STAFFORDSHIRE UNIVERSITY

UNDERSTANDING AND MODELLING OF RESIDENTIAL WATER USE BEHAVIOUR

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Abstract

There is an increasingly water scarcity issue, both for developed and developing countries. Water authorities are facing the challenges to secure the need of consumers and water saving due to the climate change and the population increase. To manage this water scarcity threat, water conservation projects are gaining overall attendances by water utilities and government. From the management perspective, it is desirable to investigate and understand how consumers use water and their water use behaviours. The main objective of this study is to develop a comprehensive understanding of residential household water use behaviour through theoretical and modelling perspectives.

This study is based on the Theory of Planned Behaviour (TPB) and proposed an extended version of the Theory of Planned Behaviour (TPB) for understanding the behaviour intervention mechanism. A survey of residential water use behaviour in China was designed and conducted in 2014 and the data was used to evaluate the extended theory. The theoretical evaluation has proved that the ETPB could increase the predictive power compared to original version of TPB, and also provide empirical evidence for the correlations among ETPB variables.

Traditionally, static behaviour intervention models are widely utilised to simulate behaviour intervention process. These static methods can predict

targeted human behaviour reasonably well, but they lack capabilities on understanding and responding behaviour change process with concerned time changes. Using the proposed ETPB theory, a dynamic behaviour intervention model for household water use behaviour prediction is presented to introduce the dynamic behavioural modelling solution. This model is based on adopted Structure Equation Model approach and Control Engineering Concept. A case study for household water consumption model using Artificial Neural Network (ANN) is proposed to explore the link between behaviour value and the water consumption amount, moreover, for evaluation of intervention trend of proposed ETPB dynamic behaviour model with system parameter identification.

This research findings demonstrated that household water consumption could be saved by using proper behaviour change management strategies. The significance of these findings about behaviour intervention modelling in water end use areas is discussed. Also, potential applications of the ETPB-ANN dynamic integrated modelling method for other research purpose are also presented.

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Glossary

ANN	Artificial Neural Network
CADM	Comprehensive Action Determination Model
CCNN	Cascade Correlation Neural Network
CFA	Confirmatory Factor Analysis
EFA	Exploratory Factor Analysis
ETPB	Extended Theory of Planned Behaviour
FFNN	Feed Forward Neural Networks
GHG	Greenhouse Gas
GRNN	Generalized Regression Neural Networks
HBM	Health Belief Model
IoT	Internet of Things
PBC	Perceived Behavioural Control
SCT	Social Cognitive Model
SEM	Structural Equation Model
TTM	Transtheoretical Model
TPB	Theory of Planned Behaviour

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1 Introduction

This chapter gives an overview of research this PhD thesis. It starts with a description of the background, definitions of the aims and objectives for this study, by the research questions and the approach to address these questions, and structure of this thesis

1.1 Water Shortage and Conservation

Considering the climate change and the increase of human population, the resources of drinking water are considered as a precious part of nature which needs to be conserved and effectively used. There is evidence that almost 80% of the world's population is exposed to high threats of water scarcity (Vörösmarty et al., 2010). Human activities are placing unsustainable demands on the water resources with over-extracted ground water supplies and inadequate water flows. In the next decades, water resources will be under more pressure by urbanisation, population growth and economic development. By 2050, around 2 billion people will be living in countries with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions (Vörösmarty et al., 2010). In the meantime, climate change is likely to exacerbate existing stressors on water resources. Almost half of the world's population will be living under high water stress of water scarcity by 2030, including around 180 million people in Africa (Vörösmarty et al., 2010). In addition, 24 – 700 million people in semi-arid places will face water scarcity.

Addressing water scarcity will require a range of adaptive approaches enacted at different levels (individual, community, area, country or international). Reducing demand by improving the efficiency of water use necessities is essential for water scarcity issues and understanding how water is used and in what ways water savings can be realized (Bradley Jorgensen et al., 2009). A comprehensive review by Inman and Jaffrey (2016) showed that demand management could reduce residential water consumption by 10-20% for a decade period. With water conservation promotion, demand management is an appropriate approach for improving water efficiency. In their review, they concluded that relatively moderate reduction could be achieved via modest price increase and voluntary alternative demand management tools but larger reductions in demand requires stringent mandatory policy instruments. In line with this finding, Renwick and colleagues (2000) made a comparison of the efficacy for different demand management methods, and found voluntary measures reduce less water demand compared to mandatory water restrictions or allocations. However, even achieved higher reduction in water remand, pricing mechanisms and mandatory approaches have drawbacks in their implementation, and limits to price elasticity of demands, and research evidence showed that mandatory approaches do not necessarily result in long-term intervention (Duke et al., 2000). On the contrary, research (Bradley Jorgensen et al., 2009) suggested voluntary approaches involving behaviour intervention are critical for long-term water use habit shifts, and these shifts can be complied with other management approaches. Moreover, different from supply-side management, demand management involves more attention on the amount and water use pattern by consumers. In this way, demand management approaches paid as much attention to behaviour study as it did to infrastructure (Brooks, 2006).

1.2 Household Water Conservation

By concerned climate change and the increase of human population, the resource of drinking water is considered as a precious part of the nature which needs to be conserved and effectivly used. About 65% of the total water use in the most cities of developing countries (including industrial consumption etc.) is from household level, which are responsible for a big share of water consumption (Geoffrey J. Syme et al., 2004). These situations decide that water conservation and management at the household level should be regard as an increasingly important issue for urban utilities and governments (Tingyi Liu, 2007). The governments have been trying to promote projects to conserve household water use with different strategies such as Chinese step water price, grey water reuse promotion, educational water saving dissemination, low-interest loans and the adoption of water conservation technologies (Blanke et al., 2007; Liu et al., 2008). However, studies show that greater understanding of water conservation behaviour and how behavioural intervention can be influenced, are supposed to play crucial role to meet the water saving targets (Yazdanpanah, 2014).

The researches for reducing household water consumption have potential to achieve significant water savings. Tradition solutions for residential water saving promotion include upgrading the network, adjusting and optimizing the water use pattern (Bates B. Kudzewics et al., 2008). It cannot be denied that water conservation in community or city level from engineering perspective could make a difference. However, these engineering solutions paid fewer attentions to the household level and cannot effectively increase the residential water conservation awareness. Behavioural change depends on encouraging residents' agreement within a broader environment of appropriate policy, information and awareness raising (Blanke et al., 2007), this has won success in the past decade for improving water conservation efficiency.

This study brings together behavioural change theory with behavioural intervention modelling to understand the household water conservation behaviour intervention process. Using these combinations, this research, therefore, offers theoretical basis of water conservation behaviour intervention and the understanding of behavioural intervention process for residential water conservation projects.

1.3 Behaviour Change

The behaviour change science is designed to target people or community with a design and implement programs ('interventionists') that produce a desired behaviour (Chen Y et al., 2005). For household water conservation, more researches have been done to change users' behaviour or specific water – relevant behaviours (Kenney D. et al., 2008). Specifically, the behaviour science can be used to understand users' attitude and reactions towards different intervention of water business like billing change. Technically, more research on behaviour change is mainly based on the development of BCM (behaviour change model) level and application of BCM level (Bates B. Kudzewics et al., 2008). The definition for the development of BCM is investigated to specify BCM framework for water use. Applications of the BCM researches mainly are focused on the mature theory of BCM for water use likes "water is money" concept by Australia States and Territories in 1996 (Marshen J et al., 2006).

Water related behaviour varies differently by areas, also, many water use related to behavioural interventions have not yet been empirically investigated because they do not lead themselves to study under existing research paradigm

(Australia Psychological Society, 2010). Models including the Theory of Planned Behaviour (Ajzen, 1991), the Theory of Reasoned Action (TRA) and Schwartz's norm activation model etc., have been applied to investigate the conserving water issues during water scarcity period in many developed countries, such as USA (Pirie et al., 2004), UK (Gilg and Barr, 2006), Australia (Hurlimann et al., 2009) and Greece (Jones et al., 2011). However, there is lack of evidences for explaining residential water conservation behaviour via theoretical viewpoints in different background, especially using a multi-purpose methodology to generate empirical model. One of the few exceptions is Zhang and Brown (Zhang and Brown, 2005) who found that with using habits and behaviour (physical behavioural pattern) as well as a household' willingness to respond to water related strategies, this had positive influence on water consumption amount. Chen et al. studied the relationship between social-psychological and residential characters of water scarcity on the one hand and drinking water choices on the other. His research found that personal health belief and other factors (income, education etc.) affected domestic drinking water choices in Shanghai (Chen et al., 2012). These researches do not, however, address how water use behaviour change can be influenced and what the adaptability for a psychological theory is in diverse cultural background. Therefore, there is a need to develop understanding of the residential water conservation behaviour intervention mechanisms. This research thus tries to fill the research gaps

This research therefore is to provide empirical evidences about the intentions of resident toward water conservation strategies, as well as water conservation behaviour change with respect to it. This study proposed the Expanded Theory of Planned Behaviour (ETPB) as a behaviour change theory basis and tested the past behaviour and self-efficacy as predictor in the whole theory which will be different from the original TPB (Theory of Planned Behaviour) model. This provides a first knowledge base for public water conservation strategies and policy development that aims to increase water conservation engagement among residents.

1.4 Behaviour Intervention Modelling

Despite its importance for scientific research and policy making, stumbling blocks to investigate water conservation behaviour are apparent in the economic research on water demand and consumption. First, standard economic models have disadvantage with neglecting psychological and sociological factors, even behaviour (Jianjun Tang et al., 2013). Also, economic drivers and characteristic of water demand gain more attention rather than social psychological determinants of water conservation behaviour (Bradley et al., 2009).

Moreover, despite the social significance of water end use research, no studies have examined the relationship between household water use and the users' behaviour intervention process, even the interactions of different influence factors. Studies in the past correlated on modelling attitude of household water use and other behaviour change variables with the total water consumption, rather than understanding the process of the behaviour intervention. It has disadvantages of not having a clear understanding about the influences by the process of behaviour change in the water use areas. Taking the social and economic models for examples, these models have high accuracy for prediction, however, their models cannot be used to supervise the behaviour change without considering the significance and understanding of behaviour intervention process (Bradley et al., 2009).

The internet supported behaviour change research has been extensively researched previously. For example, Thomas L Webb al. etc. (2010) reviewed 85 studies published coding frames for assessing use of theory and behaviour change models to promote online health behaviour change. Most commonly used methods for conducting behaviour change are theories which support to delineate the key determinants of behaviour, followed by statistical methods to analyse the factor relationship or linkages. Models and Theories are widely applied include Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB), Transtheoretical model (TTM), Health belief Model (HBM) and Social cognitive model (SCT) etc. As the technology support for analysis of behaviour change model, statistics methods are accepted by researchers (Andria and Carl, 2011). Multiple Linear Regression and Structure Equation Model (SEM) are the commonly used statistical techniques in behaviour science. Interestingly, statistic approach using SEM is still valuable to simulate behaviour change but showed less capability to simulate intervention system over time. Engineering control principles showed its applicability to areas in the behavioural science which involve dynamical systems, such as time-varying adaptive intervention (Daniel and Michael, 2007). Fundamental control engineering and adaptive intervention terminology such as dynamic system (refer to multivariate time-varying process), tailoring variables and process analysis could benefit to current behaviour change modelling research.

Using Expanded Theory of Planned Behaviour (ETPB), a dynamic behaviour intervention model for household water user behaviour prediction is presented to introduce the dynamic behavioural modelling solution. This model is based on adopted Structure Equation Model approach and Control Engineering Concept. A case study for household water consumption model using Artificial Neural Networks (ANN) is proposed to explore the link between behaviour intervention process and the predicted water consumption amount, moreover, evaluate intervention trend of proposed ETPB dynamic behaviour model with system parameter identification.

1.5 Behaviour and Water Use

Reducing water demand by improving the efficiency of water use necessitates an understanding of how the water is used and in what ways water conservation can be realized. Stumbling blocks to achieving this goal are obverse in economic and social research on water management and demand control (Jorgensen et al., 2009). Economic researches have gained more attention than the social or psychological determinants of water conservation, but it lacks evidence to integrate economic and social viewpoints from literature. The implementation and outcomes of water conservation from economic and social researches are tended to be context. Generalizations, for example, are hard to draw by using these solutions. Moreover, constrained by site and issue specific factor, economic and social theoretical and application underpinnings are derived from general theories of consumer behaviour developed in non-water domains (e.g., energy conservation, goods consumption or waste recycling, etc.). Thus, the development of integrated water conservation model is sorely necessary (Jorgensen et al., 2009).

A few studies have proposed conceptual models concerned behaviour change factors could contribute to the understanding of water conservation activities. Jorgensen et al., (Jorgensen et al., 2009) has systematically reviewed these models in his research and proposed a global social and economic household water consumption model, however, these research outcomes do not show enough evidences to reveal the relationship between water use and behaviour intervention process which is foundation to guide behaviour change in practise.

1.6 Aims and Objectives

The aim of this research is to develop an Expanded Theory of Planned Behaviour (ETPB) and propose corresponding dynamic water intervention model by concerned time changes. Within this overall aim, specific objectives were developed, providing a breakdown of the main research aim. The specific objectives of this research are as follows:

- To review the literature of the behavioural change models/frameworks for water use, the way to simulate water end use process and better understand the individual's attitude towards the conservation of household water by different data collection methods.
- To review the theory of planned behaviour and identify the method to improve the predictive power of this theory for household water use behaviour.
- To design the questionnaire for household water use behaviour investigation.
- To evaluate the extended version theory of planned behaviour and test the predictive power.

- To generate the behaviour change suggestions for improve intervention project efficiency via ETPB
- To develop a dynamic psychological model (behaviour change model) for simulating household water consumption.
- To implement the model for understanding human behavioural for predicting water end use consumption.
- To evaluate model and improve the accuracy of the stimulation results.

1.7 Research Questions

The following research question are to be answered during the course of this PhD:

1. What is the current background of research related to household water use, and what is the background for current water saving behavioural intervention projects?
2. What are the models or theories for predicting water related behaviours and have these models showed good enough prediction power?
3. What are the drawbacks of theory of planned behaviour for predicting household water use behaviours and how to improve the theory?
4. What is the survey method for household water use behaviour and how to evaluate the prediction power?

5. What are the roles for past behaviour and self-efficacy in theory of planned behaviour and how their introductions affect the original TPB model?

6. How to use extended theory of planned behaviour to guide the computer simulation for dynamic behaviour intervention?

7. How to link the psychological behaviour value to the real water consumption?

1.8 Application to Address the Research Questions

To answer these research questions, a range of methods were developed. An extensive literature review took place to answer the first three research questions.

This report has set out a clear method of approach for the simulation and conservation of end use water based on behaviour intervention modelling (Chapter 1). The investigation of water end use modelling and its behaviour understanding proved that current water use models have drawbacks in the areas of: behaviour change pattern, behaviour change understanding, modelling supports for water end use by concerned behaviour change (Chapter 2). Methodology of this study for solving the problems above has been presented in Chapter 3. In the ETPB-ANN model, the identification of four key issues has showed the text as model architecture (Section 3.3.1), methodology (including sampling, questionnaire and measurement in Section

3.1, data analysis in Section 3.2, behaviour change modelling (Section 3.3.2) and the ANN water end use model (Section 3.3.3). The statistical analysis is outlined in Chapter 4. Assessment for ETPB theory and prediction ability is presented in Chapter 5. Chapter 6 provides dynamic solutions for ETPB behavioural modelling and system identification conclusion. Chapter 7 is presented to explore the link between behavioural change and water use amount. Chapter 8 is the summary of this PhD research project.

1.9 Research Highlights

The overall contribution from this research is to develop both theoretical and computational modelling solution for understanding household water conservation behaviour. This study proposed an extended version of TPB with empirical evidence support for improving behaviour intervention understanding in water conservation domain and investigated the novel modelling solution by concerned time serials. The linkage and application for behavioural intervention theory and model have also been explored in this research by using ANN modelling method. Contributions to the knowledge in this research can be summarised as below:

1. Develop an extended theory of planned behaviour for understanding the water conservation behaviour change and improve the TPB behaviour prediction ability.

2. Explore the direct and indirect effects for introduction of Past Behaviour and Self-efficacy in TPB and test the notion difference between Self-efficacy and PBC (Perceived Behavioural Control) is the water conservation domain.

3. Analyse and evaluate the empirical ETPB model for understanding current Chinese water conservation behaviour intervention situation.

4. Use control engineering concept and system identification method to simulate behaviour intervention process and introduce time serials in the dynamic modelling system.

5. Propose a water consumption model (ETPB-ANN) considering behaviour intervention process and explore the link between behaviour intervention process and water consumption amount.

2 Literature Review

The argument set out in this chapter comprehensively reviews the area of research and describes the technological approaches that have been adopted in this area of research. This chapter is set out as follows. Section 2.1 reviews the behaviour change theories and researches, followed by section 2.2 which descripts the water use behaviour literature review. Section 2.3 is about the Theory of Planned Behaviour and its application. Section 2.4 is about the water use behaviour modelling. In section 2.5, water end use modelling technologies review is presented. Section 2.6 discusses the research gap of this study and Section 2.7 is the summary of this chapter.

2.1 Behaviour Change Theories

Human behaviour is generally complicated and determined by massive factors such as sociographic, psychological, personal, situational factors. Ajzen (1985) argued that “people approach various kinds of behaviour in much the same way and that the same limited set of constructs can be applied to predict and understand any behaviour of interest”. Ajzen and Fishbein starts to investigate attitudes and social norms and determines the behaviour which was formulated as Theory of Reasoned Action (TRA). From 1980’s onwards Ajzen added another element to the original TRA: external factors such as Perceived Behaviour Control to contribute the capacity to perform behaviour.

The theory then afterwards was named as Theory of Planned Behaviour (TPB) and explains the consequence of available alternatives, weight the normative expectations when people are faced with a situation to decide a course of action. In the model, Ajzen (1991) stated intentions can be predicted from attitude toward behaviour, Subjective Norm (SN) and Perceived Behaviour Change (PBC). This theory provided the understanding of the psychological and non-psychological influences on behaviour. Schwartz (Kaiser et al, 2005) proposed Norm Activation Model (NAM) that the precondition for conducting a behaviour is based on the awareness of consequences and understanding of responsibility. Value-Beliefs Norm (VBN) is another theory for predicting environmental behaviour based on TPB and NAM comprising contextual factors such as regulations and costs.

Recently, Klockner and Blobaum (2010) designed the Comprehensive Action Determination Model (CADM) to explain ecological behaviour via an updated framework from TPB and NAM with adding more complicated measurement of objective and perceived control. Both NAM and CADM proved a higher explanatory ability than TPB in travelling behaviour prediction, however, more research is needed to household water use field and there is a need to develop and validate a higher predictive model. Kaiser et al. (1999) proved that about 40% of the variance of ecological behaviour intention could be explained by environmental values based on the analysis of the relation between attitude and behaviour. Enhanced understanding of the stages of behaviour change, the transtheoretical model of behaviour change adds the complexity of human reasoning decision making processes.

Davies et al. (2015) reviewed all theories which considered individual behaviour as outcome and found out there are 82 theories reported in the literature. The fitness of different behaviour theories is the subject of many studies (Davies et al., 2015), and about 36 studies applied TPB as theoretical basis which proved a stronger explanatory power than other theories. However, there is no straightforward evidence about the universality of these behaviour theories in literature. TPB has been applied in considerable number of studies on theoretical sustainability and the environmental behaviours such as paying water utility bills promptly, water recycling, irrigation management and residential saving water behaviour (Lam,1999; Lam, 2006; Clark and Finley, 2007; Dolnicar et al., 2012; Gilg and Barr, 2006).

Even behaviour change theories and models have been used widely in many environmental research. Current behaviour change evaluation method is still limited to quantitative and qualitative evaluation methods. Damien Sweeney (2009) noted that the literature of measuring success of environmental behaviour change programs is very limited and that many programs lack adequate measures of evaluation. A systematic review of point-of-use water related intervention by Fiebelkorn et al. (2012) found that most behaviour change projects use statisctics analysis method to investigate the intervention process, leading to a result that cannot effectivly shows the relationship between time and the behaviour value change. As modelling and feeding back real-time behaviour intervention result has very significant meaning for behaviour intervention research, it allows the possibility of understanding for different behaviour change pattern and visibility of real time behaviour change outcome in any online or IoT platform.

2.2 Behaviour Change for Water Conservation

Water use and conservation behaviour recognition are critical aspects of water demand management highlighting the needs for understanding of psychological processes that underline residential water demand (Russell, S. and Fielding, k, 2010). In research, they concluded that only through identifying the key psychological and social drivers of water conservation, can effective policy be developed to address urban water demand management. Despite a clear need for development in this area, scant researches have been paid to the psychology in understanding and promoting water conservation behaviour change projects (Trumbo et al, 1999).

For the household water conservation, current researches are mainly focused on the development of the behaviour change model (BCM) and application of the BCM. The application level for BCM the mature theory of BCM and apply it for water use research. There are a lot of researches to change people's water use behaviour or specific water-relevant behaviours (Ezra M. Markowitz et al., 2009) in this level. Specifically, the behaviour science can be used to understand users' attitude and reactions towards different intervention of the water related business. For example, advertising campaigns conducted by Australia States and Territories in 1996 were centred on a "water is money" concept and followed a price increase for water billing. Moreover, research in the water use field is to reduce the water consumption for household, community and individual. A study by Kurz and Donaghue used combination information leaflets, labels and feedback to change water use behaviour and they have achieved about 23% reduction in 2005 (Kenney D. et al., 2008).

The development of BCM level means studies make it into BCM more specific framework for water use. The behaviour change method used for the water research is based on the original and the modern psychological research and use it to develop a new framework for water use research. Like the UKWIR project CU02 in 2012, the research team applied the new MINDSPACE behaviour change framework to encourage greater use of "self-service" facilities.

The application of BCM in the water conservation area applied social and economic model to simulate the human behaviour influence on the water consumption. Inevitably, this method has its limitation. It has been introduced as a signal or few behavioural parameters in the modelling process which is not sufficient offer a clear understanding for the intervention process. Even though many researchers have presented the models of water use stimulation and prediction (Bradley Jorgensen et al., 2009; Luaky-Froukh, M., 2001; Pblebitski, A. et al., 2010), they are still not sufficient to address the issues about how customer' behaviours changed and what is the relationship between psychological behaviour and real water consumption.

2.3 Theory of Planned Behaviour

Theory of Planned Behaviour (TPB) is a widely-applied expectancy-value of attitude-behaviour relationships which met some success in predicting behaviour. This theory is an extension of the theory of reasoned action (TRA), developed by Ajzen in 1988. Both models were designed to provide parsimonious information and motivational influences on behaviour. The TRA suggests that people' intention to engage in that behaviour is the proximal determinant. Intention represents the motivation in the sense of her/his conscious plan to exert effort to act the behaviour. In suggesting that behaviour is only under the control of intention, the TRA model limits itself to volitional behaviours. Ajzen proposed an extension version for the TRA to cover the limitations of TRA. In TPB theory, the underlying assumption is that humans are rational and make systematic use of available information

(Andrew Darnton, 2008). This theory builds on expectancy value theory to incorporate normative social influences on behavioural intention. It gives the concept for linkages between beliefs, attitudes, perceived social norms and behaviours (as shown in Fig. 1).

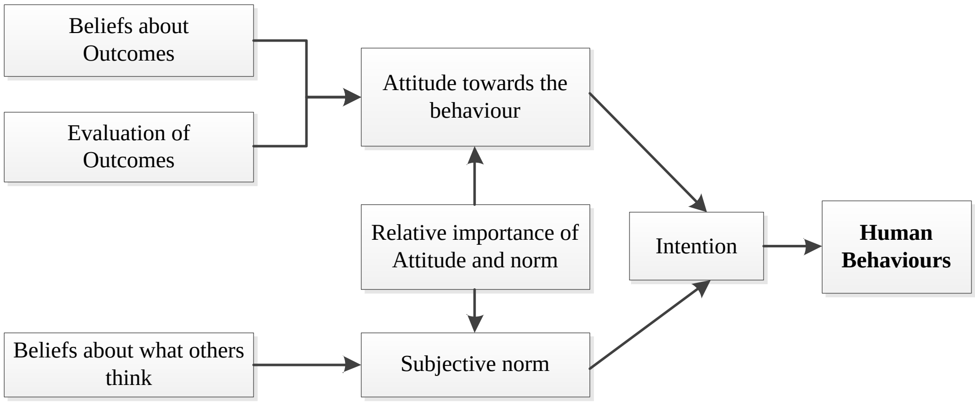


Figure 1. Theory of Planned Action (Jackson, 2005)

Theory of Planned Behaviour as an important social cognitive model (Ajzen I., 1985) has been applied in various water management domain, such as pollution reduction (Mark and Irene, 2000), plastic consumption control (Sharifah et al., 2015), waste water management (Shirley and Peter, 1995) and green purchase (Nazish Muzaffar, 2015). It gained wide applications for water conservation research and has been investigated in the application for predicting water saving behaviour in previous researches. Yazdanpanah (2014) systematically reviewed the TPB application for water conservation. In literature paying water utility bills promptly, water recycling, irrigation management and residential saving water behaviour are the general applications of TPB in environmental studies (Lam,1999; Lam, 2006; Clark and Finley, 2007; Dolnicar et al., 2012; Gilg and Barr, 2006).

Despite its significance in environmental research, the TPB research became more controversial about its sufficiency and the need for external variables which assist to the improvement of intention prediction (see examples Conner, 1999; Norazlan Hasbullah et al., 2014). Research findings above have proposed additional predictors to improve the TPB prediction power in intention and behaviour (Conner, 1999; Hagger et al., 2001a). Interestingly, on conceptual level, various divergent water conservation frameworks also exist on adding external determinants (or predictors) to specific behaviour (see examples Bradley et al., 2009; Leviston et al., 2005; Gregory and Di, 2003). Acknowledging TPB's limitation, Ajzen (1991) summarized that the TPB is open to further expansion if a theoretical justification for additional predictors is provided. Lam (2006) also argued that TPB alone is not sufficient as a basis for understanding people' intention to conserve water. Consequently, some other constructs to TPB will need to be added to increase the utility and predictive power for water conservation behaviour. In this study, an Expanded version of Theory of Planned Behaviour will be proposed to enhance the prediction ability of water conservation behaviour.

2.4 Behaviour Change Modelling

The internet supported behaviour change research has been extensively researched previously. For example, Thomas L Webb al. etc. (2010) reviewed 85 studies published coding frames for assessing use of theory and behaviour change models to promote online health behaviour change. Most commonly used method for conducting behaviour change are theories which support to delineate the key determinants of behaviour, followed by statistical methods to analyse the factor relationship or linkages. Models and Theories widely applied include Theory of reasoned action/planned behaviour (TPB), Transtheoretical model (TTM), Health belief Model (HBM) and Social cognitive model (SCT) etc. As a support technology for analysis of behaviour change model, statistics methods are accepted by researchers. Multiple Linear Regression and Structure Equation Model (SEM) are the commonly used statistical techniques in behaviour science. Most of models applied for modelling behaviour change are only based on static data analysis such as structure equation model (Munro et al., 2007; Chris et al., 2007). Even these static methods showed their capabilities for predicting targeted issue, however, they did not demonstrate enough understanding of human behaviour change process and knowledge of behaviour intervention modelling.

In Bollen’s study (Bollen, 1989), an attitude-behaviour theory testing research was conducted using standard multiple regression to illustrate TPB timeline and path diagrams. Jacob et al. (2002) systematically analysed the applied multiple regression/correlation for the behaviour sciences with behaviour data visualization, exploration and assumption checking methods. Belmon et al. (2015) utilized multiple binary logistic regression analyses to estimate the association between different personality characteristics (self-efficacy, self-identity etc.). However, even a lot of research used this method, as a static statistic approach, multiple linear regression shows few its capability to analyse complicated system, especially simulate system change over time. Canfield (2012) presented a method by using SEM to analyse the mediating conceptual framework (physical activity and sedentary behaviour). Interestingly, statistic approach using SEM is still valuable to simulate behaviour change but showed less capability to simulate intervention system over time. Engineering control principles showed its applicability in areas of the behavioural science which involve dynamical systems, such as time-varying adaptive intervention (Daniel et al., 2007). Fundamental control engineering and adaptive intervention terminology such as dynamic system (refer to multivariate time-varying process), tailoring variable and process analysis could benefit current behaviour change modelling research. Even Mohamed et al. (2014) and Yunwen et al. (2013) have successfully simulated behaviour change by introducing control engineering concept such as time delay, resistance etc. and proved this cross-discipline method can benefit behaviour change simulation research somehow, however, none of them provide a comprehensive and generic framework for behaviour change data collection and dynamic process modelling. In addition, there is lack of performance evaluation of dynamic modelling and its effects on the result prediction performance.

2.5 Household Water Use Behaviour Modelling

Social models for water use behaviour are used for predicting household water consumption by considering the social and human behavioural factors. Syme et al. (1992) investigated the house owners' attitudes against their water consumption result for a whole year in Perth, Australia. His model showed that effective demand management strategies could change the users' behaviours in combination with water price adjusts. The other example about the social model is to use the alternative water sources and technologies to investigate the receptivity of community by Clark Brown (Clark Brown et al., 2006). Thus, all the water saving ability and reuse power rely on the condition of behaviour change capacity.

Economic models are techniques indicate that price setting, price structuring and use restrictions have a direct influence on household water use (Bradley Jorgensen et al., 2009). Some researchers suggest that household characteristics play a key role in the determination of the water use, and behaviours need to be informed by local information about how to use and save water in the house. Moreover, researchers such as Kenney et al.'s research (Kenney D. et al., 2008) pointed out that residential demand depends on a lot of factors like price. Therefore, the non-price demand management programs (rebates or water smart meters etc.) can be effective for water conservation.

However, despite of the accuracy of all the various kinds of models, current water use models take no differences between the objective and subjective parameters for simulation. All the parameters are selected to input the model and calculated by the model itself. Taking the social model of household outdoor water consumption as example (Geoffrey J. Syme et al., 2004), their model analyse and use some social factors concerned with attitude and behaviour details for calculation, but it did not give any information about behavioural intervention. Some economic models like Hoffmann et al.'s model (Hoffmann, M. et al., 2006) and Kenney et al.'s (Kenney D. et al., 2008) model, considered economic and social factors, even involved in behavioural parameters (subjective parameters), however, most of those models only regard behaviour formation factors as a single or multi parameters in the models but not considered in the behaviour intervention. The development of behaviour model as an initial calculation model should play a role for understanding the behaviour process.

2.6 Research Gap

Previous studies indicated that there is still need for research in the following aspects:

- The water shortage status indicates that more research is needed on practical methods and comprehensive understanding for the water use.

- Addressing water scarcity will require a range of adaptive approaches enacted at different level (individual, community, area, country or international). There is a growing need for individual level approaches regarding water conservation.

- Reducing demand by improving the efficiency of water use necessities is essential for water scarcity issues and understanding how water is used and in what ways water savings can be realized. Even this study method paid more attention on the water use behaviour than other approaches, other studies on household water use behaviour change (either provide a picture of water use, or design of water use behaviour intervention) and demonstrating all steps from understanding, design and testing are not common.

- Most behaviour change theories evaluate the application of a theory such as TPB in different case. There is to understand the process of how to develop and extend behaviour change theories in further studies.

- There is not robust evidence that the TPB theory would be efficient and acceptable for investigating household water use behaviour, hence the need for testing.

- Self-efficacy and past behaviour have been pointed out in the literature as good predictors for people behaviour, however, studies either provide a test of self-efficacy, or the application of past behaviour in TPB framework. Studies involved two constructs introduction in TPB, and the influence of the introduction to the other constructs and TPB model are not common.

- There is different opinion in the notion difference between self-efficacy or PBC, hence the need to clarify and test these two constructs in water use behaviour practise.

- Most studies on water use behaviour change took behaviour as a static variable, indicating the need for research on understanding the linkage between behaviour intervention process and water consumption.

- Studies on behaviour intervention are focusing on the outcome behaviour change but rarely specify the behaviour change process and don't give robust evidence on how to simulate behaviour intervention process over time.

- Due to the uncertainty of introducing the behavioural process simulation into the water consumption prediction procedure, water consumption model concerned with behaviour intervention process will be a black box model. Relative studies on this field is not common.

- No studies were found attempting to clarify the linkage between behaviour value and the water consumption amount in water use modelling environment.

2.7 Summary

The aim of this literature review was to present the research background that guided this PhD research. It indicated the need for developing a household water use behaviour change theory to better understanding the behaviour intervention. Previous studies from diverse perspectives provided the basis and starting point for this work. The background was built to understand the water shortage and conservation, what is the key in this process, the potential for developing extended TPB model, how other studies linked behaviour to water consumption, and what possible modelling method can be applied to test the linkage during this research.

This literature review demonstrated examples of previous research related to water use behaviour change including challenges presented in the attempt to promote water demand management and understanding water use behaviour. It has verified the need for more research in specific areas, and these areas where this PhD research is positioned. This chapter also indicated the theoretical basis that can be used for the household water use behaviour change study. The studies presented in this literature review demonstrate the two constructs which may increase the predictive power of TPB. Also, it revels the need for developing real-time dynamic behaviour intervention model, and corresponding linkage between behaviour intervention process and water consumption amount in water use model.

3 Methodology

3.1 Introduction

This chapter presents the methodology adopted to address the research aim and objectives. The aim of this research is to test and examine the Extended Theory of Planned Behaviour (ETPB), simulating the dynamic behavioural intervention process and modelling the linkage between behaviour change and water consumption. Thus, there will be four main parts for this research: 1, Behavioural survey to capture data concerning household water use behaviour and corresponding water consumption condition; 2, Data analysis, Development and evaluation of Extended Theory of Planned Behaviour; 3, Dynamic behaviour intervention modelling; 4, Household water use modelling concerned with behaviour intervention.

The structure of this chapter is as follows. Section 3.2 is about the ETPB model development and evaluation methodology. This is followed in section 3.3 with an explanation of the data analysis methodology including the reliability and confirmatory factor analysis methods. Section 3.4 is the development of questionnaire for behavioural and water consumption data collection. Section 3.5 depicts the behaviour intervention background of this research. Section 3.6 discusses the data analysis method applied in this study. Section 3.7 and section 3.8 depicts methodology for two model development and evaluation.

3.2 Development of Expanded Theory of Planned Behaviour

There is growing evidence for the inclusion of self-efficacy as a predictor of behavioural intention (see review Bandura, 1997; Hagger et al., 2001a), behaviour (Conner and Armitage, 1999), or both intention and behaviour (Ryn et al., 1996). Self-efficacy reflects a person's internal confidence and ability to perform a behaviour (Bandura, 1997), and been regarded widely as a sub-dimensional construct of PBC as advocated by social learning theory (Terry and O'Leary, 1995). This notion overtly aligned the PBC with self-efficacy has been adopted and tested by Ajzen (1991) in many occasions. However, Charles and Michael (1998) argued that the interchangeable use of PBC and self-efficacy is inconsistent with theory. Conceptually, Terry and O'Leary (1995) made their distinction by stating that PBC reflects barriers (external aspects of control) towards certain behaviour and self-efficacy reflects the abilities (internal aspects of control). Conner (1999) and Hagger (2001b) further supported this distinction by providing a review of extending TPB and tighter different definitions based on empirical evidence. However, no research tested this distinguishing of PBC and self-efficacy in water use domain. The fact that people's water conservation behaviour is an activity with the needs of awareness, motivation and self-control ability (Syme et al., 2000), and low self-control ability to conserve water will block the promotion of a conservation strategy (Trumbo and O'Keefe, 2001). As low water conservation technologies and strategy adoption rate are the reality for many water conservation projects, based on findings above, residents will have greater intention if a higher level of internal confidence or belief is achieved, thus, self-efficacy is added in the original TPB model as a predictor for residential water conservation intention alongside a measure of perceived behavioural control.

Water conservation regarding water shortage, should not only depend on local condition, but also be influenced by historical water use background and freshwater availability in the past (Hoekestra,2000). Additionally, another widely discussed factor called past behaviour, past action, pro-environmental behaviour, self-reported past behaviour or habit, has been added in TPB for improving the explanation of environmental behaviour in several studies (Lutz Sommer, 2011; Hagger et al., 2001b; Norazlan Hasbullah et al., 2014; Dolnicar, 2012). Ouellete (1998) argue that our actions are not determined by reasoning but by habitual and automatic processes. And in literature, habit and historical water use background are usually measured by assessing extent to which a past action was engaged. Terry and O'Leary (1995) proposed that past behaviour has significant co-influence on intention with TPB variables.

Continuing in this line, Hagger et al. (2001b) proposed that the controlling for past behaviour as a predictor of all TPB variables could result in positively influencing the attitude, subjective norms, PBC and self-efficacy on intention. Other authors, by the contrast, have been sceptical of the influence of all independent variables in TPB on intention (Norman et al., 2000; Terry,1995; Yordy, 1993). As residential water conservation habit is very likely to be kept, and affect the influence of attitude, subjective norms and PBC on intention, however, whether the affect is attenuation remains unknown. Thus, in this research, external constructs are added to enhance the prediction ability and understand the construct influence in TPB.

3.3 Questionnaire and Data Collection

There are three technical parts in this research which required data for testing the outcomes and all the three parts will have different requirement for data volume and quality. For testing the ETPB theory and variables' correlation relationship, a large scale TPB psychological behaviour data will be needed. For testing the dynamic behaviour intervention modelling result, a small scale long-term behaviour observation data will be needed to support this research. As for household water use model calibration, there is a need for both psychological behavioural and household water consumption record. Thus, there are two types of data should be collected to support the modelling in this study: ETPB/TPB behavioural and household water consumption data.

3.3.1 ETPB Questionnaire

A questionnaire is a research instrument consisting of a series of questions and other prompts for the information gathering purpose. Questionnaires are typically designed for the statistical analysis, and identified as a formalised question set and framework design. This data collection method has advantages over some other types of surveys in that they are more cost effective, less effort than verbal or telephone survey, and provide standardised answers for interpreting data (Hair et al., 2003, p.256). The main function of the questionnaire is to capture the main reaction to the investigated issue, however, as a type of survey, this method is still limited in the demographic variety.

The questionnaire in this research contains three parts: the first part is the ethic content form for using data, the second part is for the ETPB questions and the third part is designed to collect residential information. The construction of the ETPB questionnaire generally followed the procedures in Ajzen's discussion (2009) and the guidance for constructing TPB questionnaires (Francis et al., 2004). The construction of a questionnaire to measure the variables in the TPB model proceeds can be divided into seven phases:

1) Define the population of interest and decide how best to select a

representative sample from this population.

2) Carefully define the behaviour in water use area and use this definition to construct general introductory statement for the start of the questionnaire.

3) Decide how best to measure intentions

4) Determine the most frequently perceived advantages and disadvantages for performing the behaviour, the most important people or groups of people who would approve or disapprove of the behaviour and the perceived barriers or facilitating factors which could make it easier or difficult to adopt the behaviour.

5) Include items to measure all constructs in the first draft questionnaire.

6) Pilot test for the draft and reword items if necessary.

7) Assess the reliability of questionnaire

TPB 7-point Likert scales (1 = strongly disagree to 7 = strongly agree) have been applied previously in water conservation behaviour research with similar research purpose, and they have established an acceptable reliability (Dolniar et al., 2012; Yazdanpanah et al., 2014). In current study, intention to perform water conservation behaviour was directly accessed by three items: (1) “I expect I will engage in everyday actions to save water around my property in the next few months” ;(2) “I intend to engage in water conservation activities in the future” ;(3)” I plan to conserve water around my property in the near future". Six items with a 7-point Likert scale ranging from very false (1) to very true (7) for measures of environmental attitude (e.g., "I think engage in water conservation activities is beneficial") and extremely unlikely (1) to extremely likely (7) for measures of PBC (e.g., For me to conserve water around my living place is easy) was utilized with four item questions. Additionally, a three-item measurement with 7-point Likert scale was used to assess Subjective norms (e.g., I feel like there is social pressure to conduct water conservation activities around my property), ranging from strongly disagree (1) to strongly agree (7).

Self-efficacy. Previous studies examined the self-efficacy influence on environmental intention by 7-point Likert scale questions (Carmen Tabernero, 2011). The measurement of self-efficacy was designed following the guide instructions of constructing self-efficacy scales (Bandura, 2006). The three most frequent responses to the level of confidence on the questionnaire was administered as follow: (1)" To what extent do you feel capable of conserving water in your property?"; (2)" To what extent do you feel capable of conserving water when you are in a rush?"; (3) "To what extent do you feel capable of conserving water when it is inconvenient?", where response scores ranged from not at all confident (1) to totally confident (7).

Past behaviour. Frequency of past water conservation behaviour was assessed using the following six items questionnaire. It was firstly used by Dolnicar and Leisch (2008) for pre-environmental behaviour and his following research about water conservation behaviour in Australia (Dolnicar, 2012). These were "check and fix leaking tap", "use minimal water in kitchen", "collect rainwater to use", "turn off taps when brushing teeth", "have shorter showers (4 min or less)" and "only run washing machine if it is full". Items to measure past behaviour was stated as "In the last six months, how often did you do specific action", response were given on a 7-point scale representing hardly ever (1) to very often (7).

3.3.2 Survey Method

Associated with descriptive and causal research situations, survey method has been applied in many social researches. Depending on the topic, goal and budget, different survey methods are being used to collect customer data for research in the behaviour change study. Szolnoki and Hoffmann (2013) compared face-to-face, telephone and online survey methods and concluded that online survey methods have advantages in lower cost and higher speed. The online survey method provides visual, interactive and flexible sampling solutions without requiring any presence from interviewer. Relying on such modes will likely lead to selective samples, raising concerns about nonresponse bias.

Taylor et al. (2009) investigated the effects of modes, such as online survey versus telephone by conducting a national survey about air quality in national parks. The results showed that telephone survey response rate was higher than online survey. Therefore, conducting online survey for sampling purpose will need a higher sampling volume even it is easier to handle than telephone surveying method. Unlike face-to-face survey, online studies may also have disadvantages in not being representative of the entire population. The online surveying method has potentials to miss the users who do not use internet very often.

In this study, an online survey method is used to collect customer behaviour intervention data with an initial big volume sampling. Also, to increase honest responses, the internet survey was designed to offer an anonymous feeling with a preamble advising (Babbie, 2013). Before the respondents start to complete questionnaire, introduction of preamble advising which mentions the importance of this research and asks for faithful reply to be given. Two criteria were set before the questionnaire was being processed: the respondents should be over 18 years old and know very well about daily water use activity in their property. This setting could somehow locate the targeted group interviewer and bring up reliability rate.

3.3.3 Pre-testing Questionnaire

As the questionnaire is designed in the UK, the questionnaire was pre-tested by sampling Chinese students 18 – 28 years participants who had fully understanding of their household water use behaviour in China. Scale response categories were altered as respondents felt more comfortable with seven-point answer setting than five-point responses. Corresponding perceived barriers or pressures for water conservation activities were also tested via face-to-face interview. The barriers then were applied in the initial version of the questionnaire for street face-to-face survey on SZ high street in 2014. The official version of the questionnaire was evaluated in terms of instructions, ease of use, reading level, clarity, item wording and response formats, and was judged to possess face and context validity (Hair, 2006).

3.3.4 Study Population

The population for this research comprises residents living in China, specifically in SZ city. A few advantages can be listed from this approach.

Firstly, China has been facing increasing critical water scarcity and conservation issues and urge for water conservation solutions. Greater challenges occurred in ensuring water supply and quality for residential and industrial purposes in urban areas due to the high economic growth and increasing urbanised population. As a result of urbanization, by 2030, it is estimated that over 50% of Chinese population will be living in urban areas which will give existing limited water resource more stress (Gavan

McCormack, 2001). The north of China, which account for half of the total area of China is using around 20% of the total water resource, has already experienced a serious water crisis in the past few decades (Zhou H. et al., 2012; Xi-Peng Deng et al., 2006). Meanwhile, the south China with abundant water resource, its gross water availability per capita decreased from 5015 cubic meters in 1980 to 3702 cubic meters in 2005, and this situation will be more critical because of the exacerbation of severe droughts in 2004, 2007 and 2010 (Guan and Klaus, 2007; Xie Jian et al., 2008; OECD, 2007). China is also experiencing water resource overexploitation and water pollution, which is leading to serious socio-economic and environmental impacts (Yong Jiang, 2009). This water scarcity background in China urges water conservation research support for its current situation.

Secondly, the country is conducting water conservation promotion projects causing corresponding water use behaviour intervention. To decrease the substantial risk of water shortages, water conservation strategies are gaining attentions and importance. Despite the fact that Chinese government has been actively conducting water saving projects such as step water price, grey water reuse promotion, educational water saving dissemination, low-interest loans and the adoption of water conservation technologies (Blanke et al., 2007; Liu et al., 2008), most of these programs are still limited in the North and North-east China with a low adoption rate (Jianjun Tang et al., 2013), and only a few middle and southern city councils have raised the awareness of saving water in the past decade such as SZ. Moreover, typical Chinese water conservation programmes focus on technological rather than behavioural interventions, which leads to a fail to develop authoritative figures capable of teaching and enforcing water saving behaviour (Yujiu Xiong et al., 2016). Hurlimann et al. (2009) argued that the normative information on specific interactions is essential for the development of policy, and the reason of low adoption rate is lacking appropriate public willingness (Blanke et al., 2007). Yazdanpanah (2014) argued that the understanding of water conservation behaviour and how behavioural intervention can be influenced, are supposed to play crucial role in the decision-making process of water conservation promotion. Hence, to comprehend and influence residential responses to current water scarcity situation, insight into residential water conservation behaviour and how the behaviour change can be influenced are prerequisites for the development of adequate and effective water conservation strategy handles in China.

According to the data from China Ministry of Water Resources in 2014, SZ local water resource can only afford about 20% water consumption for the whole city. The annual average drinking water amount per person in SZ city is only 180 square meters (1/11 to the whole country’s average data) in 2013. Due to the special location of SZ, there is no big water resource such as reservoirs around this area. More than 70% to drinking water should be draw from East River far away from the city. Moreover, the rainfall response rate for this city is extremely low. The government statistic data showed that there are about 140 days' rainfall annually in the city and the whole year rainfall volume is 3 billion square meters, however, only 500 million square meters' waters have been reused. All the factors make SZ one of the most water lacking cities in China. To ensure the water demand of SZ city, government authorities have imposed a number of water restrictions and water saving measures. Decentralized rainfall collection systems are built all around the city to reuse rainfall for watering flowers or flushing toilets after simply treated. Take the town centre of Nanshan district as an example, the rainfall collection system saved 1.44 million tons water in 2011. Also, the government is planning to develop 13 new reservoirs to reserve water for increasing huge population. Moreover, due to the promotion of ascending water price, residential social awareness, behaviour and attitudes toward saving water have changed a lot, thus requiring further understanding of the link between these factors and water end use in this area.

The targeted community, which is named as Crape Myrtle Garden, sampled in this study is in the town centre of LG district, SZ, China. It was developed by Crape Myrtle Estate in 2002. This is a typical Chinese urban mature community with 1480 households and all the buildings are designed as seven floors apartment.

3.4 Behaviour Intervention

Since March 2014, the Survey City founded an association named SAPW (SZ Association for Promoting Water-saving) for promoting water conservation technologies and projects. The initial project was conducted in the city centre in 2013. Main methods for water conservation promotion from SAPW are educational course, water conservation technology show and long-term water-saving promotions (leaflet or advertisement on social media). In May 2014, the community surveyed in this study has no yet been promoted with any water conservation project which has very good preservation of old water use habit. Since August 2014, SAPW had launched a long-term water conservation project in LG district. The project is started from educational course in all school and promoted ideas as “Save Water in LG”. Until July 2015, the SAPW has successfully many activities for water conservation education and technology promotions. In July 2015, 83.2% applicants of water conservation survey in sampling community claimed the water conservation projects promoted by SAPW has positive influence on their water use behaviour. The survey period for this study covered the beginning and middle of local water conservation project which we assumed the water conservation project has triggered behaviour change in our sampling community.

3.5 Data Analysis

This section discusses the use of statistical techniques in this study. Descriptive statistics is explained in the first part followed by the statistical analysis section. Three methods are used for statistical analysis which are factor analysis, Confirmatory Factor Analysis (CFA) and Structural Equation Model (SEM). The software used for the statistical analysis are Statistical Package for Social Sciences (SPSS) and AMOS 21 program.

3.5.1 Descriptive Statistics

Descriptive statistics could be categorised into two groups. The first group contains the central tendency of the variable represented by the mean, median or mode (Mazzocchi, 2008). The mean value is the average calculated as the sum of the sample values divided by the value number in the data set. The major characteristic of the mean is the mean computation based on all values of a data set. The median is the middle item value where in the magnitude order. The mode is the value that occurs most frequently in the data set. The second part of the descriptive statistics represents dispersion which is estimated by using the range, variation and coefficient. The range is the difference between the lowest and highest values in the data set. Standard deviation and variation serve as measures for data variability.

3.5.2 Statistical Analysis

The statistical analysis methods applied in this study includes factor analysis, confirmatory factor analysis and structural equation modelling.

3.5.2.1 Reliability

The importance of measuring accuracy for research instruments are known well as reliability, have been conducted in several studies. Reliability expresses the degree to a measurement what it purports to measure. Reliability tests should be assessed before using SEM for exploring construct relationship (Shook et al, 2004). Reliability is normally expressed by correlations, however, in practice, the assessment for reliability is conducted based on three variables: stability, internal consistency and equivalency. There are many practical strategies have been developed to provide workable methods of estimating reliability. Four methods have been most commonly used in literature.

Test-retest reliability is a method which directly assesses the degree to which test scores are consistent from one test administration to the next. This method involves group test administration, re-administration for the same group at later time and calculating the two groups' correlation. This correlation between two test scores is used then to estimate the reliability using Person product-moment correlation coefficient. The higher of the Person product-moment correlation coefficient stands for great reliability (Hair et al., 2003; Mazzocchi, 2008). Split-half method is a method calculating two groups' scores evenly split from one group. Score on each half are correlated. The correlation between two split halves is calculated using Spearman – Brown prediction formula. Internal consistency is an assessment method for the consistency of results across items within a designed test. And equivalent form (Hair et al., 2003), also known as alternative-forms reliability is giving two versions of the test to the same people on two different occasion. Sores on the two forms should have a higher correlation.

As ETPB model contains four different dimension constructs, therefore, in this research, a suitable measurement method should be the one which considers dimensional difference. The summated scale measurement is a method tend to be most appropriate scales. Internal consistency should be assessed for the entire scales but not for separated component. For using internal consistency assessment to test reliability, Cronbach's alpha (Hair et al., 2003), known as coefficient alpha is used to express internal consistency degree. The Cronbach's alpha is applied as a lower bound estimate for psychometric coefficient of reliability test. The Cronbach's alpha can be written as a function of the number of test items and the average inter-correlation among the item. Conceptual formula for standardized Cronbach's alpha is showed as below.

$$\alpha = \frac{N * \bar{c}}{\bar{v} + (N-1) * \bar{c}} \quad (1)$$

Where N is the items' number. c-bar is the average inter-item covariance among the items and v-bar is the average variance. Practically, the Cronbach's alpha test result could only be accepted when alpha value is higher than 0.7 suggested from previous research (Hair et al., 2003).

3.5.2.2 Validity Analysis

Validity implies precise results acquired from data collected. There are four major types of validity used for testing survey quality. The internal validity test is the extent to which it measures what it is supposed to measure. This type refers to relationship between dependent and independent variables which are associated with the design of experiment and only relevant in study for establishing causal relationship. External validity is a causal relationship between cause and effect. Statistical conclusion validity refers to the conclusion reached about the extent of the two variables' relationship. Construct validity refers to the association of the test with an underlying theory.

For the validity and factor analysis test criteria, the KMO (Kaiser-Meyer-Olkin) and Bartlett's Test of Sphericity (Snedecor & Cochran, 1983) are used, which is a measure of sampling adequacy to check the case to variable ratio for the analysis being conducted. This method could test whether the correlation matrix is an identity matrix and show the validity and suitability of the responses collected to the water saving issue in this research. The accepted index for KMO is over 0.6 (KMO ranges from 0 to 1). And for recommended suitable factor analysis, the Bartlett's Test of Sphericity must be less than 0.05. All the validity test is done by SPSS software. Another aspect needed for factor analysis is to test whether a variable might relate to more than one factor. In this study, rotated component matrix is used to decide this point. Rotation maximizes high term loading and minimizes long item loading, therefore producing an interpretable and simplified solution.

3.5.2.3 Factor Analysis

Factor analysis as an interdependence technique defines the underlying structure among variables in the analysis (Mazzocchi, 2008). It is a process to identify the potential causes for several observed data for finding out which are the most important (Hair et al., 2003; Mazzzocchi, 2008). This method also has been used as a foundation of structural equation modelling in the multiple regression analysis. Moreover, it serves as multivariate technique for identifying the observed items' dimensions with broad aims to identify the number of factors and what the factors represent.

The expanded theory of planned behaviour framework is a new factor model which explains the original variable observation and its covariance between other variables. In the ETPB, variables are determined by a liner combination of factors which therefore consist the proposed series of assumptions. In this study, factor analysis is applied to confirm the dimensionality of constructs and establish the discriminant validity.

3.5.2.4 Structural Equation Model

Structural equation modelling (SEM) is a complex and powerful analytical technique for measuring relationship among unobserved variables since early 20th century (Shook et al., 2004). It is a statistical model that explains the relationships among multiple variables and examines the interrelationship structure by a series equation (Hair et al., 2006). As a combination of interdependence and dependence techniques, SEM is useful in giving rise to the interdependent nature of structural model when any dependent variable turned into independent variable (Hair et al., 2006).

SEM is a combination of two statistical methods: confirmatory factor analysis and path analysis. Path analysis begins with biometrics and aims to find relationship among variables by creating path diagram. The path diagram is created by Wright in 1920 for illustrating and test direct, indirect and total effects among observed variables. The combination of factor and path analysis is based on the general structural equation model outline which consisted of measurement models and structural models.

With nearly a century's development, the SEM became a very well-known and easy-use technique. Published literatures (e.g. Shook et al., 2004; Hair et al., 2006) have already summarised many different software packages (such as AMOS, LISREL, EQS) which could be used for computing SEM analysis. AMOS was used in this study due to its easy-learning and high-speed computation ability.

The one aim of this study is to develop a structural model of household water use behaviour change and explain the relationships between constructs in the intervention process. Another aim is to develop scales for each of the constructs in the ETPB and evaluate all constructs' reliability and validity, therefore, SEM was chosen as the main statistical technique for ETPB modelling.

The relationship between objective parameters and behaviour change mechanic was investigated using a Structural Equation Model with latent variables. SEM is widely used in psychology and other social sciences, although its properties are not clear when the model structure is complicated (Syme GJ et al., 2003; Bollen, K.A., 1989; Lohmoller, J.B., 1989; T. Raykov et al., 2006).

In SEM, the path analysis is a straightforward extension of multiple regression. It is an approach to simulate explanatory relationships between observed variables aiming to provide estimates of the magnitude. The multiple regression equation basis in SEM could be expressed by math equation which offers the possibility of behaviour simulation. Main characteristics for this method is that the path analysis does not contain any latent variables in which all simulated variables could be observed, and the independent variables are assumed to have no measurement error. Navarro-Barriento et al. (2011) noted that this path analysis simulation method could be effectively applied to simulate TPB behaviour change process. The mathematic expression of behaviour intervention theory in literature offers the fundamental modelling basis of dynamic behaviour intervention modelling.

A typical SME model consists of measurement and structural models. A new model should always be proposed based on some underlying theories. There are two types of relationships which could possibly exist among constructs: dependence relationship and correlation relationship. Dependence relationship is descripted by straight one-way arrows connected to exogenous and endogenous constructs. Correlation relationship is depicted by two-way arrow only connected among exogenous constructs.

SEM goodness-to-fit is assessed with various measures as below: x^2 (chi-square), goodness of fit index (GFI), root mean square error of approximation (RMSEA, ideal value is 0 and acceptable value is less than 0.8), comparative fit index (CFI, ranges from 0 to 1 with suggested scores less than 0.9), incremental fit index (IFI, also known as DELTA2), and Tucker-Lewis index

(TLI, also known as NNFI with ideal value 1 and the other value which close to this value indicates a good fit). The good-of-fit x^2 is very sensitive to sample size and the large chi-square value of CFA reveals a high degree of freedom. Cronbach alpha reliability coefficient is applied for testing construct reliability which ideal value is 1 and acceptable value is higher than 0.5. Validity test in CFA analysis stage using maximum likelihood method was conducted to test construct validity for proposed latent variables.

In this study, three SEM models were developed and tested which are original TPB model, TPB model with self-efficacy and ETPB model. The comparison of these three modelling results could be applied to test the predictive ability of different and the influence of introducing new construct in the TPB.

3.5.2.5 Mediation Analysis

In this study, mediation analysis is performed to understand two models exist: one is corresponding to unobservable relations among variables, and other is to investigate corresponding to statistical analyses of sampling data (MacCorquodale and Meehl, 1948). The Sobel test and bootstrapping method (with default N=1000 bootstrap resamples) were used to calculate the indirect effects. The Sobel test describes the mediator potency by creating the asymptotic standard error using multivariate delta method (Natalia López-Mosquera, 2014). Analysis process is performed by a SPSS-micro which offers an estimation of indirect effect and 95% Monte Carlo confidence interval with effect size measures (Hayes, 2013).

It has been widely discussed in previous researches about the limitations of standardized regression coefficient and raw correlation in analysing the indirect effect (see MacKinnon, 2008). Kristopher (2011) argued that effect size, "degree to which the phenomenon is present in the population or the degree to which the null hypothesis is false", is capable to measure the full meaning of an indirect effect and amenable to the construction of confidence intervals. Therefore, to test the indirect influence in our proposed model, all indirect effect size from past behaviour to four variables (attitude, PBC, Subjective norms and self-efficacy) were measured instead of using standard regression coefficients in previous research (Natalia López-Mosquera et al., 2014).

3.6 Dynamic Behaviour Intervention Modelling

Behaviour intervention can be defined as a program aiming to adjust behaviour for treating disease, promoting healthy lifestyle and enhancing well-being. The last decade has witnessed an increasing interest in applying statistical and computing modelling methods for problems in behavioural health, and using these to guide the design and implementation of intervention. To understand the dynamic intervention effect of behaviour change, Daniel et al. (2012) has stated control engineering concept could work as a new solution for simulating behaviour invention process. In current research, there are three main technologies and concepts from system identification and control system engineering which have been successfully applied in the behaviour intervention research, including: optimizing interventions by personalizing treatment through adaptation; access to longitudinal data through computing and mobile technologies, and behavioural theories modelling providing insights for strategy development.

Control engineering is a broadly applicable field which refers to the examination mechanism on how to influence a dynamical system to achieve desirable outcomes. Dynamical system could represent the time-varying process and lead the output changes. Access to intensive behaviour change data in the control system engineering solution enables the application of system identification with black-box model to input and output simulation result (Daniel et al., 2012). This has greatly improved the simulation ability of the behaviour intervention process. Engineering control principles also are applicable in the behaviour sciences that involve dynamic time-varying adaptive intervention. Control systems elements such as control error, controller and disturbance variable applied in the control design algorithms and computer simulations benefits the outcome optimization (Daniel et al., 2007). Examples for successful behavioural intervention in healthcare and well-being enhancement have proved control engineering concept could improve the dynamic simulation ability of the intervention (Daniel et al, 2007; Daniel et al., 2012). This research will use the control engineering concept as modelling basis to supervise dynamic behaviour intervention model development.

Rivera (2012) stated that control engineering and system identification could assist behavioural intervention optimization. Control systems engineering examines how to influence multivariate, time-varying and nonlinear dynamic systems to achieve a desired outcome. This control engineering could provide the dynamic system modelling solution needed to transform current behaviour intervention theories into the dynamic theories for time-intensive, interactive, and adaptive behaviour interventions. In serval behaviour intervention cases, the behavioural intervention based on TPB could be presentative by control engineering analogy such as “switch” or electricity flow (Rivera, 2012). Schwartz et al., 2006 proposed that fluid analogy could be solutions for simulating supply chain and solving modelling issues with inventory management and time change introductions. Navarro-Barrientos et al. (2011) applied this concept in their research for dynamic behavioural intervention modelling in the weight control area, and successfully introduced time series for behaviour modelling process. To capture the behavioural intervention over time, this study applied fluid analogy (Navarro-Barrientos et al., 2011) to understand the behaviour intervention process with concerned time change.

In the article reviewed by Daniel (2007), despite most dynamic control engineering modelling applications in behaviour intervention are on the healthcare domain, the methodology for developing dynamic model could still be used in water conservation behaviour research which summarised as below:

(1) Model identification. Depending on the modelling basis, the model identification is a procedure to identify the basic model element (output and input), model structure and model type.

(2) System identification. The system identification is to identify the mathematical expression and variables of the dynamic model. If the behavioural model is developed based on theory or models have clear structure and input/output, Structural Equation Model (SEM) is a very commonly used method to generate mathematical model expression.

(3) Dynamic system design. Using the control engineering method, the dynamic system has been transferred and understood as different processing unit in the modelling system. Through the control of different control units and the add/delete of fundamental control engineering terminals (such as control loop, black diagram or step point), the dynamic system could simulate the adaptive intervention process of behaviour change.

(4) Model evaluation. This is the process to identify the model prediction accuracy and efficiency.

3.7 Water Use Modelling

The water use modelling requires the application of analytical techniques, (likes the stochastic modelling, multi-variable regression and Bayesian networks) and household water use database for supporting that modelling work (Christopher Bennett et al., 2013). A lot of researches have presented that models for water use simulation and prediction are capable (Bradley Jorgensen et al., 2009; Corral-Verdugo, V. et al., 2002; Gregor, G. et al., 2003). Stochastic water use model for end-use studies are based on category frequency of use, demographics, event occurrence likelihood and flow duration to simulate water demand patterns have been developed by Blokker, Vreebury and Dijk (M. Blokker et al., 2010). Blokker used a Poisson rectangular pulse model derived from metering studies and surveys. This final model has achieved up to 93% accuracy compared to the truly metering data. Bayesian conditional framework and ANNs (Artificial neutral networks) have also been applied massively for the water end use modelling. Hsiao et al. (1995) used the Bayesian framework to develop a forecasting model for heating water and the residential water demand uses. The dummy variables and the transforming variables in this model are combined with aggregated loads, appliance ownership and demographic information. This study was applied to 396 households and with acceptable relative errors ranging from 0.081 to 0.298. Christopher Bennett and Rodney A. Stewart (Christopher Bennett et al., 2013) used the data from SEQ (South-east Queensland) in Australia (over 250 households' water end-use data) to build an ANNs model. The ANNs provide the technique for aligning the databases to extract the key determinants for different end-use category. Finally, their model had averaging error values of 0.52 for a household water demand.

Due to the uncertainty for introducing the behavioural process simulation into the water consumption prediction procedure, water consumption model concerned with behaviour intervention process will be a black box model. Cho (2003) compares ANN method, exponential smoothing, and autoregressive integrated moving average (ARIMA) to predict travel demand, i.e. number of arrivals. He concluded that ANN seems to be the best method for forecasting visitor's arrivals without obvious pattern. ANN method has advantages in requiring less formal statistical training data, ability to implicitly detect complex nonlinear relationships between dependent and independent variables, and the availability of multiple training algorithms (Tu, 1996). ANN evaluation result may be influenced by different model settings, such as node number and learning rate. However, for investigating a possible solution to integrate behaviour change process into water consumption prediction, ANN method has been proved capable for exploring the unknown relationship in practices.

3.8 Summary

By reviewing the literature, this Chapter so far has outlined several aspects to be considered when end use consumption studies are designed for behaviour change. The current water end use model cannot clearly understand behaviour change pattern and management strategies for behaviour intervention. The water end use model in this research by concerned behaviour change has also identified influence factors in literature are not sufficient to point out all subjective and objective parameters. Therefore, a water end use model based on behaviour intervention should consider behaviour intervention pattern and behaviour change parameters.

In the second part of this chapter, technological basis is discussed. TPB is applied as the theory support for behaviour simulation of water end use. With enough data training, ANN could generate the water end use consumption results by concerned behaviour interventions. Table 1 presents a summary of the methodology described in this chapter, indicates the approach chosen and justifies it with examples from the studies undertaken during this PhD research.

Table 1 Summary of the research methodology

Theme	Approach in this thesis	Explanation
Survey	Online and face-to-face questionnaire	The data collection has been designed into three stages. Questionnaire is designed based on TPB indirect and direct measurement method.
Statistical Analysis	Reliability and validity test CFA and EFA test for factor analysis	
ETPB	Theory proposed based on the review of water use behaviour literature. The final model is tested using SEM.	The whole theory structure has been tested including all correlation, and indirect influence for introducing new construct.
ETPB Dynamic Model	Control Engineer Concept, Fluid Analogy, Grey box system identification	The model is evaluated using data collected from China. System identification method is based on grey box system identification procedure.
ETPB-ANN Water Use Model	ANN	A ANN model is built to identify the link between behaviour and water use.

4. Data and Statistical Analysis

4.1 Introduction

Behavioural and water use data collection is the critical and fundamental part in this research. The data offers the first-hand evidence for all the theoretical and modelling test. The aim of this chapter is to present the statistical analysis results using the methods presented in Chapter 3 from data collected in China. The results are presented in association with different data quality and analytical themes concerned with sample characteristics, water use behaviour, reliability and validity analysis.

4.2 Sampling

This study has conducted three phases of sampling due to the different research needs. In 2014, a water use behaviour questionnaire and water usage survey have been conducted in LG district, SZ city for supporting the water consumption modelling. Out of 200 apartment households sampled in this study in SZ, China in 2013, only 128 apartments which had the monthly water consumption and sent back the fulfilled questionnaire. The questionnaire response rate for this research is 64%. Nine samples have been eliminated after being known collected from a short term or unstable living condition residents in the sampling year. In 2015, a national wide large scale online water use behaviour survey was conducted to collect water behaviour intervention modelling data for ETPB structure equation modelling use. From June 2014 - June 2015, ten households' annual water use data and long-term behaviour intervention data were collected to evaluate dynamic behaviour intervention model. Every three months, the ten households were invited to fulfil the indirect and direct measurement ETPB questionnaire. And monthly water consumption and direct measurement of ETPB variables were monitored for modelling use.

Prior to the survey, a pilot study based on face-to-face interview, was carried out on a sample of 23 subjects to ensure the validity of the questionnaire setting. This pilot study was refined through water conservation experts and residents' reviews to guarantee the validity and readability. SZ, which is facing critical water shortage and has high population mobility, was finally being chosen as a representative location for conducting pilot study. 84 face-to-face interviews with equal male and female quotas, carried out with respondents who have voluntarily chosen to complete questionnaire in the town centre. 13 questionnaires had to be removed due to the inconsistencies and incomplete data. On average, respondents took 8-17 minutes to complete the questionnaire with fully understanding of the content.

The afterwards face-to-face survey is conducted in Crape Myrtle Garden, sampled in this study is in the town centre of LG District, SZ, China. It was developed by Crape Myrtle Estate in 2002. This is a typical Chinese urban mature community with 1480 households and all the buildings are designed as seven floors apartment. Fig. 2 shows the location of sampled community. Out of 200 apartment households sampled in this study in SZ, China in 2013, only 128 apartments which had the monthly water consumption and sent back the fulfilled questionnaire to us. The questionnaire response rate for this research is 64%. In the targeted community of SZ, ten volunteer households were selected for monitoring long-term behaviour intervention data. Using ETPB questionnaire, every two months' behaviour data was collected via online survey. This long-term behaviour observation was started from June 2014 to June 2015.

Figure 2. Location of research area

The follow-up national wide data collection for this research was conducted from September 2014 to July 2015, using a survey service available via an online research company. The online data collection system was set with a submission decline which indicates uncompleted questions, thus, missing values will not occur in the dataset. Also, to increase honest responses, the internet survey was designed to offer an anonymous feeling with a preamble advising (Babbie, 2013). Before the respondents start to complete questionnaire, introduction of preamble advising which is mentioned the importance of this research and faithful reply, was given. Two criteria were set before the questionnaire being processed: the respondents should be over 18 years old and know very well about daily water use activity in their property. Evenly, 3,000 participants from four different regions list of China (East coast, Central China, Northeast China, Western China, excluding Hong Kong and Taiwan) represent, somewhat, to the of Chinese population, being sent invitations to fulfil questionnaire thorough the link via social media and email, leading to a final sample size with 417 respondents (13.9% response rate).

4.3 Social-demographics Characteristics

There are two scales data collection designed in this research due to the needs of modelling and theory test. The first scale data which contains water consumption and behavioural data is designed and used for water use model evaluation. And the second scale data which only has behavioural data is for ETPB theory evaluation and dynamic behavioural intervention model parameter identification. In this section, social-demographic characteristics for both two scales data are presented. The second scale data were used for water use behaviour understanding as it covers a much wider range of respondents.

The first scale data collection is done in an urban community in China. Out of 200 apartment households sampled in this study in SZ, China in 2013, only 128 apartments which had the monthly water consumption and sent back the fulfilled questionnaire to us. The questionnaire response rate for this research is 64%. Nine samples have been eliminated after been known collected from short time or unstable living condition residents in the sampling year. Analysis shows gender groups are evenly represented with 51% male and 49% female. The modal age group is 36-45 years old (30%) with 29% in the range of 25-35 years old, 22% in the range of 18 – 24 years old, 16% in the range of 46-55 years old and 3% older than 55 years old. With respect to level of education, 27% of respondents had attended senior high school, 52% had achieved and college or undergraduate education, 11% were from postgraduate background and 10% were from primary school background. There are 64 % responses are from 30K – 100K RMB/Y income range, 25% from 100K – 200K RMB/Y income range, 9% from 200K – 500K RMB/Y income range and 2% with income higher than 500K RMB/Y. As for the number of resident from survey family, there are 55% from house with three residents, 27% from house with four residents, 10% from house with five residents and 8% from house with less than three residents. As a typical family only has three residents, three household which participate long-term behaviour observation is from three residents' family with income level at 30K-100K RMB/Y. All three families are very positive for attending any environmental friendly activities and willing to conserve water from face-to-face interview result.

For the second internet survey, 3000 participants from different regions of China have been invited to complete the questionnaire for water use behaviour study. There are 417 responses have been used to test ETPB model. The sample results have showed almost equivalent numbers of male and female participants: 47.2% male respondents and 50.6% female respondents. The mean age is 37 years (standard deviation 18) with 39.7% high school education background responses. 71% respondents are from 30K – 100K RMB/Y income range, 13% from 100K – 200K RMB/Y income range, 8% from 200K – 500K RMB/Y income range and 3% with income higher than 500K RMB/Y (and 5% respondents preferred not to say anything about their income level). As for the number of resident per house participated the survey, there are 63% from household with three residents, 19% from household with four residents, 11% from household with five residents and 7% from household with less than three residents.

4.4 Mean Scores for ETPB Scales

In this section, mean scores are presented for the ETPB scale items. The mean score values are all from the second stage data collection.

General intention mean score is 2.450 with standard deviation value 1.313, which suggests that the general intention for Chinese residents attending water conservation activity is slightly positive (2 is the neutral value) but still there are some residents who showed good intention for the water conservation activities. The question for "I intend to engage in water conservation activities in the near future" score the highest mean point out of three intention questions is 2.793 (standard deviation 1.102). On the contrary, the item "I expect I will engage in everyday actions to save water around my property" scored the lowest point out of three questions which is 2.261 with standard deviation value 1.095. This suggests that even most residents willing to attend water conservation activity in the future but their intention for everyday water conservation actions is low which means everyday water conservation engagement may not very be welcomed in the study group.

The attitude mean score showed a relative high score than intention which is 2.458 with standard deviation value 1.029. This suggests there is a large number of respondents who think the water conservation activities are positively contribute to their life or environment. In the six attitude items, the question "Water

Table 2. Survey questions, reliability and validity test results

Scales	Mean (s.d.)	CR	AVE
Intention (α=0.886)	**2.450(1.313)**	**0.7765**	**0.7028**
I expect I will engage in everyday actions to save water around my property	2.261(1.095)		
I intent to engage in water conservation activities in the near future	2.793(1.102)		
I plan to conserve water around my property in the near future	2.367(1.461)		
I intent to encourage other people to engage in water conservation activities	2.533(1.362)		
Attitude (α=0.867)	**2.352(1.029)**	**0.7678**	**0.7913**
I think engage in water conservation activities is beneficial	2.297(1.632)		
I think engage in water conservation activities is valuable	2.794(1.184)		
I think engage in water conservation activities is pleasant	2.435(1.093)		
I think engage in water conservation activities is good	2.103(1.615)		
I think engage in water conservation activities is intelligent	2.333(1.567)		
I think engage in water conservation activities is necessary	2.349(1.494)		
Perceived behaviour control (α=0.951)	**2.458(2.928)**	**0.9451**	**0.7423**
To what extent do you feel capable of conserving water when the water price is high	4.326(1.939)		
To what extent do you feel capable of conserving water when it is inconvenient	4.164(1.834)		
To what extent do you feel capable of conserving water when you are in a rush	3.653(2.305)		
Subjective norms (α=0.915)	**4.190(1.802)**	**0.9861**	**0.9220**
People who are important to me think that I should conserve water	4.354(1.681)		
People who are important to me expect that I will conserve water	3.836(1.933)		
I feel like there is social pressure to conserve water	3.964(1.238)		
The people whose opinions I value would conserve water	4.262(1.768)		
Self-efficacy (α=0.984)	**3.909(1.927)**	**0.9455**	**0.8526**
For me to conserve water around my living place	2.635(2.387)		

is easy			
I am confident that I could save water around the house and garden if I want	2.244(2.108)		
The decision to save water around the house and garden is under my control	2.302(1.164)		
I have the time and skills needed for water conservation activities	2.713(3.152)		
Past behaviour (α=0.909)	**2.889(1.407)**	**0.9640**	**0.8173**
check and fix leaking tap in the last six months	2.876(1.884)		
use minimal water in kitchen in the last six months	2.941(1.801)		
collect rainwater to use in the last six months	2.352(1.364)		
turn off taps when brushing teeth in the last six months	2.319(1.298)		
have shorter showers (4 min or less) in the last six months	2.166(1.033)		
only run washing machine if it is full in the last six months	3.136(1.641)		
use water conservation equipment in the last six months	2.189(1.904)		
Water conservation behaviour (α=0.973)	**3.721(2.359)**	**0.9683**	**0.8595**
I reuse water	2.530(2.174)		
I apply numerous water conservation technology	2.237(2.091)		
I participate water conservation activities	3.983(1.882)		
I check and repair leakage	2.148(2.014)		
I follow the government water conservation policy	3.155(2.263)		

Note. C.R.: Composite reliability; AVE: The average variance extracted.

conservation activities are valuable" scored the highest point which is 2.794 which means most respondents slightly agreed with this statement. On the contrary, the item "water conservation activities are good" has the lowest mean score which is 2.103 with standard deviation value 1.615. All the mean scores for six attitude items are in a very close value and higher than 2 means that stands most participants have a positive attitude about the current water conservation activities and think engaging for these activities is positive.

Perceived behaviour control has a 2.458 mean score value with standard deviation value 2.928. It is the highest standard deviation score for ETPB items. The three PBC items mean scores varies from 3.653 (capability to conserve water in a rush) to 4.326 (capability to conserve water when water price is high). This suggests residents have different capabilities to conserve water in different situation. The water price is a good trigger for promoting water conservation projects which could potentially bring more participants to the water conservation activities. And the capability score is smaller when the residents are in an inconvenient and rush situation. To boot the water conservation project promotion, solutions or technologies which have abilities to control water use in these situations will be needed.

In case of the subjective norm, the four items all showed a mean score. Average mean score for subjective norm is 4.190 with standard deviation value 1.802. The biggest mean score for four subjective norm items is "people who are important to me think I should conserve water" suggesting the main subjective barrier for Chinese residential water conservation activities is from close people (family, friend or partner).

Mean score for self-efficacy is 3.909 with standard deviation value 1.927. Confidence value for saving water around house or garden is the lowest mean score out of four self-efficacy items which is 2.244 with standard deviation 2.108. Most respondents believe they have time and skills needed for water conservation and the mean score for this item is 2.713 with standard deviation 3.152 which is the highest mean score for all self-efficacy questions. This suggests the conflict of the water conservation skill and real application around property. Corresponding support from local authority for increasing the residential water conservation practical ability will be needed.

Past behaviour mean score achieved 2.889 with standard deviation value 1.407. In the survey result, we raised questions about six different water conservation behaviour in the past half year including collect rainwater, shorter shower, only run washing machine when it is full, turn off tap when brushing teeth, check and fix leaking tap and use minimal water in kitchen. Responses for the shorter shower took the smallest mean score out of six past behaviour questions which is 2.166 with standard deviation value 1.033 suggesting residents did not have very good habit to take shorter shower in water conservation purpose. On the contrary, the item "run washing machine if it is full" has the highest mean score which is 3.136 with standard deviation 1.641.

This study also directly measured the water conservation behaviour by five different water conservation items. Response from "I participate in water conservation activities" achieved the highest mean score which is 3.983 with standard deviation value 1.882 suggesting many residents have participated in water conservation projects. And the smallest mean score is "I apply numerous water conservation technology" which is 2.237 with standard deviation 2.091. This result is in line with the literature review in Chapter 2 and showed the current water conservation projects have a low adaption rate in the water conservation technologies. General average mean score for water conservation behaviour is 3.721 with standard deviation value 2.359 suggesting the respondents are positively involving water conservation activities.

4.5 Reliability

A reliable measurement gives the same measurements when the study is repeated either the objects or events unchanged. If a measuring instrument were reliable, it could have a positive correlation with the true scores. In this study, the internal consistency for all the ETPB constructs are measured by SPSS, the extent to which the items correlate will with one another. In SPSS, the scale if item deleted descriptive analysis is introduced to identify if delete any item could increase the reliability value to a tolerated level. From the reliability analysis result, all the reliability values for ETPB model are higher than 0.7 which reaches an acceptable level with good reliability. When testing the reliability, the corrected item-total correlation for PB7 (seventh item for past behaviour) showed a very low value which is 0.083 (less than 0.5). Scale variance if item is deleted increased to 0.968 and the reliability for past behaviour increased to an acceptable level, thus, the PB7 should be excluded in further analysis to pass reliability test. A summary for all the reliability test of ETPB model constructs is presented in Table 3.

Table 3. Reliability analysis for ETPB constructs

Construct	Item	Corrected Item Total Correlation	Scale Variance if Item Deleted	Cronbach's Alpha if item deleted
Past Behaviour	PB1	.849	.882	.909
	PB2	.914	.874	
	PB3	.898	.876	
	PB4	.809	.888	
	PB5	.865	.880	
	PB6	.891	.876	
	PB7	.083	.968	
Attitude	A1	.950	.957	.967
	A2	.847	.963	
	A3	.946	.957	
	A4	.711	.970	
	A5	.953	.957	
	A6	.779	.967	
	A7	.953	.957	
	A8	.804	.966	
Subjective Norm	SN1	.977	.988	.991
	SN2	.962	.990	
	SN3	.979	.988	
	SN4	.968	.989	
	SN5	.951	.990	
	SN6	.973	.989	
Self-Efficacy	SE1	.959	.981	.984
	SE2	.979	.967	
	SE3	.958	.981	
Intention	INT1	.792	.836	.886
	INT2	.814	.828	
	INT3	.878	.801	
	INT4	.534	.926	
PBC	PBC1	.854	.942	.951
	PBC2	.921	.934	
	PBC3	.880	.939	
	PBC4	.731	.955	
	PBC5	.904	.936	
	PBC6	.824	.946	
Water Conservation Behaviour	WU1	.897	.970	.973
	WU2	.929	.965	
	WU3	.915	.967	
	WU4	.950	.962	
	WU5	.915	.967	

4.6 Validity and Factor Analysis

There are three components for validity and factor analysis in SPSS. They are preliminary analysis for testing whether the parameters are suitable for factor analysis (validity test) or not. In this part, the SPSS could provide validity test result, significance value and degree of freedom information. The second part is the factor extraction. In this part, the SPSS provides extraction analysis information about the extent of what level the seven parameters explain the relationship. The third part dealing with information offered on SPSS is about the rotated component matrix analysis (also known as rotated factor matrix) which is a matrix of the factor loadings for each variable onto each factor. In three information, if any test cannot pass, the error item will be eliminated until all the three tests pass and fits factor analysis requirement.

4.6.1 Initial Preliminary Analysis

The construct validity of an operationalization is an extent to which it really manipulates. For the validity and factor analysis, the KMO (Kaiser-Meyer-Olkin) and Bartlett's Test of Sphericity (Snedecor & Cochran, 1983), which is a measure of sampling adequacy to check the case to variable ratio for the analysis being conducted. This method could test whether the correlation matrix is an identity matrix and show the validity and suitability of the responses collected to the water saving issue in this research. The accepted index for KMO is over 0.6 (KMO ranges from 0 to 1). And for recommended suitable factor analysis, the Bartlett's Test of Sphericity must be less than 0.05. All the validity tests are done using SPSS software. Bartlett's test result is showed in Table 4. As in the previous reliability test, the PB7 item cannot pass. In this section, the test will be done without using PB7. The result displays that the mean KOM value is higher than 0.7, therefore, all the parameters in the questionnaire are suitable for factor analysis. Large Chi-Square value of principal factor analysis reveals a high degree of freedom.

Table 4. Initial KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.842
Bartlett's Test	Approx. Chi-Square	12698.383
	df	703
	Sig.	.000

4.6.2 Initial Factor Extraction

SPSS factor analysis test also lists the eigenvalues associated with each factor before extraction, after extraction and after rotation. In all the three exams, the SPSS could identify seven factors, thus, the seven factors for ETPB model should all be included as variables for further analysis. The cumulative explanation rate for seven factors is 87.336%. The cumulative explanation rate (from introducing 1 factor to 7 factors) in three different extraction analysis methods is shown in Table 5.

Table 5. Initial Factor Extraction

Rotation Sums of Squared Loading			Extraction Sums of Squared Loadings			Initial Eigenvalues			Component
Cumulative %	% of Variance	Total	Cumulative %	% of Variance	Total	Cumulative %	% of Variance	Total	
17.598	17.598	6.687	28.23	28.23	10.727	28.23	28.23	10.727	1
33.146	15.547	5.908	43.853	15.624	5.937	43.853	15.624	5.937	2
47.099	13.954	5.302	58.276	14.423	5.481	58.276	14.423	5.481	3
60.222	13.123	4.987	70.894	12.618	4.795	70.894	12.618	4.795	4
72.631	12.409	4.715	77.388	6.494	2.468	77.388	6.494	2.468	5
80.13	7.499	2.85	82.9	5.512	2.095	82.9	5.512	2.095	6
87.336	7.206	2.738	87.336	4.436	1.686	87.336	4.436	1.686	7

4.6.3 Initial Factor Rotation

The rotated factor matrix shows communalities information before and after extraction. There are several points to consider about this matrix. In the factor loading matrix, the factor loading value for an item in its own demission should be higher than 0.5. The value for this item in other demission should be smaller than 0.2. The higher difference of factor loading value and other demission the better test result for discriminant validity. In Table 6, the INT4 (the fourth item for intention) did not fit this requirement and should be eliminated from the validity test result.

Where PB stands for Past Behaviour; A is the short of Attitude; INT stands for intention, PBC is the Perceived Behaviour Control; WCB is Water Conservation Behaviour. The sequence of items for different variable fits the sequence in Table 3.

Table 6. Initial Rotated Factor Matrix

	Component						
	1	2	3	4	5	6	7
PB1			.893				
PB2			.952				
PB3			.913				
PB4			.847				
PB5			.878				
PB6			.938				
A1	.950						
A2	.883						
A3	.947						
A4	.739						
A5	.953						
A6	.805						
A7	.955						
A8	.851						
SN1		.966					
SN2		.954					
SN3		.967					
SN4		.962					
SN5		.944					
SN6		.967					
SE1						.923	
SE2						.929	
SE3						.918	
INT1							.810
INT2							.816
INT3							.873
INT4				.362	.403		.508
PBC1				.847			
PBC2				.914			
PBC3				.893			
PBC4				.761			
PBC5				.885			
PBC6				.845			
WCB1					.882		
WCB2					.948		
WCB3					.899		
WCB4					.961		
WCB5					.938		

4.6.4 Validity and Factor Analysis without INT 4

As the INT4 cannot pass the test in rotated factor matrix, the three tests then should be redone to check all the validity and factor analysis information without INT 4. Still, without INT 4, the KMO test value is higher than 0.6 which suggests all the items and variables are suitable for performing factor analysis. The KMO and Bartlett's test without INT 4 is showed in Table 7.

The cumulative explanation rate for seven factors is 88.178%. The cumulative explanation rate (from introducing 1 factor to 7 factors (without INT 4)) in three different extraction analysis methods are showed in Table 8. The rotated factor matrix without INT 4 is showed in Table 9 which suggests all the items passed the validity test with factor loading value higher than 0.5.

Again, after the rotation, the AVE (Average Variance Extracted) and C.R. (Composite Reliability) were tested to confirm the validity test outcome. Table 10 presents the AVE and C.R. test results. The test result indicated all reliability values were greater than suggested threshold of 0.60. As an assessment of the validity of the measures, factor loading within all the indicators, AVE (average variance extracted), and construct correlation were calculated. The result indicated an adequate convergent validity with all factor loading values, AVE, CR were above 0.5, 0.6 and 0.7 respectively. All the tests showed the data has passed the reliability and validity tests, and is suitable for structure equation modelling analysis.

The factor analysis (Exploratory Factor Analysis) has tested the correlations for different variable in the ETPB model. And through the test, two question items have been eliminated to meet the model validity requirement.

Table 7. KMO and Bartlett's test without INT 4

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.845
Bartlett's Test	Approx. Chi-Square	12492.597
	df	666
	Sig.	.000

Table 8. Factor Extraction without INT 4

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loading		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.466	28.286	28.286	10.466	28.286	28.286	6.664	18.011	18.011
2	5.918	15.994	44.281	5.918	15.994	44.281	5.906	15.963	33.974
3	5.461	14.759	59.04	5.461	14.759	59.04	5.271	14.245	48.219
4	4.619	12.483	71.523	4.619	12.483	71.523	4.9	13.242	61.461
5	2.46	6.648	78.171	2.46	6.648	78.171	4.568	12.345	73.806
6	2.088	5.643	83.814	2.088	5.643	83.814	2.842	7.682	81.488
7	1.615	4.364	88.178	1.615	4.364	88.178	2.475	6.69	88.178

Table 9. Rotated Factor Matrix without INT 4

Rotated Factor Matrix

	Component						
	1	2	3	4	5	6	7
PB1			.892				
PB2			.952				
PB3			.914				
PB4			.848				
PB5			.876				
PB6			.938				
A1	.951						
A2	.883						
A3	.949						
A4	.741						
A5	.954						
A6	.805						
A7	.956						
A8	.851						
SN1		.966					
SN2		.955					
SN3		.967					
SN4		.962					
SN5		.944					
SN6		.967					
SE1						.923	
SE2						.929	
SE3						.918	
INT1							.832
INT2							.836
INT3							.847
PBC1				.849			
PBC2				.917			
PBC3				.897			
PBC4				.759			
PBC5				.890			
PBC6				.848			
WCB1					.883		
WCB2					.948		
WCB3					.901		
WCB4					.962		
WCB5					.939		

Table 10. AVE value for latent variables after rotation

Component	Item	Factor Loading	AVE	CR
Past Behaviour	PB1	.892	. 8173	. 9640
	PB2	.952		
	PB3	.914		
	PB4	.848		
	PB5	.876		
	PB6	.938		
Attitude	A1	.951	.7913	.9678
	A2	.883		
	A3	.949		
	A4	.741		
	A5	.954		
	A6	.805		
	A7	.956		
	A8	.851		
Subjective Norm	SN1	.966	.9220	.9861
	SN2	.955		
	SN3	.967		
	SN4	.962		
	SN5	.944		
	SN6	.967		
Self-efficacy	SE1	.923	.8526	.9455
	SE2	.929		
	SE3	.918		
Intention	INT1	.832	. 7028	. 8765
	INT2	.836		
	INT3	.847		
PBC	PBC1	.849	.7423	.9451
	PBC2	.917		
	PBC3	.897		
	PBC4	.759		
	PBC5	.890		
	PBC6	.848		
Water Use Behaviour	WU1	.883	. 8595	. 9683
	WU2	.948		
	WU3	.901		
	WU4	.962		
	WU5	.939		

4.7 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is a statistical technique applied to verify factor structure. Confirmatory factor analysis is a tool that is used to confirm or reject the measurement theory. Hair et al. (2003) noted that factor analysis can be computed via either an exploratory or confirmatory perspective. But in the Exploratory Factor Analysis (EFA), data is simply explored and it provides information about the numbers of factors needed to represent data, and all measured variables are related to latent variable. Hair et al (2003) defined the usage of six-stage decision making process when applying SEM in research use. According to this six-stage theory, CFA is commonly used to cover all the fundamental construct statistical analysis from construct definition to model validity assessment.

CFA is a way for testing how well measured variables represent a smaller number of constructs (Hair et al., 2006). Using CFA must specify the number of factors within set variables and the factors will load highly before results are computed. Hair et al. (2003) noted that CFA is a tool which could identify how well the factor fits real data and has been used massively for testing preconceived theory. The measurement for preconceived theory is to specify how well the measured items match the construct sets. CFA provides solutions to estimate those relationships between constructs to variables and relationship among construct (Hair et al., 2006) therefore, CFA could be applied for testing theoretical foundation when needed.

After the screening of the above factor analysis, a CFA test is conducted to cross-validate the current structure and test the ETPB model fitness. As the ETPB model is based on the empirical study and published theories, a confirmatory factor analysis using maximum likelihood method was conducted to confirm and test the proposed theory and structure.

A CFA test for the original TPB model (model 1) with attitude, PBC and subjective norms was initially conducted. The first CFA showed a good fit of the structural equation modelling (x^2= 837.347, df=335, GFI=0.768, RMSEA=0.089, IFI= 0.950, TLI= 0.943, CFI= 0.949). Another CFA test for TPB model with external construct – self-efficacy (model 2) also exhibited good psychometric properties (x^2= 957.463, df=414, GFI=0.763, RMSEA=0.083, IFI= 0.951, TLI= 0.944, CFI= 0.951), followed by a good CFA fit test result from the proposed ETPB (model 3) which contains past behaviour and self-efficacy as external constructs (x^2= 1310.423, df=603, GFI=0.735, RMSEA=0.079, IFI= 0.945, TLI= 0.939, CFI= 0.945).

4.8 Summary

In this Chapter, the sampling data has been tested regarding reliability and validity. And the test was successful by eliminating the two question items from the survey. Exploratory Factor Analysis (EFA) (section 4.5) and Confirmatory Factor Analysis (CFA) are also presented to test the model structure and confirm if there is any confliction between different constructs. The test result has showed that current questionnaire and data are suitable for SEM analysis and there is no conflict in the construct settings in this pre-model evaluation process. The processed data is ready for further model test use.

5. Expanded Theory of Planned Behaviour

Based on the data analysis result in Chapter 4, the ETPB model and its internal relationship are tested and presented in this section. Three models (Model 1: original TPB; Model 2: TPB with self-efficacy; model 3: ETPB) have been developed using structure equation modelling method. And the finding suggested adding two additional constructs in the TPB structure could improve the prediction power of this behaviour intervention theory. Also, the role of self-efficacy and PBC, the role of past behaviour and the indirect effects of past behaviour are presented and analysed in this chapter to identify what is the influence for introducing external constructs to the TPB structure.

5.1 ETPB Architecture

As discussed in Chapter 3, the Past Behaviour and Self-efficacy should be included in the TPB for improving the prediction ability. Taking into account the original TPB predictor variables: a) attitude which reflects individual's positive/negative appraisal towards a target behaviour; b) subjective norm, the perceived external/social pressure to engage or not in a behaviour; c) Perceived Behavioural Control (PBC) reflects perceived ease/difficulty for target behaviour performance, this research added d) past behaviour which refers to the degree to value the former behaviour towards precise purpose; and e) self-efficacy, the extent or strength to people's belief in their abilities to perform a behaviour, in TPB framework as an extension version to understand how Chinese residential water conservation behaviour changes. Fig. 2 depicts the proposed Expanded Theory of Planned Behaviour (ETPB). By following the general rule of TPB behavioural hypothesis, with more positive attitude, greater PBC and subjective norm will strengthen the individual' intention to perform a behaviour, thus, hypothesis of ETPB were as follows:

H1. As attitudes towards water conservation became more positive, the residential intention to save water and adopt conservation activity increased.

H2. As subjective norm towards water conservation increased, the residential intention to save water and adopt conservation activity increased.

H3. As PBC towards water conservation increased, the residential intention to save water and adopt conservation activity increased.

H4. As self-efficacy about water conservation became more positive, a residential intention to save water and adopt conservation activity increased.

H5. As past behaviour towards water conservation became more positive, the residential attitude, subjective norm, PBC and self-efficacy on intention towards water saving increased.

H6. As the controlling of past behaviour about water conservation increased, a result of attenuating influence of attitude, subjective norms, PBC and self-efficacy on intention increased.

Finally, not only for the direct effects of past behaviour on water conservation intention but also the indirect effect that between TPB variables will be investigated. Thus, we hypothesized that

H7. Past behaviour indirectly influences water conservation intention through TPB variables (attitude, PBC and Subjective norms).

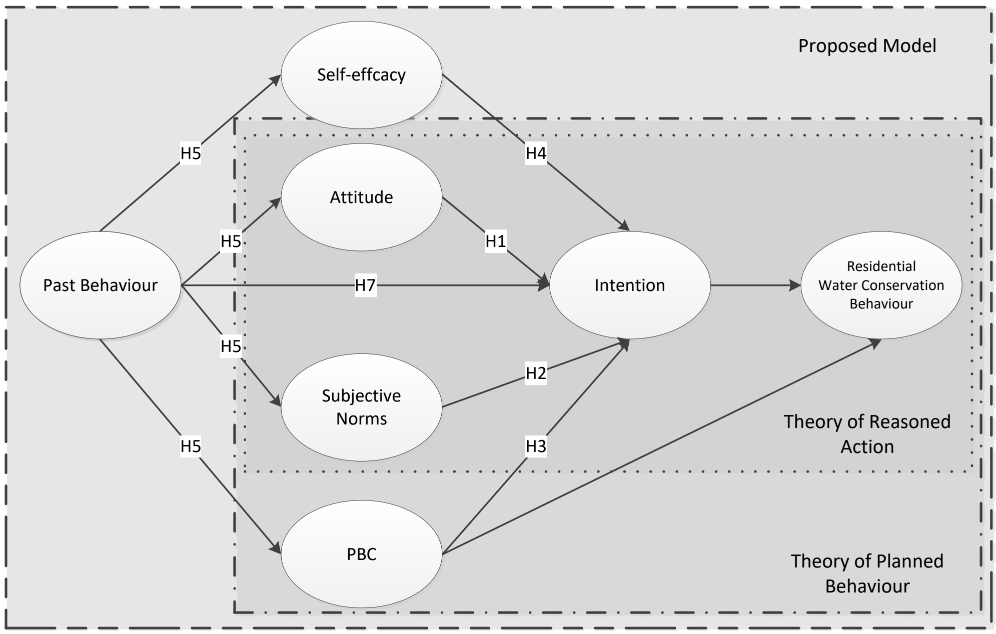
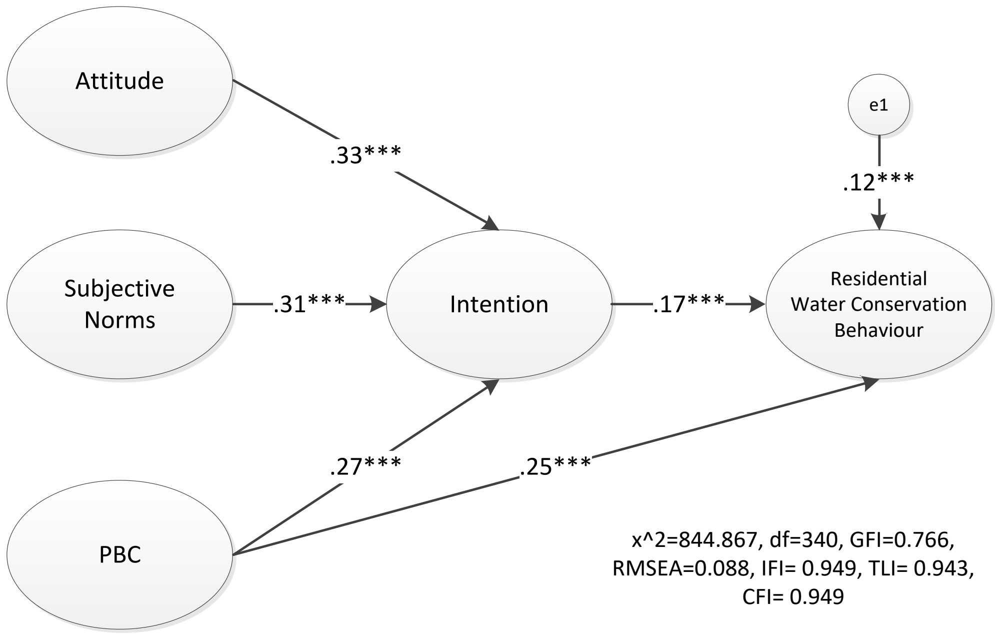


Figure 3. ETPB model for residential water conservation behaviour based on TRA and TPB

5.2 ETPB Evaluation

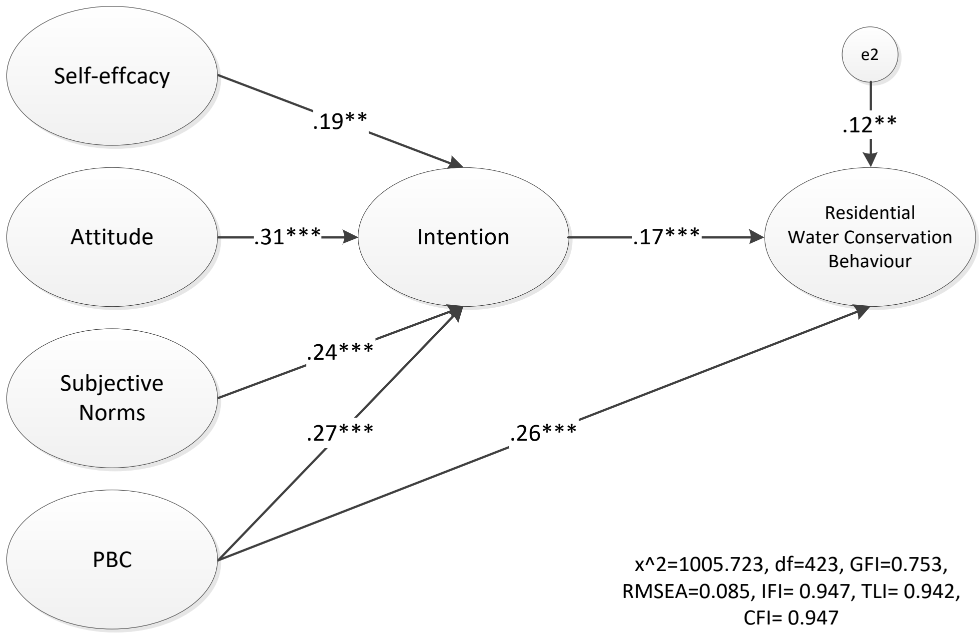
The hypotheses 1, 2 and 3 were initially tested by original TPB structural model (model 1, see Fig. 4) which has a satisfactory model fit (x^2= 844.867, df=340, GFI=0.766, RMSEA=0.088, IFI= 0.949, TLI= 0.943, CFI= 0.949) and all standardized regression coefficients were significant at 0.01 level. Based on the coefficients in the equation, the three antecedent variables (see Fig. 4) explained about 28% variance of intention and the four TPB variables (including intention) contributed 39% variance percentage for predicting water conservation behaviour. The regression paths from PBC (β=0.273, t=4.319, $p< 0.01$), subjective norms (β=0.235, t=3.710, $p< 0.01$) and attitude (β=0.293, t=4.600, $p< 0.01$) to intention were significant, therefore, H1, H2 and H3 are accepted. The finding aligned with previous studies (Lam,1999; Lam, 2006; Clark and Finley, 2007; Hurlimann, 2009; Gilg and Barr, 2006) indicating that an increase in water conservation attitude, subjective norms and PBC will result in an increase in the residential willingness to conserve more water.

An augmented version of the TPB was tested by model 2 to determine the influence of self-efficacy as a predictor of residential water conservation behaviour. The TPB model with external construct self-efficacy (model 2, see Fig. 5.) has a good model fit as well (x^2= 1005.723, df=423, GFI=0.753, RMSEA=0.085, IFI= 0.947, TLI= 0.942, CFI= 0.947). All the structural standardized coefficients are significant and self-efficacy appears to have an attenuation influences on the model 1 relationship, where regression paths from PBC (β=0.223, t=2.443, p< 0.01), Subjective norms (β=0.212, t=3.157, p< 0.01) and attitude (β=0.264, t=4.129, p< 0.01) to intention decreased. Self-efficacy (β=0.168, t=2.443, p< 0.01) was found to be positively and significantly associated with intention which confirmed the H4, and self-efficacy explained 12% variance of intention with the water conservation behaviour explained by all five variables was 43%.



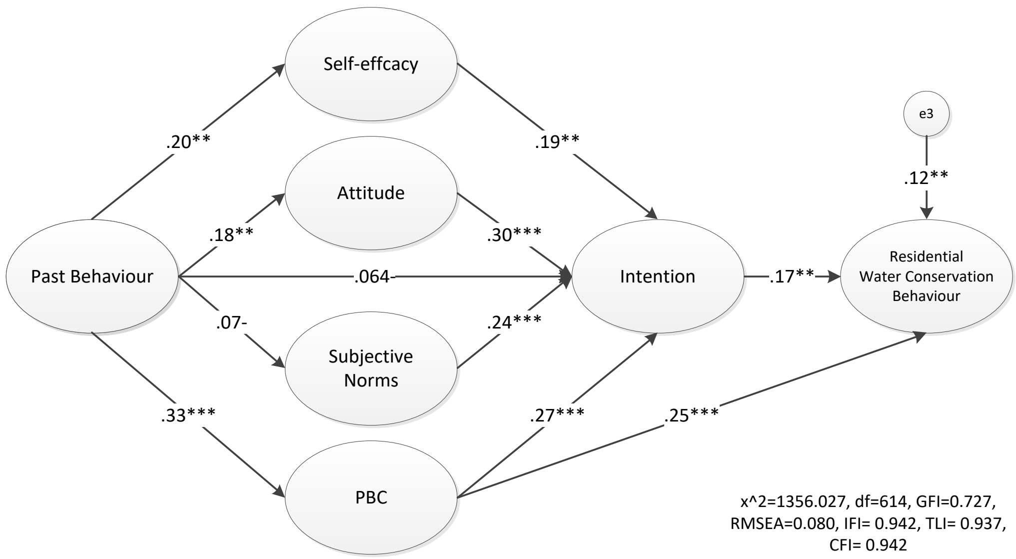
***p < 0.01; **p < 0.05; ¯p >0.05.

Figure 4. TPB (Model 1) Structural Equality Model explaining water conservation behaviour (Standardized Solution Values)



***p < 0.01; **p < 0.05; ¯p >0.05.

Figure 5. TPB with self-efficacy (Model 2) Structural Equality Model explaining water conservation behaviour (Standardized Solution Values)



***p < 0.01; **p < 0.05; ¯p >0.05.

Figure 6. Proposed ETPB (Model 3) Structural Equality Model explaining water conservation behaviour (Standardized Solution Values)

The proposed model (model 3, see Fig. 6) provided a satisfactory fit (x^2= 1356.027, df=614, GFI=0.727, RMSEA=0.080, IFI= 0.942, TLI= 0.937, CFI= 0.942). The majority of the structural regression coefficients are again significant ($p<0.01$), apart from the past behaviour to subjective norms ($p>0.05$). H5 was tested. Results showed that past behaviour has a positive influence on water conservation intention (β=0.196, t=2.757, $p< 0.01$), attitude (β=0.179, t=2.502, $p< 0.05$), PBC (β=0.380, t=5.468, $p< 0.01$), self-efficacy (β=0.302, t=3.104, $p< 0.01$) and subjective norms (β=0.076, t=1.053, $p> 0.05$), thus, H5 was partially confirmed. In order to examine H6, the 95% confidence intervals ($CI_{0.95}$) for standardized coefficients (Hagger et al., 2001a) was performed in model 2 and model 3. An overlap occurred for the confidence intervals in model 2 and model 3, and no significant attenuation of model relationships was showed as a result of the past behaviour inclusion, therefore H7 is rejected. In the proposed model, all the variables (past behaviour, subjective norm, PBC, intention and attitude) accounted for 49% of the variance in water conservation behaviour.

5.3 The Role of Self-efficacy and PBC

In previous research, studies have already pointed out that using principal components factor analysis method could identify the distinction between PBC and Self-efficacy. In this research, the principal components analysis

(KMO value = 0.845, Chi-square = 929.538, df=21, $p<0.001$) with factor matrix rotation produced PBC and self-efficacy as showed in Table 11. PBC is significantly related to the external beliefs such as water price and in the inconvenient water use circumstance. Self-efficacy is not associated with these items, but with the belief related to confidence to save water and control of water conservation decision making. The result provided evidence to discriminate validity between the two conceptualizations of control. In Fig. 6, it also showed that the inclusion of self-efficacy in the original TPB model did not attenuated the relationship between PBC and intention, which indicated the variance that PBC shares with intention is not accounted for by self-efficacy. This supports the findings that have made the distinction between self-efficacy and PBC in water conservation application.

Table 11. Distinguishing self-efficacy in TPB: rotated factor matrix for principal components analysis

Items	Factor Loading	
	PBC	**Self-efficacy**
To what extent do you feel capable of conserving water when the water price is low	0.862	0.268
To what extent do you feel capable of conserving water when it is inconvenient	0.881	0.216
To what extent do you feel capable of conserving water when you are in a rush	0.790	0.304
For me to conserve water around my living place is easy	0.372	0.659
I am confident that I could save water around the house and garden if I want	0.397	0.861
The decision to save water around the house and garden is under my control	0.194	0.847
I have the time and skills needed for water conservation activities	0.235	0.763

5.4 The Role of Past Behaviour

In this study, mediation analysis is performed to understand two models: one is corresponding to unobservable relations among variables, and other is to corresponding to statistical analyses of sampling data (MacCorquodale and Meehl, 1948). The Sobel test and bootstrapping method (with default N=1000 bootstrap resamples) were used to calculate the indirect effects. The Sobel test describes the mediator potency by creating the asymptotic standard error using multivariate delta method (Natalia López-Mosquera, 2014). Analysis process is performed by a SPSS-micro which offers an estimation of indirect effect and 95% Monte Carlo confidence interval with effect size measures (Hayes, 2013).

It has been widely discussed in previous researches about the limitations of standardized regression coefficient and raw correlation in analysis of the indirect effect (see MacKinnon, 2008). Kristopher (2011) argued that effect size, “degree to which the phenomenon is present in the population or the degree to which the null hypothesis is false”, is capable of measuring the full meaning of an indirect effect and amenable to the construction of confidence intervals. Therefore, to test the indirect influence in our proposed model, all indirect effect size from past behaviour to four variables (attitude, PBC, Subjective norms and self-efficacy) were measured instead of using standard regression coefficients in previous research (Natalia López-Mosquera et al., 2014).

The finding in Table 12 revealed that past behaviour did not show significantly effect on water conservation intention through Subjective norms. All the other indirect influences relationship from past behaviour to intention were significant, thus, H7 was partially confirmed. The bootstrap results also reveal that all the significant indirect effects are trusted between zero for the predicted confidence intervals except from relationship of “past behaviour → Subjective norms → water conservation intention”. These findings indicated that residential past water conservation behaviour has significant mediating role in the relationship between Subjective norms and water conservation intention.

Table 12. Indirect effects analysis

Independent variable	Mediator	Dependent variable	Effect size	se	Mediation confidence interval	
					Lower	Upper
Past Behaviour	Attitude	WCI	0.0554**	0.0303	0.0147	0.1404
Past Behaviour	PBC	WCI	0.0857***	0.0446	0.0194	0.1996
Past Behaviour	Subjective Norms	WCI	0.0230-	0.0238	-0.0260	0.0680
Past Behaviour	Self-efficacy	WCI	0.0620**	0.0253	0.0209	0.1253

***p < 0.01; **p < 0.05; ⁻p >0.05.

5.5 Summary

Little research has focused on development of residential water conservation decision-making process. The current study provided an understanding of residential water conservation intention to perform a conservation behaviour by incorporating two constructs: frequency of past water conservation behaviour and self-efficacy into the original TPB model. The proposed Expanded Theory of Planned Behaviour (ETPB) was tested using three SEMs, which showed that this model could offer a useful and effective framework to analyse the inter-relationship existing between TPB variables (attitude, intention, subjective norm and PBC), past behaviour and self-efficacy. In the same way, the proposed model benefits in the identification of how these two new constructs (past behaviour and self-efficacy) influence on original TPB relationship. This study represents, for the first time, the analysis of indirect influence of past behaviour on residential water conservation intention in the ETPB framework, therefore, may be helpful for related water conservation research and public decision-making process.

The study findings hold both theoretical and practical implications. First, the finding indicated that the proposed model supports the prediction of Chinese residential water conservation intention. The modelling comparisons showed that the proposed model represents a substantial improvement over the TPB (model 1) and TPB with self-efficacy (model 2). Second, this study found that past water conservation behaviour and self-efficacy have a significant positive association with water conservation intention. Also, it is the internal aspects of control in the face of barriers (self-efficacy) with PBC that reflects external barriers control that affect Chinese residential water conservation intentions. The findings suggested that governments should provide a good education and environment for residents to participate the water conservation activities involved in policy promotion, which will foster personal improvement and competence. With regard to PBC, Blanke et al. (2007) argued that policy supporting institutions should provide in some case financial assistance and coordination to help resident conquer external barriers.

Third, as showed in Table 12, this study indicated that among the four mediator variables in proposed model, only subjective norms cannot significantly mediate the impact of past behaviour on water conservation intention. This finding implied that past behaviour shapes attitude, self-efficacy and PBC towards a behaviour, and these enhance residential water conservation decision. Accordingly, water conservation project managers should consider the residential water conservation background areas before starting to promote and install water conservation technologies. It is suggested that water conservation technologies should fit past residential water conservation background (behaviour). For example, if residents in an area have a long-term habit to take short shower, the corresponding technologies to enhance shorter shower time will be easier to gain success in the case. And the development of more effective water conservation strategies is essential to improve their residential experiences while participating in a project.

Fourth, the present study is, the first to examine the past behaviour influence on residential water conservation intention, attitude, PBC, subjective norms and self-efficacy. The Control of past water conservation behaviour did not attenuate the influence of TPB relationship and self-efficacy which is consistent with Hagger et al.'s (2001a, 2001b) finding, but contrary to the previous studies (see examples Yordy, 1993; Norman et al., 2000). The lack of social cognitive attenuation influence by past behaviour suggests that past water conservation behavioural engagement does not have the similar cognitive-reducing influences on residential water conservation intentions that reported in literature. One of the reason may be that most Chinese residents do not have organized past behavioural patterns as developed countries.

6. ETPB Dynamic Behaviour Intervention Modelling

In statistics, mathematic and computational modelling, a grey box model is a model combines partial theoretical structure with data to complete the model. The theoretical structure varies from information, theory or only parameters from literature. In this study, the theoretical structure is based on validated ETPB model. It is opposed to the black box model where no model or structure is assumed and different from white box model which is purely theoretical.

In this chapter, the dynamic ETPB model based on ETPB theory is simulated and tested using data from ten voluntary households. As a grey box model, the inputs of ETPB dynamic behaviour intervention model were replicated, and the internal model parameters were estimated via a grey-box system identification procedure in MATLAB.

6.1 ETPB Structural Equation Model

Based on the proposed ETPB theory, the behavioural intervention process is simulated via dynamic behaviour intervention modelling technique. In this section, the extrapolation details for dynamic behaviour intervention model will present which include SEM expression and dynamic model.

For the ETPB SEM, path analysis model chose a vector η and endogenous variables and a vector ξ of exogenous variables is expressed as follows:

$$\eta = B\eta + \Gamma\xi + \varsigma \tag{2}$$

$$\begin{bmatrix}\eta_1\\\eta_2\\\eta_3\\\eta_4\\\eta_5\\\eta_6\\\eta_7\end{bmatrix} = \begin{bmatrix}0&0&0&0&0&0&0\\\beta_{21}&0&0&0&0&0&0\\\beta_{31}&0&0&0&0&0&0\\0&0&0&0&0&0&0\\\beta_{51}&0&0&0&0&0&0\\0&\beta_{62}&\beta_{63}&\beta_{64}&\beta_{65}&0&0\\0&0&0&0&\beta_{75}&\beta_{76}&0\end{bmatrix}\cdot\begin{bmatrix}\eta_1\\\eta_2\\\eta_3\\\eta_4\\\eta_5\\\eta_6\\\eta_7\end{bmatrix} + \begin{bmatrix}1&0&0&0&0\\0&\gamma_{22}&0&0&0\\0&0&\gamma_{33}&0&0\\0&0&0&\gamma_{44}&0\\0&0&0&0&1\\0&0&0&0&0\\0&0&0&0&0\end{bmatrix}\cdot\begin{bmatrix}\xi_1\\\xi_2\\\xi_3\\\xi_4\\\xi_5\end{bmatrix} + \begin{bmatrix}0\\\varsigma_2\\\varsigma_3\\\varsigma_4\\\varsigma_5\\\varsigma_6\\\varsigma_7\end{bmatrix} \tag{3}$$

Where B and Γ are β_{ij} and γ_{ij}'s matrices regression weights, respectively, and ς_i is a vector of disturbance variables. η_i stands for influence factors towards targeted behaviour. The ETPB path analysis model for equation (3) is showed in Fig. 7. For simplicity and without loss of generality, only one exogenous variable exists in each compartment. Thus,

$$\eta_1 = \xi_1 \tag{4}$$

= the degree to value the former behaviour towards precise purposes

$$\xi_2 = b_1 \times e_1 \tag{5}$$

= strength of beliefs about the outcome × evaluation of the outcome;

$$\xi_3 = n_1 \times m_1 \tag{6}$$

= normative beliefs × motivation to comply;

$$\xi_4 = c_1 \times p_1 \tag{7}$$

= strength of each control belief × perceived power of control factors.

$$\eta_5 = \xi_5 \tag{8}$$

= strength to people's belief in their abilities to complete the goal

Where b_i is the set for behaviour belief value, e_i is the set of evaluation of outcome. n_i the normative belief set, m_i is the set for motivation to comply value, c_i is the set of control belief, p_i is the set of power of control belief.

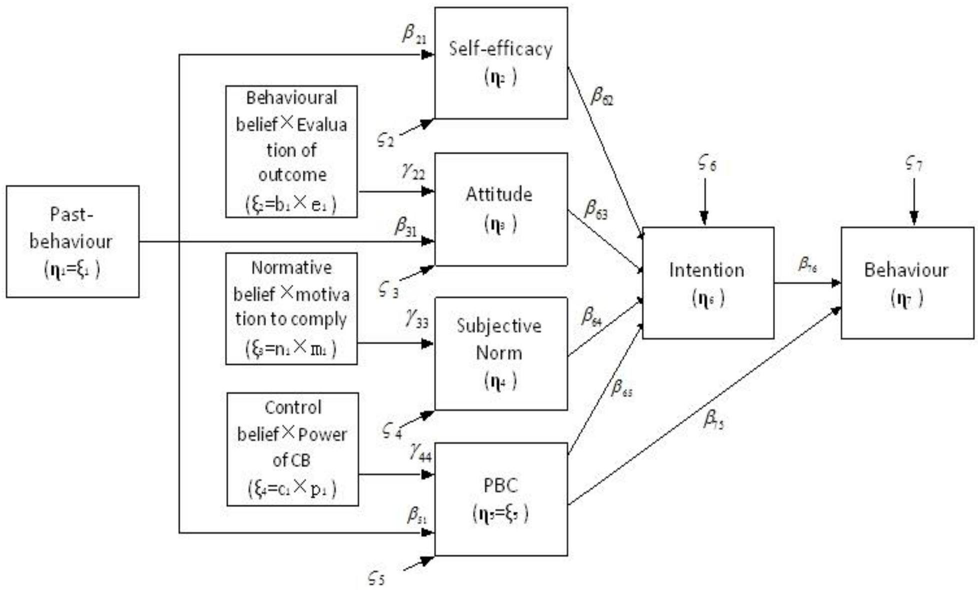


Figure 7. ETPB path diagram with five exogenous variables ξ_i, seven endogenous variables η_i, regression weights β_{ij} and γ_{ij} and disturbance ζ_i.

6.2 Dynamic Fluid Analogy for ETPB

Using multi-regression as foundation, path analysis only could represent a static system which is not capable of capturing any changing behaviour over time.

The water flow/fluid analogy for this study is expressed in this section in Fig. 8.

The TPB model parameters were sorted into five inventories: attitude, subjective norm, PBC, intention and behaviour and presented as five different water tanks. All tanks are replenished and depleted by flow which stands for mathematical equation balance details and the tank storage status is the direct measured ETPB value. The behaviour intervention path model coefficients γ_{ij} and β_{ij} are inflow/outflow resistances. Generally, the behaviour intervention process of ETPB could be expressed by the accumulation equation of different flow tanks:

'Water Tank' Accumulation = Fluid Inflow – Fluid Outflow (9)

system time delay for Equation (6) leads to a system of differential equations accordingly:

$$\eta_1 = \xi_1(t) = \beta_{21}\eta_1(t-\theta_1) + \beta_{31}\eta_1(t-\theta_2) + \beta_{51}\eta_1(t-\theta_3) + (1-\beta_{21}-\beta_{31}-\beta_{51})\eta_1(t)$$

(10)

$$\tau_2\frac{d\eta_2}{dt} = \beta_{21}\eta_1(t-\theta_1) + \gamma_{22}\xi_2(t-\theta_4) - \beta_{62}\eta_2(t-\theta_8) - (1-\beta_{62})\eta_2(t) + \zeta_2(t)$$
$$= \beta_{21}\eta_1(t-\theta_1) + \gamma_{22}\xi_2(t-\theta_4) - \beta_{62}\eta_2(t) + \zeta_2(t)$$

(11)

$$\tau_3\frac{d\eta_3}{dt} = \beta_{31}\eta_1(t-\theta_2) + \gamma_{33}\xi_3(t-\theta_5) - \beta_{63}\eta_3(t-\theta_9) - (1-\beta_{63})\eta_3(t) + \zeta_3(t)$$
$$= \beta_{31}\eta_1(t-\theta_2) + \gamma_{33}\xi_3(t-\theta_3) - \beta_{63}\eta_3(t) + \zeta_3(t)$$

(12)

$$\tau_4 \frac{d\eta_4}{dt} = \gamma_{44}\xi_4(t-\theta_6) - \beta_{64}\eta_4(t-\theta_{10}) - (1-\beta_{64})\eta_4(t) + \zeta_4(t)$$
$$= \gamma_{44}\xi_4(t-\theta_6) - \beta_{64}\eta_4(t) + \zeta_4(t)$$

(13)

$$\tau_5 \frac{d\eta_5}{dt} = \beta_{51}\eta_1(t-\theta_3) + \gamma_{55}\xi_5(t-\theta_7) - \beta_{65}\eta_5(t-\theta_{11}) - \beta_{75}\eta_4(t-\theta_{13}) - (1-\beta_{65}-\beta_{75})\eta_5(t) + \zeta_5(t)$$
$$= \beta_{51}\eta_1(t-\theta_3) + \gamma_{55}\xi_5(t-\theta_7) - \eta_5(t) + \zeta_5(t)$$

(14)

$$\tau_6 \frac{d\eta_6}{dt} = \beta_{62}\eta_2(t-\theta_8) + \beta_{63}\eta_3(t-\theta_9) + \beta_{64}\eta_4(t-\theta_{10}) + \beta_{65}\eta_5(t-\theta_{11}) - \beta_{76}\eta_6(t-\theta_{12}) - (1-\beta_{76})\eta_6(t) + \zeta_6(t)$$
$$= \beta_{62}\eta_2(t-\theta_8) + \beta_{63}\eta_3(t-\theta_9) + \beta_{64}\eta_4(t-\theta_{10}) + \beta_{65}\eta_5(t-\theta_{11}) - \eta_6(t) + \zeta_6(t)$$

(15)

$$\tau_7 \frac{d\eta_7}{dt} = \beta_{76}\eta_6(t-\theta_{12}) + \beta_{75}\eta_5(t-\theta_{13}) - \eta_7(t) + \zeta_4(t)$$

(16)

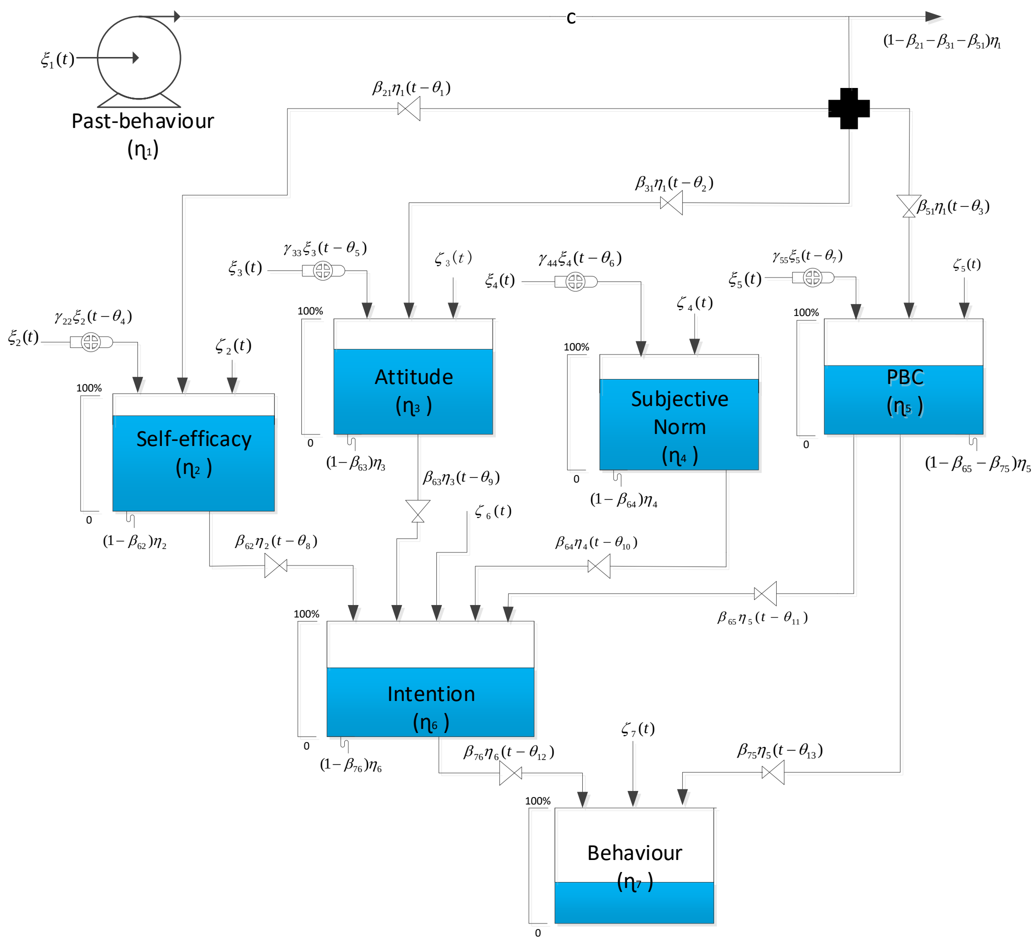


Figure 8. Flow Analogy of Behaviour Intervention Process

Where, $\eta_1(t) = \xi_1(t)$, $\xi_2(t) = \mathrm{b}_1(t) \times e_1(t)$, $\xi_3(t) = \mathrm{n}_1(t) \times m_1(t)$, $\xi_4(t) = \mathrm{c}_1(t) \times p_1(t)$, $\eta_5(t) = \xi_5(t), \theta_i$ is time delay and τ_i is constants to capture the capacity of each tack. The other factors are defined as above. A number of important considerations of Equations (10) - (16) are as below:

- When $\frac{d\eta_i}{dt} = 0$, the behavioural intervention became steady. Equations (10) – (16) reduce to the SEM model without approximation.
- Coefficients γ_{ij} and β_{ij} correspond directly to gains in the system.

- In the system, the outflow resistances from PBC are subject to $\beta_{65} + \beta_{75} \leq 1$.
- The initial level of all inventories are determined by Equations (10) – (16) at steady state.
- The past behaviour is formed from a long-time water use habit. In this study, the past behaviour gives constant input to the dynamic system and is assumed no changes during the intervention procedure.
- The water end use conservation behaviour change marking strategies normally have no negative influence on consumers and the water conservation behaviour intervention process cannot cause any apparent uncomfortable and inconvenient influences. In this study, we assumed that there is no reverse response in tanks and the fluid flowing process.

Behavioural response habituation as a result of repeated simulation is a well-known phenomenon that could be observed in many behavioural situations. Considered one of the simplest forms of learning, habituation is complex and covers many processes including spontaneous recovery of the response when the stimulus is withheld, more rapid habituation following prior series of habituation and recovery, effects of frequency. Most basic habituation processes have been simulated from machine learning perspective in literature (Marsland, 2009). Marsland (2009) proposed many modelling methods for basic characteristics of habituation in the first order derivatives system to depict exponential decays. Since this study is to simulate ETPB and habituation in the same system, a nonlinear consideration is used to represent both with a parameter varying strategy. This study focuses on the common characteristics of habituation:

- Repeated application of the stimulus resulting in a progressive decreased response.
- If the stimulus is withheld, the response recovers at least partially over time.
- More frequent stimulation results in more rapid or more pronounced response decrement.

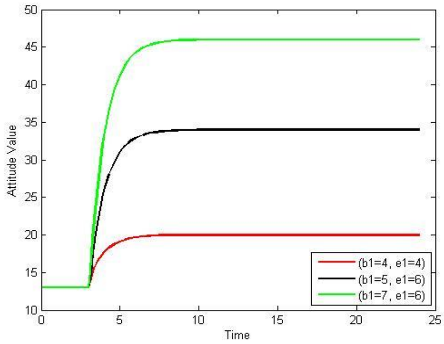
6.3 Illustrative Simulations

The ETPB dynamic model was designed to show with step change to ξ_1. Initial values is set as b_0=3, e_0 =3, n_0 =3, m_0 =3, c_0 =3, p_0 =3 to stand for a typical individual with slightly negative attitude at the beginning of intervention project. Time delay $\theta_1 \sim \theta_7$ =0, two days' delay to intention to behaviour with $\theta_8 \sim \theta_{13}$ =2 were assumed for the intervention. Inflow resistances γ_{ii}=1, transfer resistances β_{ij}=0.5 and time constants (in days) are $\tau_1 = \tau_2 = \tau_3$ =1, τ_4 =2, τ_5 =4, which means this individual can understanding all the intervention strategy and perform this targeted behaviour within a week. The initial values at t =0 for past behaviour, self-efficacy, subjective norm and PBC are $\xi_1(0)$ = $\xi_2(0)$ =20, $\xi_4(0)$ = $\xi_5(0)$ =9 respectively. Fig. 9 shows the behaviour change process in ETPB model with three different targeted attitudes: b_1 =4, e_1 =4; b_1 =5, e_1 =6; b_1 =7, e_1 =6. The unit for time in this model is 'day' and no outside influence is assumed.

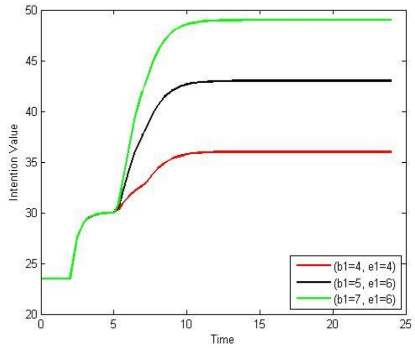
In Fig. 9, different targeted attitude could lead to different behaviour value. The larger ξ_1 value, the larger intention and behaviour value. Note that $\xi_1 = b_1 \times e_1$, then the separated value for b_1 and e_1 cannot decide how behaviour value changes in this dynamic system independently. As a detail analysis for other input variables is shown in Fig. 10, the step response for different time delay is examined. Note that the larger τ_i leads to slower dynamics, which means, the system has a longer shift to a steady state and intervention strategy chosen takes more time to achieve goal.

As the curve of behaviour change process is shown in Fig. 10 (c) two periods exist with stable output, the two step jumps mainly is caused by time delays of the input and transfer. Understanding and adjusting these time delays correctly will benefit the effects of behaviour intervention strategies. If the behaviour change process could be interrupted with reasonable stimulation, the goal of behaviour change can be reached earlier. Then the model inputs with b_1 =7, e_1 =6 as initial values and is tested by three different time delay sets from low, medium and high time delays in the dynamic system （$\theta_1 \sim \theta_7$ =0，$\theta_8 \sim \theta_{13}$ =2），（$\theta_1 \sim \theta_7$ =1，$\theta_8 \sim \theta_{13}$ =3），（$\theta_1 \sim \theta_7$ =3，$\theta_8 \sim \theta_{13}$

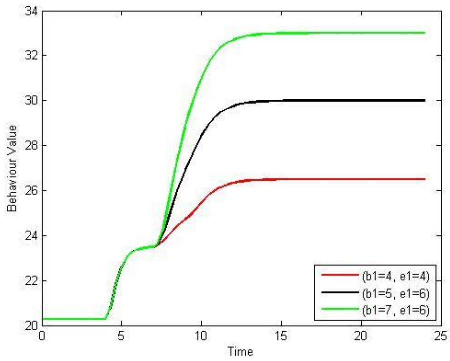
=4）. The results with different initial simulation variables are showed in Fig. 10 as below.



a



b



c

Figure 9. Behaviour change curve with variable attitude input (time unit is "day")

a attitude curve

b intention curve

c behaviour change curve

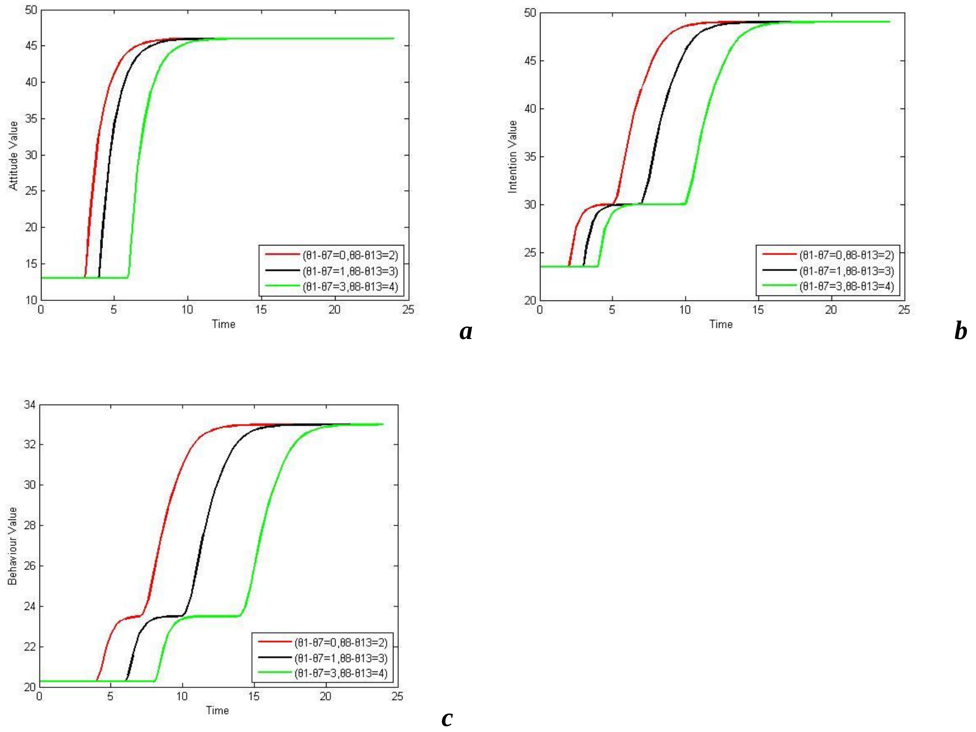


Figure 10. Behaviour change curve with variable time delay (time unit is "day")

a $\theta_1 \sim \theta_7 = 0$, $\theta_8 \sim \theta_{13} = 2$

b $\theta_1 \sim \theta_7 = 1$, $\theta_8 \sim \theta_{13} = 3$

c $\theta_1 \sim \theta_7 = 3$, $\theta_8 \sim \theta_{13} = 4$

6.4 ETPB Dynamic Model Estimation and Validation

In this section, grey-box modelling strategies used for ETPB model are outlined, and results from fitting Auto Regressive with exogenous input (ARX) parametric models are presented (Ljung, 1999).

Monthly directly measured ETPB data from ten households in the sampled community is used to obtain model parameters from the proposed structure using semi-physical identification techniques (Ljung, 1995). Fig. 11 illustrates the averaged direct-measured ETPB data from ten household. Every three months, the ten households were invited to fulfil complete ETPB indirect measured questionnaire to capture their detailed ETPB variable input. In the model development procedure, the correlation between different ETPB variables (empirical model) are used to represent the β_{ij}. Constants to capture the capacity of each tank τ_i is estimated by average Direct Measured ETPB variable divided average Indirect Measured ETPB variable.

Therefore,

$\beta_{21} = 0.20$, $\beta_{31} = 0.18$, $\beta_{51} = 0.33$, $\beta_{62} = 0.19$, $\beta_{63} = 0.24$, $\beta_{65} = 0.27$, $\beta_{75} = 0.25$, $\beta_{76} = 0.17$;

$\tau_2 = 0.37$, $\tau_3 = 0.14$, $\tau_4 = 0.52$, $\tau_5 = 0.29$, $\tau_6 = 0.55$, $\tau_7 = 0.78$.

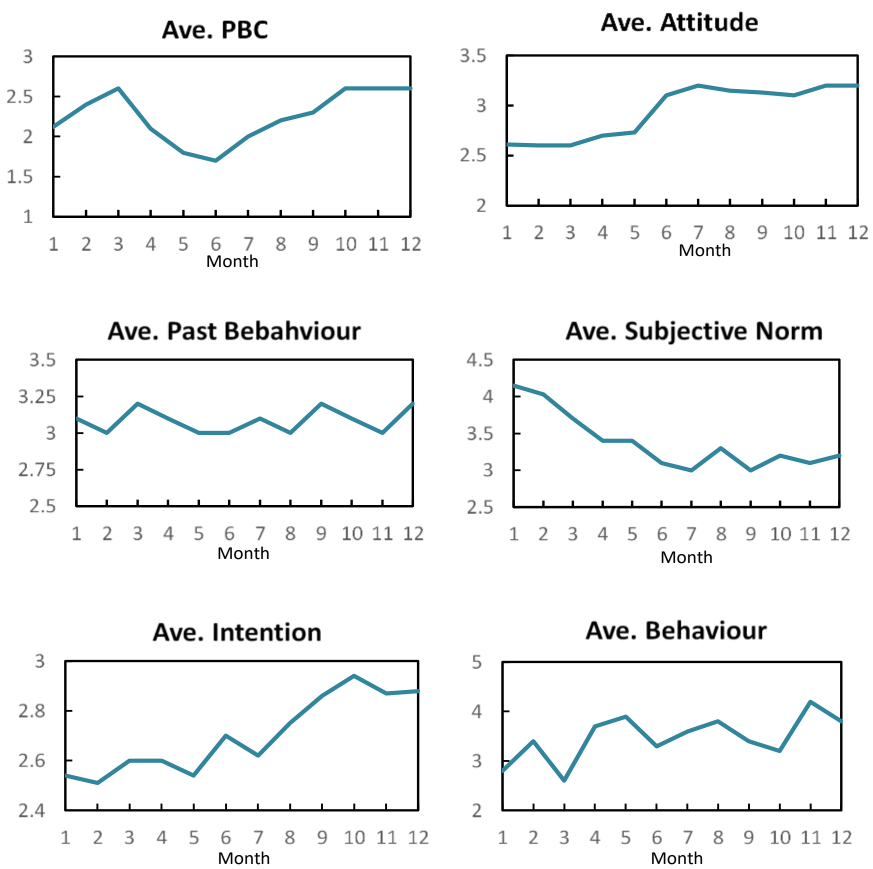


Figure 11. Averaged behaviour observation scoring for a subset of ten households

In this data based study, the purpose is to explain the effects of five inputs over one output in the context of the model. However, there are other signals that were still present in the modelling procedure as non-measurable data. Some of these signals like environmental context and intrapersonal stats could be responsible for much of variability in the output (Martin et al., 2014). To account for variability, quarterly average data is used instead of monthly data. This modelling consideration may be interpreted as a smoothing filtering action applied to the raw data. The model parameters are estimated using the system illustrated in Fig. 12. by using grey-box system identification procedure (Lindskong and Ljung, 1995; Ljung, 1999). This work allows the search of parameters to keep the defined model structure.

The selected variables and their respective match with the ETPB model are

- Directed measured TPB variables: PBC, Attitude, Subjective Norm and Intention.
- Self-efficacy.

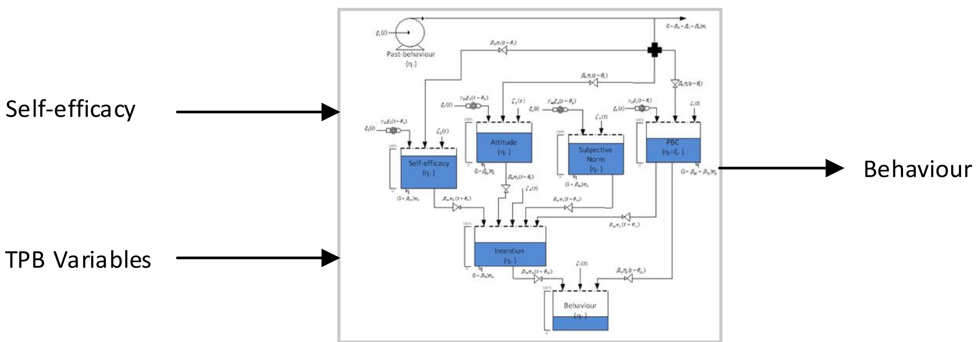


Figure 12. ETPB model semi physical subsystem

Grey-box parameter estimation relies on two sources of information to estimate the required parameters: prior knowledge of the system (i.e, the ETPB dynamic model) and experimental data (long-term water conservation behaviour observation). The state space representation of the grey-box system has the structure:

$$\dot{x}_p(t) = A(\theta_p)x_p(t) + B(\theta_P)u_P(t) + Ke(t) \tag{17}$$

$$y_p(t) = Cx_P(t) + v(t) \tag{18}$$

Where:

$x_p = [\eta_1 \dots \eta_7]$ donates a vector of n=7 state variables,

$u_p = [\eta_2\ \eta_3\ \eta_4\ \eta_5\ \eta_6]$ donates a vector of m=5 input variables,

$y_p = [\eta_7]$ donates a vector of p=1 output variable,

$A \in R^{n\times n}, B \in R^{n\times m}, C \in R^{p\times n}$ are the state matrices,

$\theta_p \in R^{np}$ donates a vector of $np = 4$ unknown model parameters,

$e(t)$ and $v(t)$ are uncertainties associated to each one of the states and output,

According to the structure of ETPB, the unknown model parameters are

$$\theta_p = [\gamma_{22}\ \gamma_{33}\ \gamma_{44}\ \gamma_{55}]^T \tag{19}$$

The prediction-error identification methods (PEM) (Ljung, 1999; Martin et al., 2014) are used to estimate θ. The one-step ahead prediction error of the system is

$$\varepsilon(t, \theta_p) = y_p(t) - \hat{y}_p(t|t-1, \theta_p) \tag{20}$$

where $\hat{y}_p(t|t-1,\theta_p)$ is the predicted output based on estimated models (Martin et al., 2014).

The system identification is computed in MATLAB using *idgrey* and *greyest* commands in system identification toolbox. The estimation of unknown parameters are

$$\gamma_{22} = 1,\ \gamma_{33} = 1,\ \gamma_{44} = 1.14,\ \gamma_{55}=0.92$$

The behaviour simulation result is generated in ETPB model by using the parameters identified in this section. To keep order consistent, the collected behaviour value has been times five (measured data is the average direct behaviour value, but simulation result is the addition of five question scoring) and showed in the Fig. 13 with simulation result.

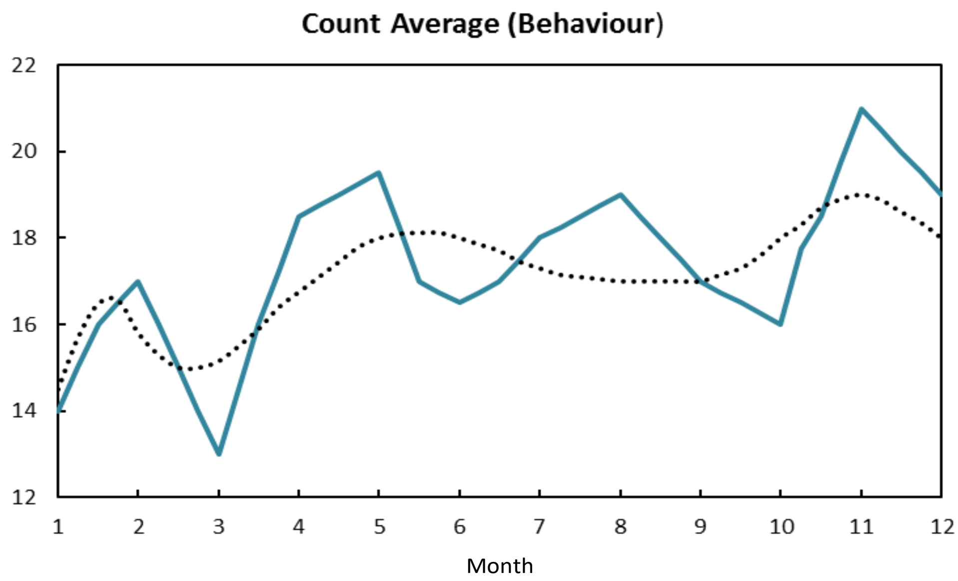


Figure 13. Behaviour observation data (Solid Line) against behaviour simulation result from the ETPB Model (Dotted Line)

Model fitness is calculated by using the Equation (Martin et al., 2014) below:

$$fit\,\% = 100\% * \left(1 - \frac{\|y_p - \hat{y}_p\|}{\|y_p - Mean(y_p)\|}\right) \quad (21)$$

where $\|\ldots\|$ is two-norm (i.e. for a vector α is equal to $\|\alpha\| = \sqrt{\alpha^T\alpha}$. The fitness for the ETPB model is

$$Behaviour(\eta_7) = 46.94\%$$

6.5 Summary

Compared to the researches who used the similar modelling methods in literature (Martin et al., 2014), the fitness of ETPB model showed about around 47% understanding of the behaviour intervention process and the simulation result could generally match the trend of change from observation. However, there are still some mismatches between the data and model simulation result due to the unmeasured dynamics, disturbances and unknown external signals. And from the theoretical perspective, even the ETPB has improved the prediction and explanation ability of water conservation behaviour, still, the theory cannot reveal all the behaviour intervention processes which might need further research supports in this aspect. Inevitably, the questionnaire data collection method could bring the disturbance of matches in this model evaluation study. But it is observable that the simulation result showed the same shape of response could be predicted from ETPB model.

7 Behaviour and Water Use

7.1 Overview

To qualify and link the behaviour intervention process to the actual water consumption amount, it is necessary to build a theoretical water use model concerned behaviour change factor. In Chapter 3, many indirect and direct drivers for water consumption have reviewed. Different from Jorgensen's integrated water conservation model, all the psychological variables such as attitude, intention and subjective norm are processed in the ETPB model to support the understanding of behaviour intervention process. All the psychological factors are represented as behaviour value according to the ETPB theory.

Due to the uncertainty for introducing a behavioural change model into the water consumption prediction procedure, the final water consumption model will be a black box model. To identify the relationship between behaviour change and water consumption, in this study, the Artificial Neural Networks (ANN) is applied to support the modelling process. In the first part of this chapter, an ETPB-ANN model is presented to understand the behavioural change intervention and its relationship to water use. This model will consider how important system variables respond to changes in input variables overtime. The second part of this chapter is about the ANN model architecture and the third part is the simulation result. The modelling of this chapter is conducted via Matlab software.

7.2 ETPB-ANN Model Architecture

Researches already pointed out that integrated model can be applied to give answers to dynamic systems about what variables to measured, its measure frequency, speed for intervention and the functional form of the outcome responses (Navarro-Barrientos et al., 2011; Jorgensen et al., 2009). This dynamic ETPB-ANN model contains the behavioural intervention simulation model and the water use ANN model. It considered the importance of system variables respond to interactions between input parameters overtime. In the behavioural intervention model, intervention acts towards end use were measured and inputted to TPB mathematic expression (SEM). At the same time, with the objective parameters and water use data, ANNs based water use model can output the results of the water consumption.

In the model, we believe the behaviour change model should exist dependently as a part for better understanding the behaviour intervention. The significant meaning for the dependent dynamic behaviour model is to calculate the behaviour intervention process in an isolated model and this could fix the disadvantages of traditional water use models especially for guiding proper behaviours for saving water.

This dynamic ETPB-ANN model contains the behavioural intervention simulation model and the end use ANN model. It considered the importance of system variables respond to interactions between input parameters overtime. In the behavioural intervention model, intervention acts toward end use were measured and inputted to TPB mathematic expression (SEM). At the same time, with the objective parameters and water use data, ANNs based end use model can output the results of the water consumption. Fig. 14 shows the general conceptual diagram for the intelligent integrated philosophy of household water use model.

Influence factors of water consumption in this model will be separated into two kinds by reviewing the former researches about water use behavioural change in Chapter 3. The criterion of selection for those two kinds of parameters is based on TPB and the social and economic model reviewed above. This paper suggests using ETPB model as an independent model and integrated with ANNs end use model for simulation. Behavioural change model exists as a separated part in ETPB-ANN model for better understanding the behavioural interventions. This ETPB-ANN model could not only have a better understanding of behavioural intervention, but also can be used to fix the weak points of former end use modelling, especially for guiding proper behaviours for saving water.

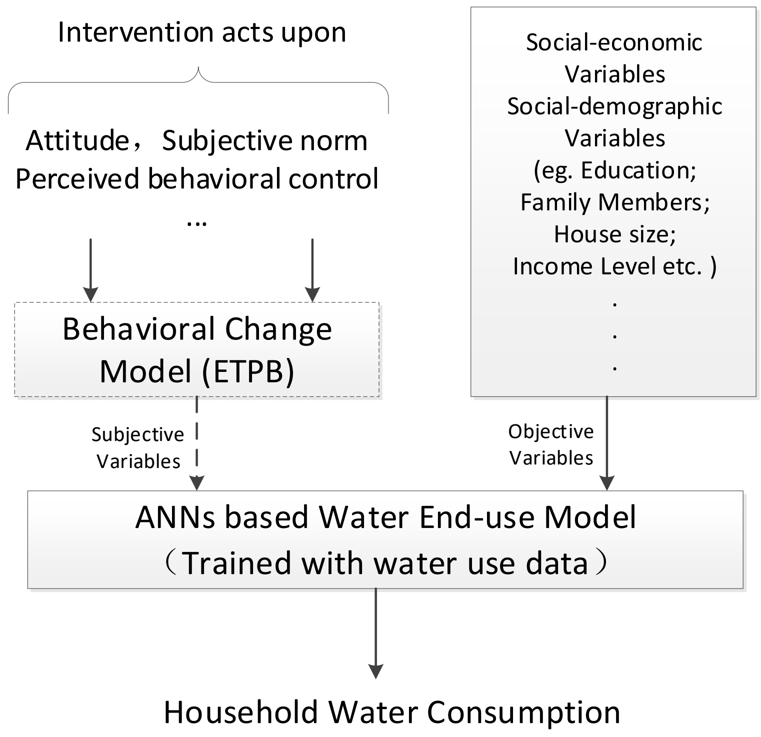


Figure 14. ETPB-ANN Model

7.3 ETPB-ANN Input Parameter

7.3.1 Influence Factors for Water Use Behaviour

A range of influence factors for water use behaviours have been identified in previous researches. All the factors, which influence the consumer's water use behaviours could be defined as direct drivers or indirect drivers (Bradley Jorgensen et al., 2009; Corral-Verdugo, V. et al., 2002; Gregor, G. et al., 2003). Bradley Jorgensen et al. concluded his research result about the drivers for consumer's water use in his research (see Table 13) (Bradley Jorgensen et al., 2009). All the analysis about the drivers for water use have different discretionary characteristic. The reason for the consumption diversity of outdoor use is due to the habit of people using their outdoor facilities and the condition (size and kinds) of them. Indoor water use situation could be more stable compared with outdoor use. The influence factors for indoor water use include house condition, regulatory environment and personal characteristics.

Moreover, the behaviours are more likely to be influenced by consumers' mind. Using Stern (2000) as a guide, the determinants of psychological behaviour can be categorized into five underlying causes: attitudinal factors, beliefs, habits or routines, personal capabilities, and contextual forces. Specifically, behavioural belief, normative belief and control belief are the main factors, which could alter what consumers are thinking about their water use behaviours. Those factors are rely more on the education standard and the responsibility consumers could feel about their water use condition etc. And those factors are directly or indirectly influenced by water management strategies and policy from Water unities and authorities.

The drivers of water use and saving are used to choose our input for modelling especially for TPB model. However, this is still not sufficient to meet all simulation requirements. Cara Beal et al. (2011) concluded with a discussion of the typical characteristics including the social perspectives of water consumption, socio-demographic trends, gender and education; household water appliances. All the factors could affect the household water use from residents in Australia. The analysis conclusion showed which factors could influencing the water use more. Based on their research finding, this research identifies the different parameters influences to the model. The other method to support the parameters selection is the TPB model. In Icek Ajzen's research to the TPB model, the sample TPB standard questionnaire will help this model to know which factors could influence and they will be selected as subjective parameters (Icek Ajzen, 1991). If this model is used as a dynamic model, all the parameters in the model should be long-time observed.

In summary, the impacts of these influencing factors on the water use consumption, the processing influence end use, how important it could be and how they interact with each other, are still in question. Researches are intended modelling all the factors which change household water use.

Table 13. Drivers for household water use (Bradley Jorgensen et al., 2009)

Direct-Drivers	**Indirect-Drivers**
Climate/seasonal variability (e.g.,tariff structure and pricing etc.)	Person characteristics (e.g. subjective norm, behaviour Control
Regulations and ordinances (e.g., water restrictions etc.)	Institutional trust (i.e., trust in the water provider)
Property characteristics (e.g., lot size, pool, bore etc.)	Inter-personal trust (i.e., trust in other consumers)
Household characteristics (e.g., household composition etc.)	Fairness
Person characteristics(eg. Intention, knowledge about water)	Environmental values & conservation attitudes
Incentives/disincentives (e.g., water restrictions, local government planning regulations etc.)	Socio-economic factors (e.g., income, household composition, age, gender, education, etc.)
	Intergenerational equity

7.3.2 Subjective and Objective Parameters

There are a lot studies have identified a range of direct and indirect drivers of water behaviour (Jorgensen et al., 2009). However, the direct and indirect driver classification method is based on the parameter influence strength to the water use amount which cannot offer clear picture for how the psychologically behavioural change works in the water use prediction process. To clarify the psychological influence on water use, this study classified the direct and indirect driver by using the TPB behaviour change theory and defined the subjective and objective parameters as below:

- The subjective parameters are those parameters that could be influenced by human mind, such as attitude, attention to the different household water use behaviour which could only exist in the TPB/ psychological model.
- The objective parameters are the those that already exist and could not be changed easily or at all, such as education level, house size and whether located in rural area or not.

Therefore, the subjective and objective parameter for ETPB-ANN model are as presented in Table 14.

Table 14. Subjective and objective parameter for household water use

Subjective Parameters	**Objective Parameters**
Attitude	Household characteristics
Subjective norm	Climate/seasonal variability
Moral norm	Person characteristics
Beliefs about behaviours	Regulations and ordinances
Intention	Incentives/disincentives
Past behaviours	Socio-economic factors
Descriptive norms	Property Characteristics

7.4 ANN Water Use Model

Artificial neural networks are biologically inspired computational system that relies on the collective behaviour of many processing elements (neurons), which are interconnected in some information-passing settings (Hassan, A.E., 2001). The perceptron of ANN is comprised by a series of weighted connections, layers, the summation function and the activation function (Christopher Bennett et al., 2013). ANN structure is arranged in layers that allow the network to learn from input data and the corresponding output data, which is commonly known as the generalization ability of ANN (Junguo Liu, Hubert H.G et al., 2002). During the calculation, the specific training algorithm alters the weights and structure dynamically by a manner.

A typical three-layer back propagation neural network which is applied in this study is showed in Fig. 15. It contains a four nodes' input layer, a four nodes' hidden layer and a three output nodes' output layer. Numeric weights exist with each inter-node connection. $W_{h,i}$ and $W_{o,h}$ represent the strength of node connections among three layers. In back propagation ANN, the input vector first calculates from input layer to output layer by using non-linear function, then back propagated with error between target value and calculated output. All weights can be modified by time with different training mechanism in the "feed forward" process, until the network outputs an acceptable error.

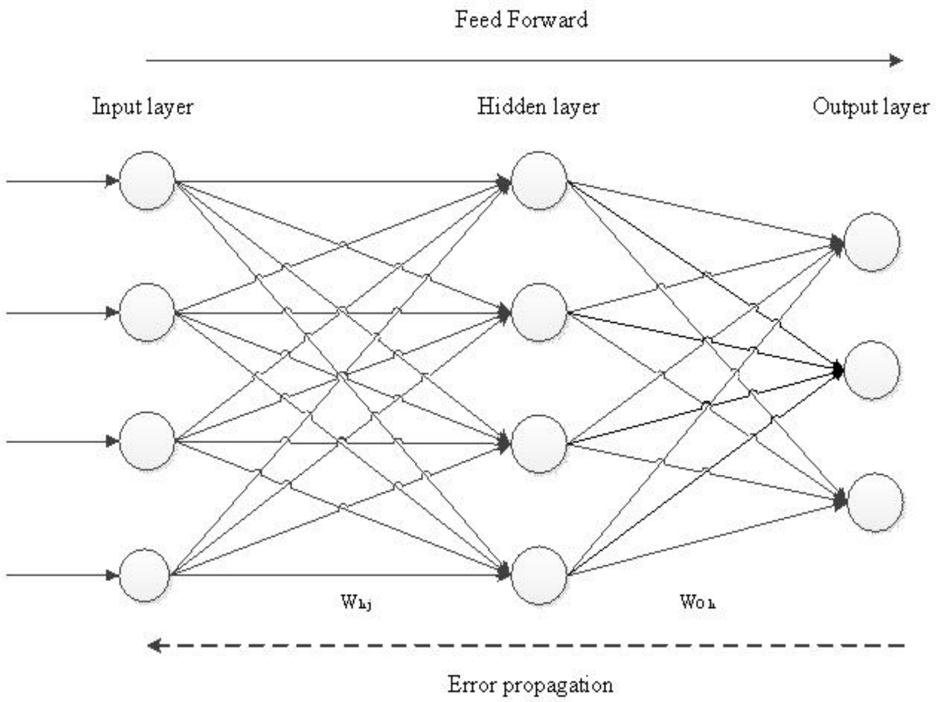


Figure 15. Typical three-layer back propagation neural network

Equation (22) - (24), below, display the function of sigmoid activation perceptron, which is usually applied in ANN because of the deviate's convenient mathematical expression (Junguo Liu, Hubert H.G et al., 2002).

$$v_j = \sum_{n=1}^{m} w_{jh} x_h \quad (22)$$

$$\sigma(v_j) = \frac{4}{1 + e^{-xv_j}} - 7 \tag{23}$$

$$Y_j = \sigma(v_j) \tag{24}$$

Where χ is the input variables, χ_h is the input variable of input vector h, m is the number of input variables, w_{jh} is the weighted connection from input variables h to perceptron j, v_j is the summation term of perceptron j, σ is the activation function, and Y_j is the output from perceptron j.

It can be derived as $\sigma'(v_j) = \sigma(v_j)(1 - \sigma(v_j))$. Fig. 16 shows the graph of basic sigmoid function $F(\chi) = \frac{1}{1 + e^{-x}}$.

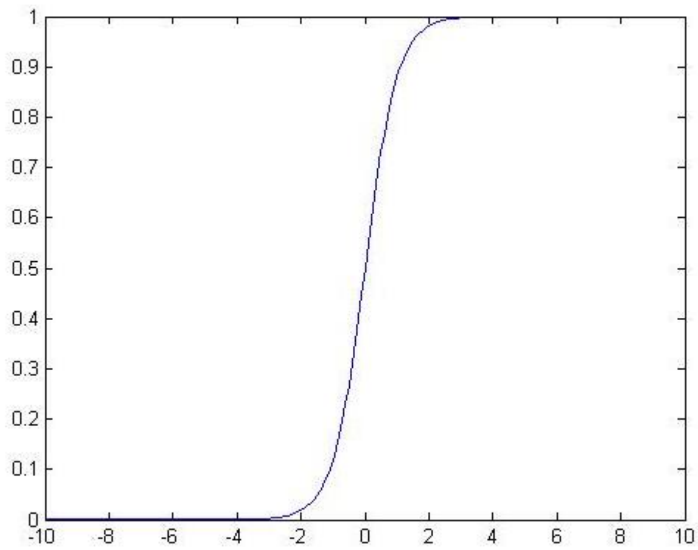


Figure 16. Basic Sigmoid transfer function

The error back propagation provides mechanics to update weights connecting the hidden layer and output layer by Eq. (25) below.

ANN error function:

$$E = \sum_{i=1}^{M} \sum_{i-1}^{N} \left(e_i(j) - t_i(j)\right) \tag{25}$$

$$\Delta w_{ij}(n) = \alpha \frac{\partial E}{\partial w_{ij}} + \eta w_{ij}(n-1) \tag{26}$$

Where M , N are the number of input and output nodes, $\Delta w_{ij}(n)$ and $w_{ij}(n-1)$ are weights between node i and j during the adjacent interaction n and $(n-1)$; and η, α are momentum factor and learning rate.

The structure of ANN model in this study is a multiple-layer networks. This multi-layer networks consist of an input layer of value consisting of house size (HS), number of resident (NOR), month (M), education level (EL), income level (IL) and ETPB Questionnaire Calculated behaviour value (BV), two hidden layers of perceptron and an output layer for outputting the Water Consumption Data (WCD with a unit of Ton/month). Numbers of nodes in hidden layer is set as two. BV (Questionnaire Calculated Behaviour Value) is calculated according to findings of regression equation in literature about water saving behaviour change in Chapter 5. The behaviour calculated from ETPB questionnaire record is followed by Equation as below.

$$BV = (Observed\ Intention\ \times 0.17) + (Observed\ PBS\ \times 0.25) \tag{27}$$

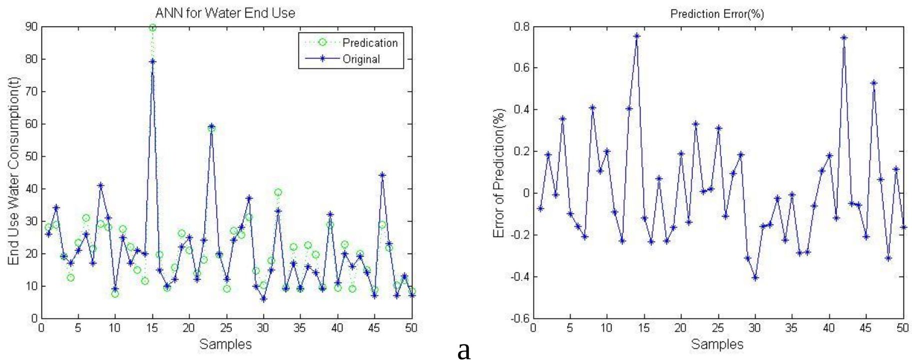
The model development was limited to predict internal demand component especially for those houses which are apartments, and this is one kind of the most common houses in Chinese main cities with public sharing garden in the community. Additionally, household leakage was not considered as this is highly inconsistent and uncertain, and the leakage prediction is related to a range of other variables not collected in the questionnaire of modelling.

The artificial neural network for household water consumption is expressed as follows:

$$WCD = F(W_2F(W_1R + \psi_h I) + \Psi_0 I) \quad (28)$$

Where WCD is the standardized water consumption data as output vector, R is the standardized input vector which consisting house size (HS), number of resident (NOR), month (M), education level (EL), income level (IL) and questionnaire calculated behaviour value (BV); F(x) is the sigmoid function; W_1 is the weight vector between input and hidden layer; W_2 is the weight vector between hidden and input layer; Ψ_h and Ψ_0 are the threshold vector of hidden layer and output layer; I is an unit matrix. 50 prediction data were compared with original data to test the accuracy of this ANN model. The accuracy of testing result in this model is showed in Fig. 17. The mean prediction error (%) of ANN water consumption model between the original data and predication data is less than 0.8%. In this study, prediction error is evaluated in two aspects: gap (error) assessment for both original data (training data) and prediction data (testing data) (Liu et al., 2002). The gap assessments for this model can examine the ability for reorganization and reproduction of the original data set. Root-mean-square and R^2 (Scott et al.,

1992) are applied as statistical tools to evaluate the model. Statistical evaluation result is showed in Table 15.



a b

Figure 17. Prediction error test of ETPB-ANN model: the error for prediction (a) and the prediction error in percentage (b).

Table 15. Statistical evaluation result of ETPB-ANN

	Original Data	**Prediction Data**
Data volume	50	50
R^2	0.936	0.914
Correlation coefficient	0.99	0.905

7.5 ETPB-ANN Evaluation

Model evaluation in this section is mainly concerned with two parts: evaluation of behaviour intervention trend and estimation of system parameters. Data used for ANN training is collected from 119 household in SZ, China in 2014. The data was organised by monthly record with behaviour score and water consumption record. For one household, thus, the database has included 12 data sets in tracking the whole year behaviour value change and consumption change. The database applied for modelling evaluation has been tested with reality and validity. PB7 and INT 4 which have not passed the tests, are not been used for any further calculation.

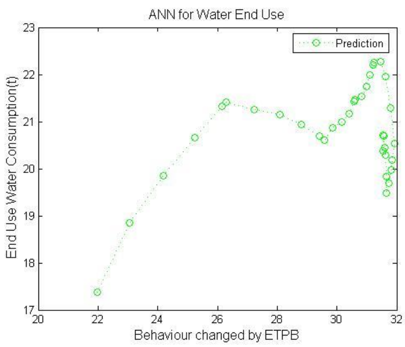
To identify the effectiveness of dynamic ETPB model, this study compared the results generated from ANN water consumption model with the results generated from ETPB behaviour change model by giving a setting of household, such as EL, NOR etc. to both models, the different household settings might lead to different water consumption trend, namely, different household water end use behaviour.

In this case study, all inventory values are directly measured by ETPB questionnaire, inflow resistances of each inventory could be calculated as $\gamma_{22} = 1$, $\gamma_{33} = 1$, $\gamma_{44} = 1.14$, γ_{55} = 0.92. Thus, inventory output transfer resistances could be interpreted by inventory coefficients. Mechanism for setting transfer resistances variables is referred to TPB parameter coefficients and regression equation analysis outcomes in Chapter 5 and Chapter 6 which offers a mega analysis of behaviour change parameters' correlation and regression, thus, transfer resistances are set as $\beta_{21} = 0.20$, $\beta_{31} = 0.18$, $\beta_{51} = 0.33$, $\beta_{62} = 0.19$, $\beta_{63} = 0.24$, $\beta_{65} = 0.27$, $\beta_{75} = 0.25$, $\beta_{76} = 0.17$. In order to present a typical reporter, initial mass input of each inventory is set by using mean variable value with b_0 =3, e_0 =3, n_0 =1, m_0 =5, c_0 =5, p_0 =1. Time constant τ_i is the mean rate of initial indirect measurement of inventory to direct measurement of inventory (ETPB questionnaire score), thus, time constant in this case are $\tau_2 = 0.37$, $\tau_3 = 0.14$, $\tau_4 = 0.52$, $\tau_5 = 0.29$, $\tau_6 = 0.55$, $\tau_7 = 0.78$.. Three intervention strategy is simulated with dynamic expression of system time delay parameters ($\theta_1 \sim \theta_7 = 0, \theta_8 \sim \theta_{13} = 2$), ($\theta_1 \sim \theta_7 = 1, \theta_8 \sim \theta_{13} = 3$), ($\theta_1 \sim \theta_7 = 3, \theta_8 \sim \theta_{13} = 4$) (units of delay is in "month"), by which means, this intervention strategy could influence reporter's attitude, PBC, SN and Self-efficacy immediately. Fig 17 (a) showed the ETPB behaviour intervention process simulation with variable intervention designs and outside influence (white noise signal $\varsigma_i = \mathrm{N}(0{,}5)$).

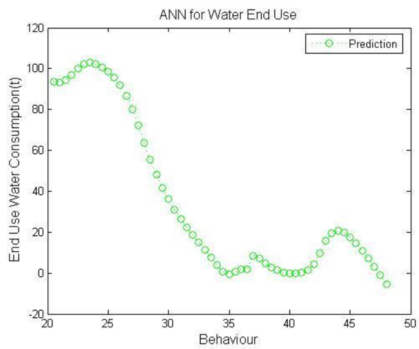
Water consumption prediction result of ANN is generated for behaviour intervention trend in comparison to ETPB dynamic model. ANN initial inputs are set as HS (House Size) = 2, NOR (Number of Resident) =3, EL (Education Level) =3, IL (Income Level) =2, which stands for a 87 m*m apartment with three residents older than 12 years old, education level for this reporter/representative (normally represent the landlord's education level) is bachelor degree and household annual income is 100K-200K RMBs.

The output of behaviour from ETPB should be interpreted as amount of water saved in this case. Because the BV and ETPB behaviour (amount of water saved) have first order relationship, therefore, if the increase of amount of water saved in Fig. 17 (a) could match water consumption decrease trend in

Fig. 17 (b), we will assume ETPB dynamic model could generate right behaviour intervention trend. In Fig 18 (a), curve of ETPB model is with a steady start at the beginning and shows a rapid increase in the middle, followed by relatively steady trend at the end. Fig. 18 (b) can generally match Fig. 18 (a)'s trend with a rapid decrease of water consumption in the middle of curve, followed by a relatively steady state at the end. However, for the beginning part of the intervention (trend of curve), ETPB model showed less capability to simulate the increase of amount of water saved at the early beginning in Fig 18 (a). This is because the setting of dynamic system is with first order deviation in inventory equation which could not simulate inverse response.



a



b

Figure 18. Behaviour intervention of ETPB and ANN water consumption model
a ETPB behaviour intervention with outside influence
b ANN behaviour intervention (one step change BV versus water consumption)

7.6 Summary

The results of the ETPB-ANN model showed that the high calculated behaviour value cannot lead to low end use water consumption fully. That is because the end use water consumption condition for consumers are not just influenced by behaviour, but also can be impacted by weather change or other factors. When the behaviour value is increased by changed from ETPB, the end use water consumption has a rapid jump in the beginning then followed by a fall in the middle term of the year. At the end of the year, the water consumption seems to be descending and showed no clear liner relationship towards behaviour increase. The reason for the jump of curve of water end use at the beginning and the middle-end of the year was due to the increase of water use with weather change or other influences. And it can be proved in Fig. 14, when the month is set as 6, with higher behaviour change value, the end use water consumption value became lower except the periods behaviour value smaller than 23 and higher than 42. This is caused by that the data volume at these two input zones ([20, 23] and [43, 50]) are insufficiently to support ANN training and generation of correct prediction. Without enough data from low behaviour and high behaviour value zones, the ANN model cannot generate current result effectively. But for the common behaviour value zone [23-43], the ANN can work with high accuracy.

For generating a smaller end use water consumption results, water utilities need promote strategies which could lead consumers to have a high attitude, PBC, Subjective Norm, self-efficacy values and smaller time delays in the strategies of promotion process. It can be achieved by giving consumers' right concept for saving water (advertisement or leaflet), increasing the social pressure for saving water (education or increase the water bill), guidance for how to achieve the saving goals step by step, and encouragement of achievement. To minimalize the period for achieving targeted behaviour, efficient positive stimulation strategies are developed in the stages of understanding and forming the right water saving habits through education or marketing strategies.

Apparently, the ETPB-ANN model can be used to simulate any communities or consumers for saving water with enough data training the ANN. In addition, the modelling methods for understanding the behaviour intervention process have potentials, which can be applied in fields about targeted behaviour like energy saving, GHG control, water footprint research, body weight control or quit smoking.

Moreover, the limitation for this study is argued as follows. Firstly, the ETPB model cannot cover all the information of the mechanism of behaviour change. It can be improved by further psychological research and other methods, like multivariate modelling method and time extrapolation method etc. to employ for simulation comparison. Moreover, other ANN technologies like GRNN (Generalized Regression Neural Networks), CCNN (Cascade Correlation Neural Network) and FFNN (Feed Forward Neural Networks) are suggested to be applied in the modelling process. Further research can be deployed in the above fields to overcome the limitations.

8 Conclusions and Future Work

8.1 Introduction

This chapter presents the research conclusion of this PhD research. It describes how the aims were met and objectives accomplished, indicating the outcomes that leaded to these conclusions. The seven research questions are placed here with the corresponding answer extracted from the individual chapters. The further research for this study is also presented in this chapter.

8.2 Achievement of this Research

The overall aim of this study was to develop a behavioural change theory and corresponding modelling methods to understand household water conservation behavioural intervention process. The literature review for TPB, behavioural intervention and water use modelling provided the knowledge that informed the design of this research. The three stages data collection involved the development of ETPB questionnaire and data analysis methodology, which contribute the data basis for all the evaluations. Using these data, the theory of ETPB and dynamic behavioural model are tested and proved to be used in water conservation behaviour domain. Special objectives were developed to understand the link between behaviour and water use amount to provide a possibility for ETPB further application in water use area.

In general, all the aims for this study has been achieved.

These objectives are described below, following each research question that guided this project.

8.3 Research Questions

The following research questions were answered during this PhD study:

1. What is the current background of research related to household water use, and what is the background for current water saving behavioural intervention projects.

Chapter two answered the first research question by presenting a comprehensive literature review. It demonstrated the current research background in water conservation, TPB, statistical analysis, behaviour modelling and water use modelling. It presented the importance of understanding behaviour intervention process in water use, and the exiting challenges to develop new behavioural theory and modelling solutions. A number of studies mentioned the universality of TPB theory, also demonstrated the existence of a gap in the literature, where studies involving improvement of behavioural model prediction ability, behavioural intervention modelling and the link of water use and behaviour could be merged into one research project.

2. What are the models or theories for predicting water related behaviours and are these models showed good enough prediction power?

In order to provide answer to this research question, the chapter 3 is designed to explore solutions for this study. A detailed review has been conducted in that section. Combination of methods was used to provide these results, including data collection, quesionnaire design, statistical analysis, SEM for ETPB, dynamic behaviour modelling and ANN model. The detailed methods were identified as follows:

- ETPB development
- Influence factor identification for water use behaviour
- Questionaire and Data Collection, including quesionnaire and survey design
- Pre-suvery design
- Behaviour intervention
- Statistical Analysis, including reliability, validity, EFA and CFA analysis.
- Behaviour modelling, including control theory concept, fuild analogy and system design.
- Water use modelling, including model structure and ANN modelling.

3. What is the drawbacks of theory of planned behaviour for predicting household water use behaviours and how to improve the theory?

Through the review, TPB research became more controversial about its sufficiency and the need for external variables which assist to the improvement of intention prediction. A lot of researches mentioned TPB prediction ability changes when used in different research domain or different cultural background. However, no research has tried to improve TPB prediction and understanding ability in water use behaviour domain, which means no enough evidence of development for TPB model has been addressed in literature. Moreover, as a typical developing country, very limited research addressed the Chinese residential water use behaviour issue from literature. Beside, as Ajzen metioned in his publications, the TPB cannot offer fully understanding of behavioural intervention process, therefore, a new theory which could provide more profund understanding of behaviour and the prediction ability is needed. All the above findings are presented in Chapter 2.

4. What is the survey method for household water use behaviour and how to evaluate the prediction power?

The suvery method has been presented in Chapter 3, including a comprehensive analysis of sampling area, population and water conservation background analysis. The survey has been conducted into three stages: stage one is a pre-suvery test which is a face-to-face test for the questionnare in the city centre of SZ; stage two is a face-to-face survey in a targeted community which involves a lot of behaviour change promotion activities in the city; stage three is the online survey in a nationaly wide which could provide the database for development of the empricial ETPB model. This research also observed ten households for a year's length with their behaviour and water use information.

The evaluation method is presented in Chapter 5. EPA and CFA provided the intitial test for the conflition of different construct settings in ETPB. Using SEM and corresponding fitness test could evaluate the ETPB empricial model fitness. In this study, the mediation analysis is also presented to test the relationship between PBC and self-efficacy and the indirect effect for introducing the new constructs.

5. What are the roles for past behaviour and self-efficacy in theory of planned behaviour and how their introductions affects the original TPB model?

In Chapter 2, the TPB model and the positions for past behaviour and sef-efficacy have been reviewed and proposed in content. The ETPB suggested the past behaviour and self-efficacy should play a role in TPB behaviour understanding as the follows:

As self-efficacy about water conservation became more positive, a residential intention to save water and adopt conservation activity increase. As past behaviour towards water conservation became more positive, a residential attitude, subjective norm, PBC and self-efficacy on intention towards water saving increase. As the controlling of past behaviour about water conservation increased, a result of attenuating influence of attitude, subjective norms, PBC and self-efficacy on intention increase. Past behaviour indirectly influences water conservation intention through TPB variables (attitude, PBC and Subjective norms). Finally, not only for the direct effects of past behaviour on water conservation intention but also the indirect effect or TPB variables will be investigated. Moreover, the self-efficacy has been provided to be different in the application of TPB in water use area compared to PBC in Chapter 5.

6. How to use extended theory of planned behaviour guide the computer simulation for dynamic behaviour intervention?

The dynamic behaviour intervention model is developed by using the empricial findings in Chapter 5. This research used the ETPB as simulation basis offering the structure knowledge of model system and particially understanding system parameter identification.This part of work is showed in Chapter 5 and Chapter 6.

7. How to link the psychological behaviour value to the real water consumption?

A ETPB-ANN model is developed to explore the link of behaviour value to the water consumption. The findings suggested the behaviour could be a very important variable for predicting water consumption and an index to understand the water conservation project progression. The ETPB-ANN also provide the solution to link these two variables in a dynamic modelling system with high prediction accuracy.

8.4 Recommendations for Future Work

This research proposed a behavioural model for understanding the water conservation behaviour and two models. By incorporating two constructs in TPB: frequency of past water conservation behaviour and self-efficacy as significant predictors of residential water conservation behaviour, the proposed system explained 49% of the variance in the extended TPB model. These findings are comparable to previous studies of water conservation behaviour in the USA, UK, Australia and Greece demonstrating the universality of the TPB to predict residential water conservation behaviour.

Different from individualistic cultures (e.g. UK or US), people in our research area emphasize shared values and are relative loyal to the collective “we”, have their unique cultural background, according to Hofstede’s individualism-collectivism dimension. High power distance, which refers to the high extent of individuals’ acceptance that government of organization is distributed equally, as another label for Chinese culture also makes Chinese residents perceive lower internal control focus with a belief that certain behaviour is more influenced through their own decision and evaluation. Louise et al. argued that the effect of subjective norm on intention would be stronger in countries high in collectivism and power distance. Our findings support this argument, having a larger correlation (standard solution value 0.31 in model 1) for the relation subjective norms (SN) to intention. In the TPB theoretical application perspective, these findings about Chinese culture differences have important practical implications for water conservation project managers in understanding drivers of residential water conservation behaviour and when starting marketing promotions across nation. The impact of subjective norm on conservation intention is greater in China, thus, promotion messages should likely be more effective in persuading residents to participate in the water conservation activities compared to individualistic and low power distance countries.

Moreover, apart from research findings, several limitations of this study should be pointed out. Firstly, due to the complexity of the behavioural information format, this study did not address the translation method for other behavioural information such as image and video. Further research, therefore, will investigate more detailed solutions for translating behavioural information from other channels. Secondly, this system only showed capability to study individual's behavioural intervention process, however, for a community and city level, the modelling method in the system cannot work very effectively due to the theory basis we applied in this research. There will be a need apply a community based behavioural intervention model in the system to simulate large population's behaviour in the future research. Adding the populated information in the consumption modelling process could ideally offer a solution for this limitation. Thirdly, some other analysis and machine learning technologies such as cluster analysis and decision tree are also suggested for digging more information of behaviour, this should be considered in the future research.

As for the behavioural change model, using the more advanced control system solutions to improve the behaviour intervention modelling ability should be one of the aims in the future work. A few studies from psychological research have mentioned that there is a self-judgement action in self-cognitive theory could guide the acceptance of behaviour change promotion. This will require more profound understanding for the control engineer in the close loop control unit area. Future research should address this point as well. The results of the ETPB-ANN model showed that the high calculated behaviour value cannot lead to low end use water consumption fully. That is because the end use water consumption condition for consumers is not just inflected by behaviour, but also can be impacted by weather change or other factors. When the behaviour value is increased by changed from ETPB, the end use water consumption had a rapid jump in the beginning then followed by a fall in the middle term of the year. According to the ANN model, in order to generate a lower end use water consumption results, water utilities need promote strategies which could lead consumers to have a high attitude, PBC, Subjective Norm, self-efficacy values and smaller time delays in the strategies of promotion process. It can be achieved by giving consumers' right concept for saving water (advertisement or leaflet), increasing the social pressure to form the saving water (education or increase the water bill), guidance for how to achieve the saving goals step by step, and encouragement of achievement. In order to minimalize the period for achieving targeted behaviour, efficient positive stimulation strategies are developed in the stages of understanding and forming the right water saving habits through education or marketing strategies.

Extensions of this model include implementing work with practical application and modification of model. A long-term goal is to develop a dynamic water end use model which is based on this theoretical model and could be used for guiding consumers to lead to proper water conservation behaviours and saving energy, but not just water. The extension of ETPB-ANN model for behaviour guidance should be done with the support of control engineering concept and behaviour change simulation analysis.

The strategy for using ETPB-ANN model to guide behaviour change is to test all the influence factors, including parameters present in the model, and propose the mathematical methods for behaviour change simulation. Also, the existing mature marking or behaviour change strategies are evaluated via ETPB-ANN by considering the potential outcome of the model prediction result. Moreover, by classification the different behaviour use pattern through hidden Markov model, different solutions for behaviour guidance could be investigated to guide further research.

8.5 Summary

It is possible to draw some conclusions from the results presented in this section. Firstly, the ETPB model or other advanced behaviour theory could be developed to provide more detailed understanding of behaviour intervention in water use. The ETPB model is the new try for exploring the behaviour theory in the application of this domain. ETPB model and its empirical model can be used to guide the Chinese residential water conservation project promotion and understand the limitation of current water conservation strategies. The outcome could be translated into more practical guidance by merging in IoT or other informatics system. To apply the control engineering in the modelling of a psychological theory is the new trend for behavioural change result. And the survey method could be improved if there is more way to improve the engagement of users. Participants felt bored if the behavioural questionnaire has been repeatedly fulfilled for a long time. Through increased engagement in the survey, they generally took the time to follow the guidance to complete the questionnaire. Therefore, this research concludes that an integrated behavioural monitoring platform with proper engagement encourage setting can be one of the solutions to promote the sustainable behaviours change for water conservation.

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Appendix 1 Questionnaire Content (English Version)

Household Water Use & Conservation Survey

Please return completed survey to our project researchers or put it in the envelope provided and mail to:

D110, Beacon Building,
Staffordshire University,
Beaconside Road,
Stafford, Staffordshire
Postcode: ST18 0AD

CONSENT FORM

Title of Research Project: **Investigating and Modelling for Describing Behaviour Change of Household Water Consumption**

PLEASE NOTE: ***It is important you sign this form otherwise we cannot use your survey information***

Your involvement in the Survey of Residential Water Use is highly valued. Please review the information below and sign in the box provided if you agree to participate in this study.

I acknowledge that:

- I agree to participate in this project.
- I will not be identified personally at any stage of the project and all data will be kept confidential and only seen by researchers involved in the research project.
- Questions in regards to my participation have been answered to my satisfaction.
- I understand that this study has been cleared in accordance with the ethical review processes of the Staffordshire University. If I have any questions concerning my participation in this study I should feel free to contact the researchers involved.
- I understand that I can withdraw from this study at any time without penalty and without giving any explanation for my withdrawal.
- I understand that I may ask that part or all of my data be removed from the study without penalty or explanation. Data that is removed from the study will be deleted and will not be included in any of the further investigations.

By signing below, I confirm that I have read and understood the information package and note that my involvement in this research will include participation in the following activities.

- Completion of the initial survey by adults in the household
- Accessing my household water data from council for one year prior (July 2013 to July 2014).

Name	
Residential Address: Phone Number: Email:	
Signature	
Date	

Thank you for your time and participation

CONSENT FORM FOR WATER DATA

Title of Research Project: **Investigating and Modelling for Describing Behaviour Change of Household Water Consumption**

I authorize my local council to provide water consumption data for the address listed below to researchers from the above project. The specific information to be provided to the researchers is water consumption data for the year prior (July 2013 to July 2014).

I understand that the data will be used to assist the researchers to better understand how people use water in their homes and what factors determine their water use.

I understand that data from the household meter readings will be kept confidential and only used for the purposes of the research.

***PLEASE NOTE:* It is important you sign this form otherwise we cannot use your survey information. Obtaining your water data is an essential part of our study.**

WATER ACCOUNT DETAILS

NAME OF THE ACCOUNT (AS SHOWN ON THE ACCOUNT)

First Name(s):	Family Name:

PROPERTY NUMBER/ID (if available)

Unit:	Number:	Street:
Suburb/Town:		Postcode:

I am the registered owner of the premise nominated above.

Signature:____________________________ Date:__________________________

Printed name:____

INSTRUCTIONS FOR COMPLETING THE SURVEY

Please take the time to fill out this survey about water conservation around the house and garden.

Your response will contribute to an overall picture of how people in your community feel about conserving water.

This survey will take approximately 20 minutes to complete.

Please be as open and honest as possible when you are answering each question. Some questions may seem similar, however please answer each question with care as they all provide important information.

All your responses will be kept confidential and your information will not be seen by anyone outside of the research team.

DIRECTIONS:

1. Please read each question carefully and then circle one response on each line:

   E.G. CORRECT METHOD   INCORRECT METHOD

   1 2 3 4 (5) 6 7   1 2 3 4 (5 6) 7

2. After completing the survey, please look through the whole document again and make sure that you have not accidentally missed any items or circled two responses for one question.

3. Return the survey to us in the envelope provided, or scan and email the survey to :

y028136c@student.staffs.ac.uk

THANK YOU FOR YOUR TIME

First, we would like to focus on everyday actions that you and others do around the house and garden that help to save water.

We do recommend you can save more water by referring to those actions listed on the ways to conserve water.

1. I think engaging in everyday actions to save water around my property(s) is : (Please circle one response on each line)

Extremely bad 1	*Quite bad* 2	*Slightly bad* 3	*Neither* 4	*Slightly good* 5	*Quite good* 6	*Extremely good* 7
Extremely harmful 1	*Quite harmful* 2	*Slightly harmful* 3	*Neither* 4	*Slightly beneficial* 5	*Quite beneficial* 6	*Extremely beneficial* 7
Extremely worthless 1	*Quite worthless* 2	*Slightly worthless* 3	*Neither* 4	*Slightly valuable* 5	*Quite valuable* 6	*Extremely valuable* 7
Extremely unpleasant 1	*Quite unpleasant* 2	*Slightly unpleasant* 3	*Neither* 4	*Slightly pleasant* 5	*Quite pleasant* 6	*Extremely pleasant* 7

2. I expect I will engage in everyday actions to save water around my property(s) in the next few months

strongly disagree 1	*Disagree* 2	*Slightly disagree* 3	*Neither agree nor disagree* 4	*Slightly agree* 5	*Agree* 6	*strongly agree* 7

3. I want to engage in everyday actions to save water around my property(s) in the next few months

strongly disagree 1	*Disagree* 2	*Slightly disagree* 3	*Neither agree nor disagree* 4	*Slightly agree* 5	*Agree* 6	*strongly agree* 7

4. I intend I will engage in everyday actions to save water around my property(s) in the next few months						
strongly disagree	*Disagree*	*Slightly disagree*	*Neither agree nor disagree*	*Slightly agree*	*Agree*	*strongly agree*
1	*2*	*3*	*4*	*5*	*6*	*7*

5.		
a	if I encourage the other people around me to conserve water, I feel that I am doing something positive for the society	Unlikely 1 2 3 4 5 6 7 Likely
b	It causes a lot of inconvenience to the consumers if they want to conserve water.	Unlikely 1 2 3 4 5 6 7 Likely
c	If I am the officer who want consumers save water in their houses, I will give them some suggestions to make them conservation behaviour conducted easier.	Unlikely 1 2 3 4 5 6 7 Likely
d	If I am doing the job for a water saving officer, I've got to go to the consumers' community more often.	Unlikely 1 2 3 4 5 6 7 Likely

6.		
a	Doing something positive for the society is:	Extremely undesirable 1 2 3 4 5 6 7 Extremely desirable
b	Causing a lot of inconvenience to the consumers is:	Extremely undesirable 1 2 3 4 5 6 7 Extremely desirable
c	Giving them some suggestions to make them conservation behaviour conducted easier is:	Extremely undesirable 1 2 3 4 5 6 7 Extremely desirable
d	Going to the consumers' community more often is:	Extremely undesirable 1 2 3 4 5 6 7 Extremely desirable

7.

a Most people who are important to me think that

I should 1 2 3 4 5 6 7 I should not

save and conserve water in the house and garden.

b It is expected of me that I refer peoples who can use more water in their house

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

c I feel under social pressure to save water around the house and garden

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

d People who are important to me want me to save water around my properties

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

8.

a Officers from the energy department think I

should not -3 -2 -1 0 +1 +2 +3 should

save and conserve water in the house and garden.

b My close friends think I

should not -3 -2 -1 0 +1 +2 +3 should

save and conserve water in the house and garden.

c My family members would

do not -3 -2 -1 0 +1 +2 +3 do

associate me with saving water in my house and garden.

9.
a Officers from the energy department and their approval of my practice is important to me
not at all -3 -2 -1 0 +1 +2 +3 very much
b My close friends' support and what they are thinking is important to me
should not -3 -2 -1 0 +1 +2 +3 should
save and conserve water in the house and garden.
c Doing what Other family members thinking and doing is important to me about my practice
not at all -3 -2 -1 0 +1 +2 +3 very much

10. I am confident that I can save water in the next few months if I wanted to						
strongly disagree	*Disagree*	*Slightly disagree*	*Neither agree nor disagree*	*Slightly agree*	*Agree*	*strongly agree*
1	*2*	*3*	*4*	*5*	*6*	*7*

11.
For me to save water in the house and garden is
easy 1 2 3 4 5 6 7 hard

12. The decision to save water around the house and garden is beyond my control						
strongly disagree	*Disagree*	*Slightly disagree*	*Neither agree nor disagree*	*Slightly agree*	*Agree*	*strongly agree*
1	*2*	*3*	*4*	*5*	*6*	*7*

13. Whether I save water around the house and garden or not is entirely up to me						
strongly disagree	*Disagree*	*Slightly disagree*	*Neither agree nor disagree*	*Slightly agree*	*Agree*	*strongly agree*
1	*2*	*3*	*4*	*5*	*6*	*7*

14. How confident do you feel, in general, about your ability to conserve water?						
Not at all confident			*No ideas*			*Very confident*
1	*2*	*3*	*4*	*5*	*6*	*7*

15.

a Officers from the energy department and their approval of my practice is important to me

not at all -3 -2 -1 0 +1 +2 +3 very much

b When I am using water and feel rushed, how possible for you to keep saving water at that time.

Unlikely -3 -2 -1 0 +1 +2 +3 Likely

c The water saving practice and behaviour are inconvenient for me.

Unlikely -3 -2 -1 0 +1 +2 +3 Likely

16.

a Officers from the energy department and their approval makes it

much more difficult -3 -2 -1 0 +1 +2 +3 much easier

to save water in my house and garden.

b Feeling rushed during the time you using water makes it

much more difficult -3 -2 -1 0 +1 +2 +3 much easier

to save water in my house and garden.

c When the water saving practice and behaviour is inconvenient for me, I am

less likely -3 -2 -1 0 +1 +2 +3 more Likely

to save water in my house and garden.

17. The information you provide in the following section will be used to draw more meaningful conclusions from the survey results. Your individual responses will remain strictly confidential.

Please remember that you will NOT be identified in any feedback from these surveys.

a) How old are you?

b) What is your sex? MALE or FEMALE (please tick)

c) What is the household's annual income before tax (gross income)?

- ☐ Less than £19,000
- ☐ from £19,000 to £30,000
- ☐ from £30,000 to £50,000
- ☐ more than £50,000

d) How many people usually live in your house?

Adults: ____________________ Children: ____________________

Ages: ____________________

e) What is the highest level of education you have achieved? (please circle)

Primary School | High School | Trade/ TAFE | Tertiary Undergraduate | Tertiary-Postgraduate

f) How many years have passed since your house or property is built? (please circle)

Less than 10 years | 10-50years | 50-100years | more than 100 years

Any issues about the survey or the topic that you would like to comment on?

____

____

____

____

CONGRATULATIONS!

YOU HAVE REACHED THE END OF THE SURVEY!

Thank you for taking the time to participate

in this important study.

This survey is part of a study about how to conserve water by investigate the consumers' behaviours towards their household water use.
We will be conducting further research that requires that completion of short surveys and the provision of some additional information.
Again, your involvement will remain completely confidential.

Please do not hesitate to contact the researcher if you have any questions or concerns. If you indicated that you would like to be involved in future surveys, we will be in touch in the near future.

☐ Please tick this box if you are NOT interested in being involved in future research.

Appendix 2 ETPB Model Simulink Structure