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# Integrated assessment of water management strategies: framework and case study

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**Abstract:** Over half of the world's population lives in sizable cities, and in many of these cities, urban water managers struggle to provide safe water supplies while maintaining the health of the environment. Can Tho, at the heart of the Mekong Delta, is trying to plan for sustainable urban development when faced with by rapid population growth and industrialization, changes to the hydrology of the Mekong, and challenges related to climate change.

A previous study used an iterative process of stakeholder engagement workshops, data collection and householder survey to identify and evaluate water management strategies that would support sustainable urban development in Can Tho. These activities highlighted the water-related needs of the city, using the Water Needs Index, and developed possible strategies to address the arising issues. These strategies were evaluated using Bayesian Network Analysis to test for viability in the local context, and holistic system effectiveness. This is an integrated assessment methodology applicable not only for Can Tho, but suitable to other cities or regions. Stakeholder engagement is an important aspect of this process that promoted local ownership, and common understandings of outcomes and research results. The integrated methodology gained considerable traction in the local context, with funding agencies and local government either adopting, or wanting to adopt the recommendations arising from the study. The paper outlines the framework for assessment and integration of research activities to inform planning and implementation of urban or regional water management strategies through the experiences in Can Tho.

The applied framework has five steps designed to move from an exploration of the local context, towards the identification and preparation for management strategy implementation:

1. Develop an understanding of the local context, and generate baseline information as a foundation for subsequent steps.
2. Identify the city's needs, in terms of water management, or water-related issues, as defined by of the six dimensions in the Water Needs Index approach.
3. Identify and short-list possible strategies to be further developed and planned.
4. Assess the short-listed strategies for their likelihood of achieving desired goals, and their performance, against the Water Needs Index assessment, conducted using a participatory modeling approach involving Bayesian Networks.
5. Demonstrate and pilot the selected strategies, and plan for subsequent strategic implementation.

As part of this process, we identify the responsibilities and tasks required to ensure the success of short-listed strategies. The process also identifies important institutional factors and barriers to identified strategies.

The approach primarily builds on the lead author's studies in the Pacific Islands, and on the research team's experiences in applying the Integrated Urban Water Management approach. This is the first large scale application of the framework, and it has been shown to be a surprisingly effective way of engaging local stakeholders around the problem of water management who then have shown significant motivation to action and adopt other project outcomes. It is the authors' belief that the approach can be successfully applied in different contexts and most likely also to other sectors; although this may require some amount of process appraisals.

***Keywords:*** *Integrated assessment; Integrated Urban Water Management; Bayesian Networks; Water Needs Index*

## 1. INTRODUCTION

Many cities in the world are currently grappling with a combination of rapid population growth, and water related challenges, including water scarcity and water quality problems. Many cities still have a relatively large proportion of people without access to safe drinking water and basic sanitation. Most governments have also signed on to the Millennium Development Goals, for which one of the goals is to "*reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation*" (United Nations, 2010). To deal with challenges and to achieve the goals that planners and governments set, while dealing with climate change, it may be necessary to employ a series of urban water management strategies. The choice of a water strategy will depend on local circumstances and it is prudent to assess the possible impacts of a water strategy before adopting it, in order to ensure that it provides desirable outcomes. There are multiple perspectives and key criteria that need to be considered when assessing urban water strategies. The use of triple bottom line concepts, to consider social, environmental and economical considerations in planning, has become mainstream practice, used in Integrated Urban Water Management. Taking into account multiple perspectives can however be a difficult task because it has been argued, and the authors believe this to be true, that urban water planning is a "wicked planning problem". As defined by Rittell and Webber (1973), goal formulation and problem definition is an open-ended and rather value-driven exercise, for which de facto decision making by knowledgeable experts can be ethically questionable. This justifies the adoption of a deliberative approach when evaluating urban water systems, as argued by Alexander et al. (2010). In this way, there is opportunity for stakeholders to negotiate between themselves, ideally in a transparent fashion, on how to incorporate the sometimes conflicting value judgments that are fundamental pieces of water assessments and strategies. This paper describes an applied framework for the identification and analysis of water management strategies in applied in a case study in Can Tho, Vietnam. The aim was to inform climate change resilient strategies for sustainable urban water services. This new framework builds on previous frameworks developed for small town water management (Moglia, 2010). This paper also presents the framework for identifying and assessing urban water strategies in a way that acknowledges and considers the choice of water strategies as a multi-faceted, complex, social and wicked problem. To define the framework, we extend the Integrated Urban Water Management framework with theory from social learning practice (Bandura, 1977), management of complex adaptive systems (Snowden and Boone, 2007), and inductive theory building (Locke, 2007).

## 2. CAN THO: CASE STUDY LOCATION

Can Tho is one of Vietnam's largest cities, which in 2008 had a population of around 1.2 million people and by 2020 the population is expected to increase to 1.65 million people (Neumann et al., 2013). Can Tho's climate is tropical and monsoonal with two seasons: rain between May to November; and dry between December and April (Thanh et al., 2010). It is the largest city of the Mekong delta region, and is experiencing an increasing level of industrialization and urbanisation. The coverage of urban water infrastructure is uneven while septic tanks are reasonably spread (Neumann et al., 2013). Critically there are only a couple of functional wastewater treatment facilities and a large number of industries and households are known to release wastewater directly into waterways (Neumann et al., 2011). Moreover, there is only limited municipal solid waste management in Can Tho (Thanh et al., 2010). This region is also expected to experience significant climate change impacts, including the possibility of salinity intrusion, changed rainfall patterns, hotter climate, changed evapo-transpiration and changed river flow patterns (Dragon Institute, 2009). The key challenge that Can Tho faces is to keep up with provision of water and wastewater services while ramping up efforts for environmental management and protection at a time of rapid population growth and economic development, whilst at the same time dealing with climate change and other future uncertainties (Moglia et al., 2012). The case study was part of the CSIRO-AusAID Research for Development Alliance, and was conducted to demonstrate how IUWM could be used as a climate change adaptation activity, in the context of providing water and wastewater services.

## 3. FRAMEWORK STEPS

The framework has five key steps as shown in Figure 1:

- Develop an understanding of the local context, and generate baseline information as a foundation for subsequent steps.
- Identify the city's needs, in terms of water management, or water-related issues, as defined by of the six dimensions in the Water Needs Index approach.
- Identify and short-list possible strategies to be further developed and planned.
- Assess the short-listed strategies for their likelihood of achieving desired goals, and their performance, against the Water Needs Index assessment, conducted using a participatory modeling approach involving Bayesian Networks.
- Demonstrate and pilot the selected strategies, and plan for subsequent strategic implementation.

This article describes the first four activities, as applied in Can Tho.

### 3.1 Developing local understanding

Urban water management is highly dependent on the local context because what works in one location is unlikely to work in another location, due to a range of both hydro-physical and socio-cultural factors (Alexander et al., 2010). To develop an understanding of the local context requires local information, and the first task is to identify important qualitative and quantitative data, and any critical data gaps. The project's and the framework's first activity was a facilitated workshop (Moglia et al., 2010) which has a number of purposes:

1. Introduce the project to stakeholders to clarify scope and methodology, and the roles of researchers.
2. Define the six dimensions of the Water Needs Index (WNI). This sets a boundary of the project, and defines terms that stakeholders are familiar with.
3. Identify available data related to the six dimensions of the Water Needs Index; and this helps initiate the thematic sector review and identify data gaps to be addressed, such as by household survey.

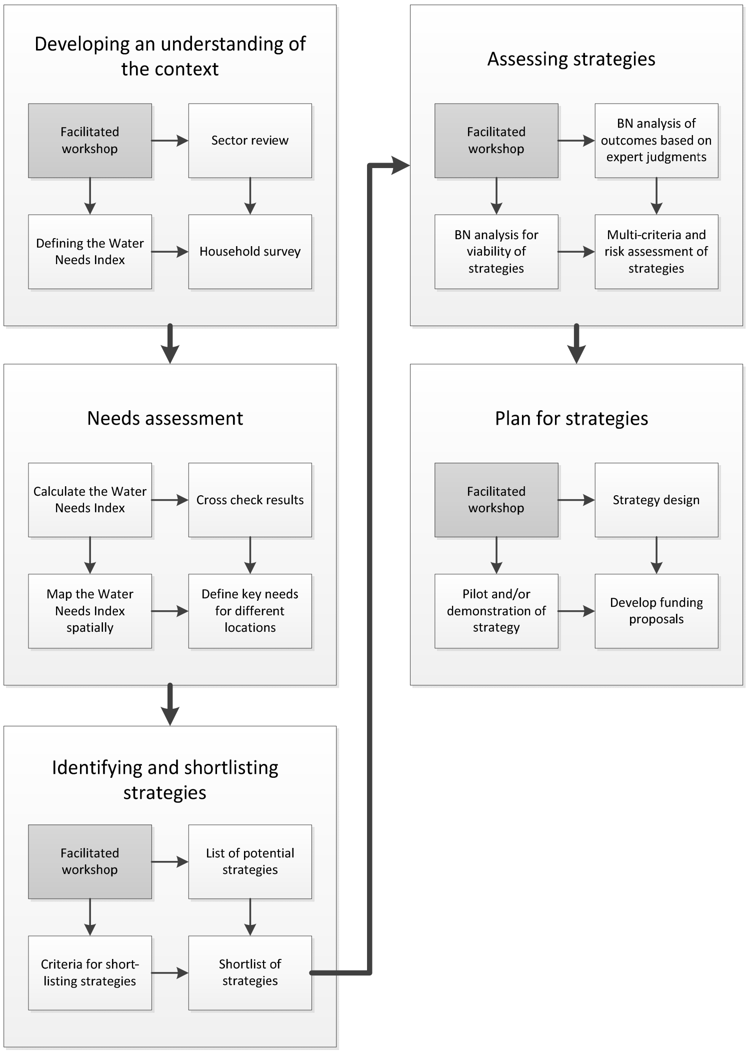


**Figure 1.** Progression of the framework from the initial facilitated workshop until the planning for implementation of strategies.

Guided by the workshop outputs, and to develop an understanding of the context, we collected existing data from reports, grey literature and information/data from stakeholders (government departments and local water companies). We also conducted a survey of 1,200 households across the Can Tho area (Neumann et al., 2013). The generated understanding and data were synthesized into a sector review, with themes based on the dimensions of the WNI (Neumann et al., 2011). The six dimensions of the WNI, as identified in the facilitated workshop, are shown in **Error! Reference source not found.**. This allows for the succinct definition of issues, and ability to communicate clearly with a common language/understanding with project stakeholders (Moglia et al., 2012). The analysis of the situation in Can Tho formed the sector review (Neumann et al., 2011).

On the basis of this review, the following issues arose: 1) infrastructure was lagging for much of the community and there was very limited wastewater treatment facilities; 2) the groundwater, especially in some parts, was influenced by reductions in water tables and declining water quality; 3) seasonal flooding was expected and part of life for most residents, but the negative consequences of urban flooding was further exacerbated by changing river flow patterns, 4) water and sanitation access was variable across the city and much of the treated water was lost through leakage; 5) surface water quality testing indicated that a range of parameters on average exceeded national regulations; due to the increase in nutrient and organic matter from households, agriculture, fish farming and processing industries; 6) there is not much known about the health of aquatic eco-systems although a range of threats to these systems were identified.

**Table 1**. Dimensions of the Water Needs Index.

| Dimension | Examples of issues |
|---|---|
| Aquatic Eco-systems (A) | River eco-systems (fish, birds, vegetation)<br>Aquaculture impacts |
| Flooding (F) | Damages from floods<br>Effectiveness of protection measures<br>Frequency and extent<br>Tides, upstream flows and rainfall |
| Groundwater (G) | Pollution of groundwater<br>Over-extraction<br>Protection measures<br>Salinity |
| Infrastructure Systems (I) | Pipes and storages – breakages<br>Treatment facilities – appropriate?<br>Leakages and infiltration |
| Water & Sanitation access (W) | Households and other customers access style to water<br>Related to WHO's "access to improved water services"<br>How is water being supplied? Or not supplied? |
| Water Quality (Q) | Health impacts<br>Fit for purpose quality<br>Behavioral aspects<br>Pollution of water sources / wastewater disposal |

As part of the sector review, a number of data gaps were identified and to address at least some of these issues, a survey of 1,200 households was conducted (Neumann et al., 2013). The survey provided data on issues such as the spatial variability of groundwater concerns; the link between rates of illness and available sanitation, source of drinking water and perceived water quality; and the spatial distribution of the state of service provision. Survey responses also highlighted the issue of surface water quality as the highest community concern.

### 3.2 Assess needs

It is recognised that integrated water management requires a holistic approach that allows a range of sub-sectors, and stakeholders to come to joint agreement on the water management needs across an area – so that effective management strategies can be devised (Sullivan et al., 2003). Index methodologies have emerged as a useful approach for facilitating this process. Therefore, the collected data helped to calculate the WNI at a ward scale (unit of approximately 10,000 people), as described by Moglia et al (2012) and illustrated in **Figure 2**. This allowed identification of the areas that are most in need of improved water management. We note that Can Tho is what Bakker (2010) referred to as a splintered "urban network", with islands of centralised public water supply. The surface water quality is variable and particularly polluted in some areas due to local water flow patterns and pollution loads. Cross-checking of water quality data revealed that surface water quality is more problematic in the dry season. By integrating knowledge local capacity and knowledge of stakeholders has increased, as typically they understood the water situation from perspectives of their disparate knowledge and experience . For example, in the first facilitated workshop, reports of poor conditions in parts of the city (O Mon) were disputed, but were later confirmed by the collected data. The WNI methodology provided a means to reduce the bias of those who tended to make decisions primarily in areas in which they had a reasonably good knowledge. Important issues to be addressed for the city arose:

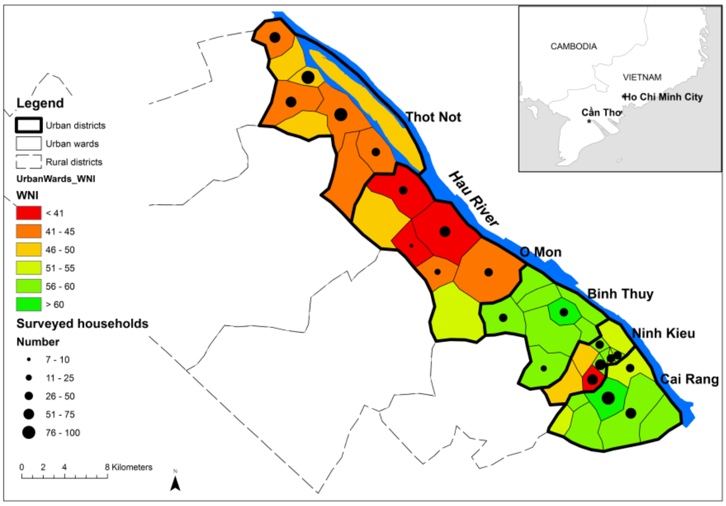


**Figure 2.** Map of the calculated WNI, with colors of wards representing the WNI value. Red colors indicate worse conditions, and green colors indicate better conditions.

- Large areas had low rates of appropriate sanitation facilities.

- Some areas, especially those with a mixed supply situation, had very high health risks.
- Households near industrial clusters tended to report deteriorating availability and/or quality of groundwater.
- Some areas were associated with very poor surface water quality (low dissolved oxygen), particularly for areas with high density populations, and restricted water flows.

### 3.3 Identify and short-list strategies

The project aimed to identify and implement water management strategies addressing the needs of the city, this entailed responding to conflicting goals of stakeholders. The approach used incorporated the Action Research method drawing on international best practice for stakeholder participation (HarmoniCOP, 2005). It is critical to ensure that stakeholders influence the identification of strategy alternatives in a transparent manner, and in a way that highlights the contentious topics and sometimes conflicting goals. The role of researchers is to facilitate the process and ensure multiple perspectives are considered. To achieve this, a facilitated workshop was conducted in order to identify strategies that will address the needs and key dilemmas of the city. International experts in urban water management provided five suggested strategies, and local experts and stakeholders brainstormed to develop a further 20 options. Participants were provide with details of each strategy, i.e. approximately what the strategy was; how it would be implemented; who would be involved; the costs related to the strategy; the technology to possibly use; the risks of implementing the strategy; the suitability in different circumstances; and the expected impacts on the six WNI dimensions. Furthermore, participants were asked to rate the strategies for their social, economic, technological and environmental acceptability. The scale for this was: 5) ideal; 4) acceptable; 3) acceptable with minor conditions; 2) acceptable with major conditions; 1) not acceptable; and 0) no idea. From the list of strategies, we developed a shortlist that best addressed the city's water management dilemmas, would achieve important triple bottom line goals, were supported by local stakeholders, and would be resilient to climate change impacts. Based on this criteria, a short-list of five strategies was identified: 1) Provision of rainwater tanks for households that lack piped water supply; 2) Promotion of behavioral change to reduce solid waste disposal into surface waters; 3) Developing cluster scale wastewater treatment for industries; 4) Developing cluster scale wastewater treatment for households and improved sanitation; 5) Investing in large pipeline linking of water treatment plans.

### 3.4 Assess strategies

The evaluation of the viability and effectiveness of urban water strategies is a task that is difficult as cause and effect relationships are often difficult to establish and are at times only temporary. Furthermore, performance criteria of strategies are sometimes nebulous and hard to define, such as liveability of cities, public health impacts, economic productivity impacts and community acceptance. Measuring proxies of these performance criteria may be possible but is often very costly. Rigorously establishing generic cause and effect relationships impacting on these performance criteria is technically challenging. Nonetheless, the fourth step in the process is to assess the chances of each strategy achieving hoped for impacts in various local contexts, as well as the strategies' projected impacts. The likely impacts and chances of success, of the implementation of strategies in a given socio-technical context is dependent on a range of factors operating in a network of nested cause and effect relationship. This is cognitively difficult to grasp for experts and stakeholders for a number of reasons. Difficulties are primarily due to the biases and limited cognitive abilities of human beings, such as: motivational effects like wishful thinking distorting judgments because of potential payoffs and penalties; limitations on the amount of information humans can process which leads to the application of overly simplistic heuristics; inappropriate heuristics such as for example giving overdue weight to that which can easily be observed or that which can more easily be imagined; and a tendency to be overly confident in one's own analysis. To limit such biases and to describe the nested cause and effect relationships which influence the likely success and impacts of strategies, we used a facilitated workshop process to map out the relevant cause and effect relationships. Secondly, by collecting expert and stakeholder judgments, we were able to convert nested cause and effect relationships into Bayesian Network (BN) models; noting that it would always be impossible to train BNs in a statistical manner due to the lack of sufficient data sets, i.e., a large set of attempted implementations of a strategy in the given context. Implementations of strategies tend to be non-repeatable exercises and results are highly context dependent. An example of this kind of model is shown in Figure 3. This diagram was developed by stakeholders and experts in a workshop setting, and judgments (i.e. conditional probabilities, as well as probabilities of states) were assigned using judgments of experts, within their domains. This takes into account the fact that no one individual would have a full understanding of all factors, but collectively; experts often make judgments about difficult, complex matters. We note that some factors could be controlled if stakeholders took responsibility; for example a stakeholder may agree to provide an appropriate and affordable rubbish collection service, increasing the chances of having a functioning and high performing solid waste management strategy. The analysis allowed the identification of priority areas, critical enablers, key difficulties and key benefits. Specifically, it was found that one of the strategies had a very low likelihood of achieving desired outcomes, i.e.

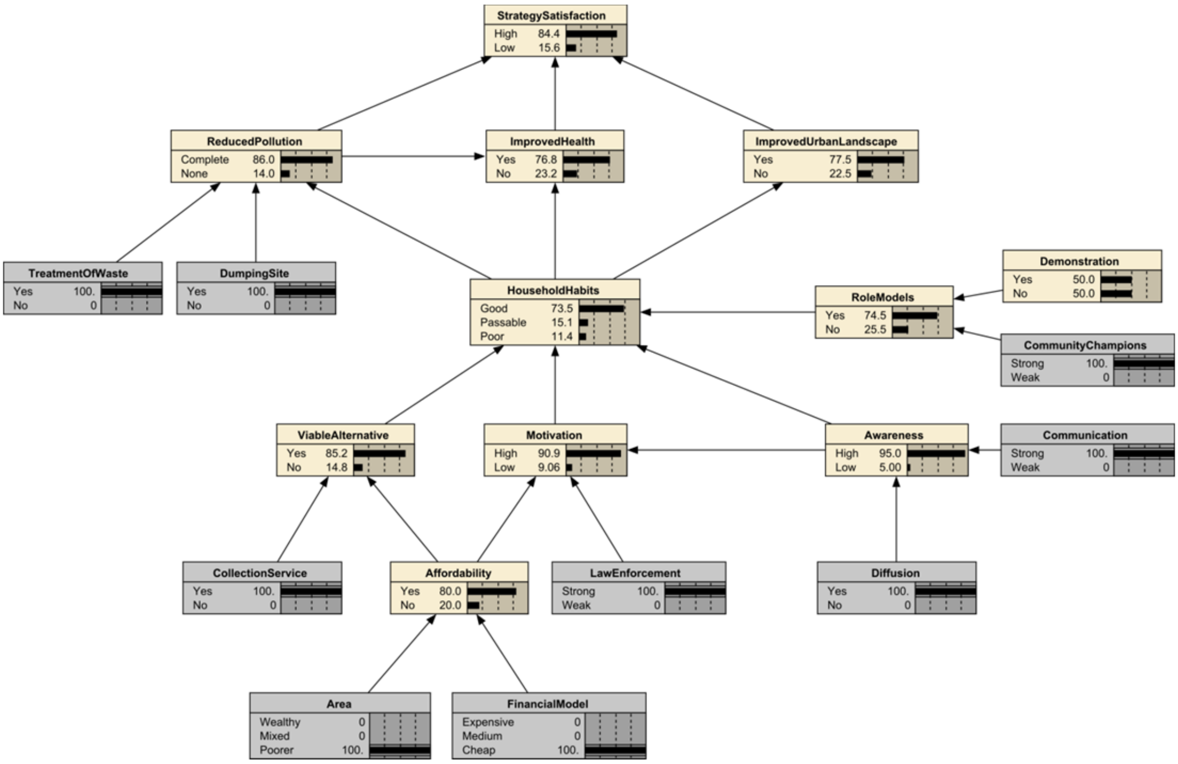


**Figure 3.** Pathway to impact diagram showing the cause-and-effect relationships that impact on the chances of successful implementation for the strategy to improve solid waste management in Can Tho City. This has been developed in the BN software Netica and quantified using expert judgments, and other available data.

strategy 5 to link water treatment plants with large pipelines. This was the case even when technical issues could be solved, and the main difficulties related to a combination of institutional and financial problems, and the concerns about public health when mixing supplies. Without having a pipe network that is in good condition, and 24-hour supply, this strategy would fail. Furthermore, it was found that it would be possible to more or less ensure the success of the other four strategies, but it was also found that this depended on the cooperation of multiple actors. Some strategies were also found to be limited in their applicability across the urban landscape. For example, land and roofing restrictions put restrictions on the possibility of wide-spread adoption of rainwater harvesting. Land restrictions were found to be a critical concern for the purpose of widespread adoption of cluster scale wastewater treatment. It was also found that there was a mismatch between wastewater treatment standards in Vietnam, and the imperative to ensure affordable sanitation and wastewater treatment for all parts of the community. We also identified which areas that could be targeted for the different strategies. For example, cluster scale wastewater treatment ought to be rolled out in areas with concerns about surface water quality and the condition of groundwater systems. Finally, we also developed a BN model to describe the impact on the WNI dimensions of carrying out combinations of the strategies in different areas, for different scenarios. This was to allow local water planners to feed into the urban planning process of the city, by recommending strategy portfolios designed to achieve targeted outcomes, in a transparent and auditable process. We hope to incorporate these strategic planning processes into the city's development of the City Masterplan. To date, , this has not been achieved, yet local stakeholders have adopted parts of the recommendations, and appear very willing to continue to work with the research team to adopt more of the strategic planning processes into their future practice.

### 3.5 Involve stakeholders

Stakeholders are important in this process for at least three reasons: 1) they have an interest in the outcomes of the process; 2) they may need to be involved in the implementation of strategies so their buy-in is critical; and 3) they typically have both data and knowledge, thus potentially providing critical understanding of the urban water system. Stakeholders in the project were identified in an informal stakeholder mapping exercise, utilising the knowledge of experts with prior experience in Can Tho, and the local stakeholders. As part of the project, there have been engagement activities involving in-country policymakers, urban managers and researchers to facilitate the development of practical knowledge that they can use to assess and guide investment options. Specifically, this has involved: close collaboration with researchers at the local university; a series of facilitated workshops; and meetings and interviews with chosen stakeholders during each trip to Can Tho.

## 4. DISCUSSION AND CONCLUSIONS

This paper describes an integrated assessment approach, to identify a city's water management needs, and to develop strategies to improve urban water planning. . The process involved iterative stakeholder engagement, the development of a knowledge base, and systems analysis to evaluate identified strategies against goals and criteria. As such, this provided a generic framework that could be easily reproduced in a different location, and thus overcoming one of the key difficulties in water management, i.e. the problem of dependency on the local context. The project has achieved good traction with local stakeholders, and has been given a prestigious award from the city. Some of the recommendations have been taken up by local water managers but it appears some of the project outcomes have been more easily adopted by local water planners, i.e. the spatial representation of the developed knowledge base in a map book; and the implementation of strategies after follow up pilot studies, such as the household scale rainwater tanks. We perceive there to be two key hurdles when getting stakeholder adoption. Some outputs required further funding, and some of the outputs did not easily feed into current planning practices due to institutional inertia, and sometimes local stakeholders required training in the developed methods. The study looks to continue in the next phase of the AusAID-CSIRO Research for Development Alliance, and the focus now shifts towards training and ensuring adoption, the replication of the method, and the upscaling of results to achieve region-wide impacts

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