yet started distributing. The first village system was brand new and thus there were no customers to survey; however there was a private bottled water company operating in the same village. Therefore families could still be surveyed to determine why they had or had not bought the private water and if they would buy the new bottled water. The second village was operating; however it was experiencing a huge reduction in sales and customers. The third village was operating successfully and was producing a small profit for the shareholders. Additionally, villages 1 and 3 used river water, while village 2 used both rainwater and river water. A smaller fourth system, that used well water as a source, was analysed to determine any additional factors that may affect bottled water. A total of 36 families were surveyed.

3.2. Survey 2: Criteria influencing the uptake of chlorine

A small observational survey was conducted in collaboration with a local NGO located in Poipet in order to determine the social and technical factors that affect the implementation and uptake of chlorine in rural areas.

3.3. Survey 3: Criteria influencing the uptake of water treatment technologies in Cambodia

This survey was specifically sent only to professionals with whom the authors have previous experience and who have worked extensively within the water treatment sector in Cambodia. This included NGO Directors, Project Leaders for large international organisations, long term volunteers and local water treatment technology implementers.

This survey was carried out in order to 'face' validate the input variables selected for the model, following the multistage validation approach for modelling developed by Naylor and Finger (1967). Face validation is the first stage in the approach and assesses that the model appears correct at face value. Therefore general assumptions and model processes can be validated through personal experience, review from experts in the field or from literature. The survey was set up online in a clear and simple format that allowed the applicant to fill in the form and return efficiently. The survey comprised of three sections: (a) section 1 asked the applicant to select the water treatment technology that they had most knowledge of; (b) section 2 asked the applicant to identify how important each factor (among 27) in affecting the successful implementation of their chosen technology; and (c) section 3 asked the applicant about specific aspects of the technology, including questions on the appropriate socio-economic status (SES), appropriate water sources, and how many people can the technology provide for.

In order to ensure the survey was filled out correctly, similar variables were included and thus the correlation between the similar factors could be analysed to determine how well the survey had been filled in. Once the survey was filled in on-line by the applicant, it was sent back to the authors for analysis.

4. Results and Discussion

4.1. Survey 1: Criteria influencing uptake of Bottled Water

Family Size

It was evident that on average, families that bought bottled water were smaller than ones that didn't (Fig. 1). One of the reasons for this may be that a smaller family requires less water and therefore has a lower expenditure on bottled water.

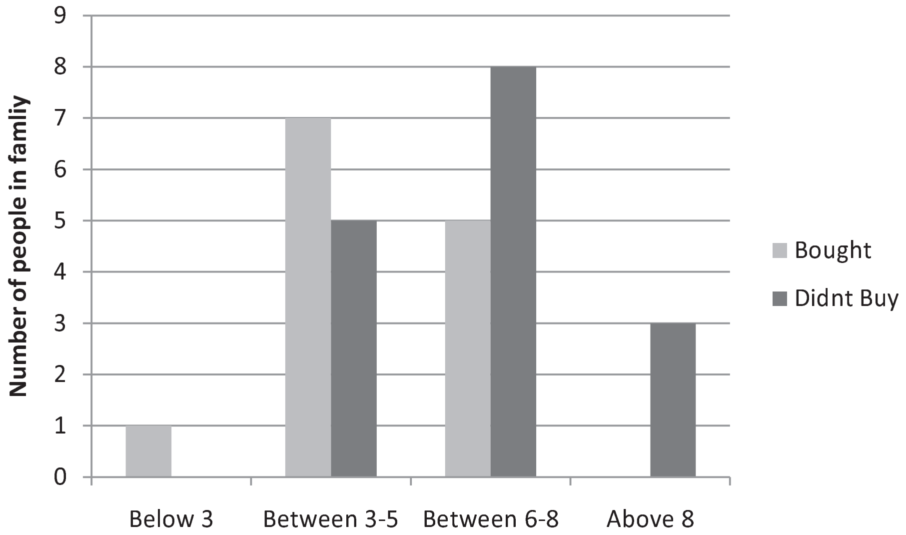


Figure 7 Significance of Family size

Wealth

It was evident that the overall wealth of the area was a major factor in determining the success of the project. The wealth of a family was measured by four identifiable features; concrete foundations on their house, if the family owned any motor vehicles or a TV, and finally the presence of a latrine. If a household displayed none of the four characteristics then they would receive a wealth scoring of 0. If the family displayed all of the four characteristics they would receive a scoring of 4. The average wealth rating for families who bought bottled water was 2.4 compared to 0.8 for families who didn't buy (Fig. 2).

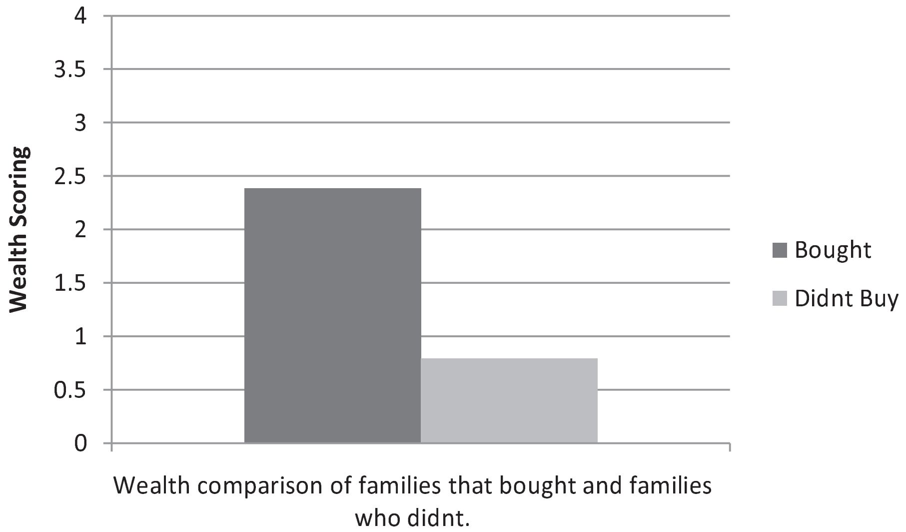


Figure 8 Average Wealth Scoring

Piped Systems

The presence of an existing piped system was a large influence on a family's choice to buy bottled water. This is evident when comparing the response of families to seasonal change in village 1 (existing piped system) and village 3 (no existing piped system). It is clear in village 3, that the amount of bottled water users sharply rises in the dry season due to the lack of alternative water sources (Fig. 3). Whereas the number of bottled water users does not vary for village 1, but the number of piped water users increases (Fig. 4). This indicates that untreated piped water is a more attractive option to users compared to bottled water.

In summary, through observations and survey results, it was evident that the most significant social factors affecting the implementation of bottled water were wealth, family size, household rainwater storage capacity and season. It should be noted that a specific factor in this case study was the presence of an existing untreated piped water system, which greatly reduced the number of bottled water users.

4.2. Survey 2: Criteria influencing the uptake of chlorine

It was clear that a majority of the users were not able to use their chlorine tablets (Fig. 5). This is because they had no access to safe 10 litre storage containers as the road conditions were not good enough to visit the local market, they work all day during the rainy season and the storage containers are far more expensive compared to the chlorine tablets.

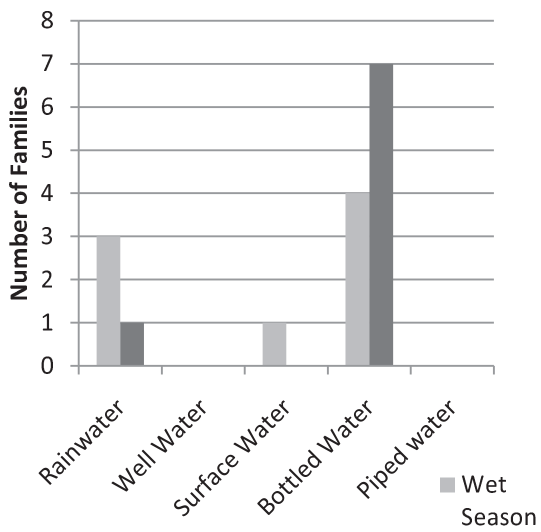


Figure 3 Village 3 - Water source

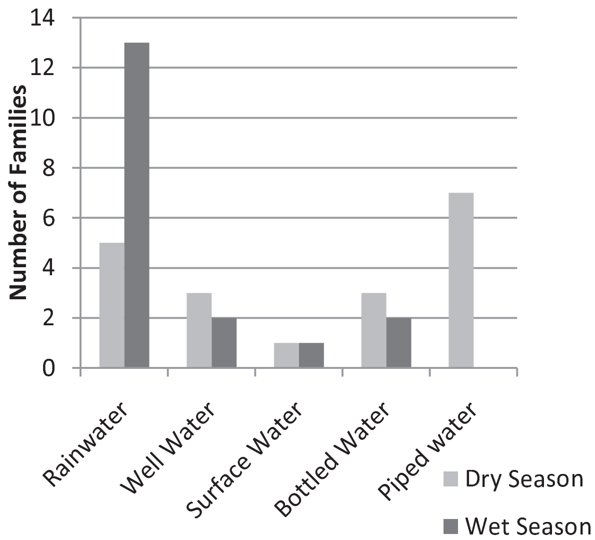


Figure 4 Village 1 - Water source

Only 5 people out of 15 candidates bought chlorine tablets. The main reasons for this were that they either had a very low SES, the market was too far away to get replacement tablets or they did not have storage.

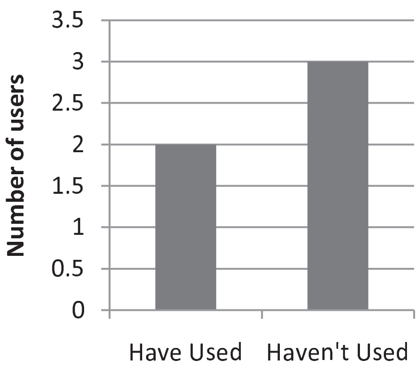


Figure 5 Comparison between the number of people who have and have not used the chlorine tablets after two weeks.

In summary, the main most significant factors identified by the survey were: (a) the cost of the technology, (b) location of technology distibutor, and (c) distance to the local market. The enthusiasm of the village leader was also observed to have a strong influence on users choice of technology.

4.3. **Survey 3:** ***Criteria influencing the uptake of water treatment technologies in Cambodia***

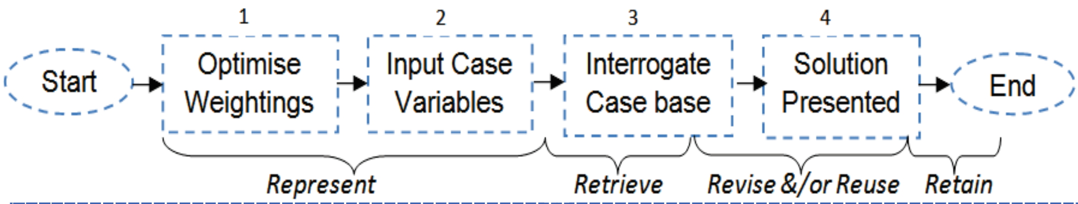
The results from the survey were split into two sections for analysis: (i) household water treatment & storage technologies, and (ii) centralised systems (Table 1). Therefore, for the purposes of this study, the ten most significant factors were determined for each section.

The results obtained in survey 3 corresponded well with both the bottled water and chlorine surveys 1 and 2. However, one conflicting factor was the significance of existing water treatment projects for centralised systems.

Table 1 Most significant factors that influence the uptake of water treatment technologies in Cambodia.

	Household Water Treatment and Storage Technologies		*Centralised Systems*
1.	Cost of Technology	1.	Water Source
2.	Location of Technology distributor	2.	Location of Technology distributor
3.	Water Source	3.	Seasonal Variation
4.	Enthusiasm of village leader	4.	Climate Change
5.	Level of education of user	5.	Wealth of user
6.	Presence of arsenic	6.	Presence of pesticides
7.	Distance to market	7.	Cost of technology
8.	Distance to large water source	8.	Level of education of user
9.	Existing/past water treatment projects in area	9.	Population density
10.	Flooding	10.	Presence of calcium carbonate in the water source

Data obtained in the aforementioned surveys will be used to develop a CBR model with which to select an appropriate water treatment technology for each case study. Once the model has been developed, it will be tested using real data collected through an ongoing survey of past and current water treatment projects in Cambodia. Each case also requires output values. These are the values that are currently sought in order to determine if a technology will be successful or not. For the case of water treatment selection the output values may be the percentage of drinking water treated by the technology, the user satisfaction and the length of time of ownership of the technology. This ongoing survey will provide 100 cases containing the factors identified above and the output values for each case. This is considered sufficient to test the accuracy of a CBR model. The model process can be seen in Fig. 6.

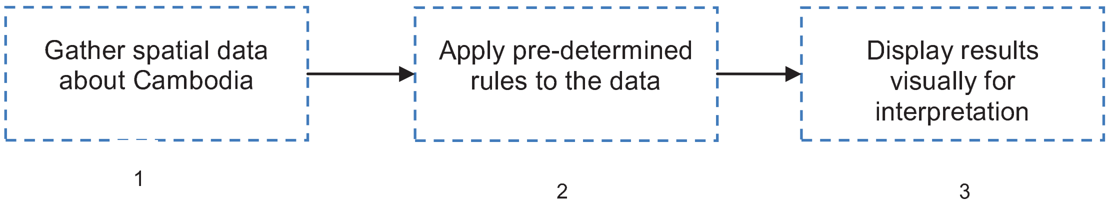


No	*Description*
1	Past cases must be stored in the case base in such a manner that they can be retrieved and compared to future problem cases. Variables determined through analysis of data collected through two case studies, practitioner and past project surveys. Weightings are applied to the case-base variables through the use of Genetic Algorithms.
2	The user enters the characteristics of a the chosen project site to form a problem case, characteristics may include factors such as main type of water source, average wealth, distance to water source, population density etc.
3	The similarity scoring of each past case to the problem case is calculated. The cases with the highest similarity scoring based on parameters chosen by the user are retrieved.
4	The retrieved case may not be the final answer as it may need to be revised and adapted to better fit the problem case. This is the self learning section of the model. It mimics human learning by continuously adding cases and their solutions to the case base in order to improve future accuracy.

Figure 6 Model Flow Chart

4.4. Rule Based Reasoning and Geographical Information Systems

Geographical Information Systems (GIS) can be used for strategic planning to determine what areas of Cambodia are suited to different types of project strategy. Multiple layers can be added to the system, each layer containing different types of information. These layers can then be overlaid or multiplied using different rules for different project types to determine which areas are more suited to different project types. GIS is based on rules, therefore in order to construct the model, rules must be applied to each criteria. Without an extensive data set it will not be feasible to assign numerical rules to the relationships between different model criteria. Therefore for the purpose of this paper, rules will be based on literature, experience, case studies and surveys prepared by the authors.



No	*Description*
1	Spatial data will be based on the significant factors mentioned in the surveys and observations above and will be gathered from a number of sources. There are four main categories of data required in order to ensure the holistic nature of the problem is accounted for. These are social, environmental, technical and economic.
2	Rules will be formed through an amalgam of literature, experience, case studies and surveys. They will represent the relationship between system factors and the outcome of the project
3	Results will be displayed on a thematic map. The user can choose whether the map will display the areas that are best suited to a particular project type or will display the different project types that can be used across an area of interest.

Figure 79 RBR & GIS model process

4.5. Comparison of RBR and CBR

Critical comparison of RBR and CBR approaches has highlighted that both RBR and CBR have advantages and disadvantages. It is for this reason that each method may be more effective in certain situations compared to the other. For the purpose of this study, a comparison of both methods was made, and a suggestion of what situation may be more appropriate for each method is summarised in Table 2.

Table 2 Comparison of RBR and CBR

RBR	*CBR*
• Large scale planning	• Small scale
• Long term planning	• Short term planning
• Visual	• Intuitive
• Requires expert knowledge to create and operate model	• Requires an extensive data set
• Difficult to accurately determine rules	• Does not require complex statistical analysis

5. Conclusion

There is an imperative need for a method which to aid the selection of water treatment technologies and strategies in Cambodia. This method needs to take into account not only the technological but also social, geographical and economic factors which affect the implementation of water treatment projects. This study has identified the use of a decision support system as a potential solution. A decision support system could come in many forms, two of which, CBR and RBR have been outlined in this paper. It is evident that there are advantages and disadvantages to both CBR and RBR. RBR is more suited to long term water treatment planning whereas CBR is suited to small-scale single project decisions. Both methods have the potential to greatly improve the efficiency and effectiveness of projects for the provision of potable water in Cambodia. Furthermore these tools can be adapted to work in any developing country.

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