CHAPTER ONE

INTRODUCTION

1.1 Preface

Rainwater harvesting is simply collecting, storing and purifying the naturally soft and pure rainfall that fall upon the roof. Based on Athavale (2003), the term water harvesting refers to collection and storage of natural precipitation and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering interventions. It is aimed at conservation and efficient utilization of the limited water endowment of a physiographic unit, such as watershed. Rainwater may be utilized for both potable and non-potable requirement such as drinking, cooking, laundry and landscape irrigation. The application of an appropriate rainwater harvesting technology can make possible to the utilization of rainwater as a valuable and necessary water resource. Rainwater harvesting is a technique that has been used throughout history (Ngigi, 2003). Rainwater harvesting has been practiced for more than four thousand years and necessary in areas having significant rainfall but lacking of centralized government supply system. It is also suitable to use in areas where good quality fresh surface water or groundwater is lacking.

This dissertation therefore put an aim to assess the maintenance performance of rainwater harvesting (RWH) system in Malaysia. The performance is judged from the instrument which is developed through the research framework. The discussion starts with establishing the research concept by determine the overview of RWH in Malaysia, research foundation, research question and objectives of study. It is then briefly explained the methodological approach in visualizing the framework which include the research scope, data collection and analysis technique, before summarizing the entire points research outline.

1.2 Problem Statement

In Malaysia, although rainwater harvesting (RWH) system is still considered as a new phenomenon (Othman *et al.,* 2007) but with the support and effort of government in promoting the application of RWH in building, the numbers of building using the RWH is increased from time to time. The system has been applied for various type of building such as housing, institutional and commercial (Shaaban and Huang, 2007). Based on International Water and Sanitation Centre (IRC), approximately an investment cost for RWH is between 2% - 7% from total construction cost (depends on type of system used). This is a big investment as to ensure the RWH can be used throughout the building lifetime.

Even though the application of RWH is ongoing, there is no specific guideline in maintaining RWH. Literature shows there is very limited study dealing with maintenance of the system experiencing in Malaysia (details explained in chapter two, page 16-26). Furthermore, Che-Ani *et al.* (2009) has stated that the maintenance performance of RWH system in Malaysia was not properly being implemented. From these circumstances, it seems like the designers assume that the RWH needs no maintenance or can be self-operated on its own.

This result perhaps the deficiencies in RWH performance as a whole. It is really a waste of resources if the system installed is dysfunctional due to lack of maintenance. In relation to this scenario, this research concentrates on the assessment of RWH maintenance performance in Malaysia via Maintenance Performance Quadrant of RWH.

1.3 Research Foundation

Green technology is a national agenda nowadays. One of the green technology available for the building is rainwater harvesting. To date, there are numerous building projects that incorporate RWH as part of water supply. This research concentrates on the post construction stage which is the maintenance aspect of RWH. It accesses the physical condition of the system.

While many studies concentrates on the design aspect of RWH, (Ghisi (2009), Sturm *et al.* (2009), Su *et al.* (2009), Moore *et al.* (2008), Lau *et al.* (2005)), this study is compliments the other study as mentioned. The existing condition provides useful information for the maintenance team to evaluate the performance of RWH for their building. The physical condition evaluation is part of asset management cycle in achieving optimum asset benefits, as outlined by Dasar Pengurusan Aset Kerajaan (DPAK). This is in support to the intention of Malaysian government in achieving the success of Total Asset Management (TAM).

Maintenance performance is key aspect in sustaining the RWH system. With the initial investment in installing the RWH, the organization must be able to monitor their investment in the form of maintenance performance. This will ensure the building owner achieves the value for money. The physical condition of RWH supports the ideas in tracking maintenance performance as a whole.

1.4 Objectives of the Study

The aim of this research is to improve the maintenance management of RWH in Malaysia. In addressing this aim, the following objectives have been established:

1. To overview the practice and implementation issues of RWH system in Malaysia.
2. To develop the assessment framework for RWH system in Malaysia.
3. To assess the maintenance performance of RWH system.

1.5 Research Methodology

This research used quantitative approach for data collection and data analysis. This is based on study by Casley and Kumar (1988) who described two types of data collection methods are qualitative and quantitative. Quantitative method is used to produce numerical data while qualitative method results are described in words. Sekaran and Bougie (2009) categorized data collection into primary and secondary. Primary data is defined as the information obtained directly that relates to the variables on the research for example data from questionnaire and interview whereas secondary data refer to existing sources for example company records, government publications, reference books, journal, magazine and website. The research methodologies selected for this research are based on four types of methods that are literature review, condition survey, questionnaire survey and data analysis. All the methods are important because it will become a guideline in doing this research.

1. Literature review

The methodology including all data collection and related outsource information available. For example it is from reading of journal, books, references, newspaper, internet information and etc. Besides that, other unpublished resources are also made available for supporting the literature survey. These include presentation notes, seminar paper, discussion forum as well as minutes of meeting from the relevant local authority.

2. Condition survey

Building condition survey forms part of the research methodology. It is going to be carried out in the selection of building that applies RWH. The population of the building will be drawn from the list that available from the ministry of Housing and Local Government (MHLG) and Department of Irrigation and Drainage (DID). It has to be so since the MHLG and DID are the government agency that responsible in implementing RWH system in Malaysia. The survey framework has to be first completed before embarking the site visit.

3. Questionnaire survey

The target of respondent for questionnaire survey is maintenance party such as the developer and local authority which two technical person and one management person for each building who involved directly with RWH maintenance on their building. The result from the survey will be used as "check and balance" and will complement with the condition survey result. This is to portray the real scenario in discussing the maintenance aspect of RWH.

4. Data analysis

From the condition survey and questionnaire survey, the data is going to be transformed in the numerical format as to suit with the statistical analysis. In other words, one set of numerical data will be developed, in the effort of providing descriptive statistic as well as inferential (if any). Condition survey is analyzed based on CSP1 matrix (Che-Ani *et al.*, 2011) and questionnaire survey using Statistical Package for Social Sciences (SPSS) version 15.

1.6 Research Scope

This research limits itself to RWH projects that are in operation and managed by three government agencies only namely National Hydraulic Research Institute of Malaysia (NAHRIM), Department of Irrigation and Drainage (DID) and Local Authority (LA). This is because these three government agencies are the main implementer of RWH for government projects. The projects are located nationwide and that involved in various types of building. However, this research excluding RWH projects in Sabah and Sarawak due to the number of projects is too small. This will not bring any adverse impact to the credibility of the results. Moreover, almost all of the population for this study is located in Peninsular Malaysia. Statistically there are forty-six projects and only three projects located outside Peninsular Malaysia.

1.7 Research Outline

The research outlines represent the summary for the whole content of this report. It describes the workflow of overall research process. This report is arranged in six chapters.

Chapter one deals with the background and introduction of the research. The research question is given as to drive the research process. Brief research concepts and methodology is explained as to give an overview on how the research is carried out to determine the maintenance of RWH system in Malaysia.

Chapter two and chapter three form as literature review in this study. Chapter two discusses the concept of RWH. It reviews the background and elements of RWH, as well the practices in the world generally and Malaysia specifically. It also reviews the implementation issue of RWH system in Malaysia. Chapter three specifically looks on the conceptual development of RWH maintenance evaluation. The RWH maintenance evaluation practices have been interprets before stressed on the developing of RWH maintenance evaluation framework.

Chapter four explained about research methodology adopted in developing the instrument. It starts with the population and formulation of research instrument. The data collection and analysis technique is discussed afterwards.

Chapter five looks into the data analysis of primary data collection until the performance measurement. Discussion of findings also provided to explain the current scenarios of maintenance of RWH system in Malaysia.

After considering all the key points, it is then highlighted in chapter six. The discussion about research question is described as to determine its achievement in relation to the study. The recommendations are also provided to improve the existing scenarios of the maintenance of RWH system in Malaysia.

1.8 Significance of the Study

In the mission to become developed country in 2020, the sustainable architecture must be put in a forefront. This in line with the other develop nation in the world. RWH technology is part of the sustainable architecture and it has to be combined with the theory of building performance. Having this in line, the focused evaluation of RWH must be carried out. This is also to ensure RWH can sustain in the whole building life cycle as well as makes our investment worthwhile. While the other scholars discussing about the design of the RWH, this research compliment the idea by putting itself in the continuation of the system.

Therefore this research becomes significant from the perspective of;

a. *Academic society*

The theory of building performance is ongoing demand within the academic society. This theory basically covers across the board of built environment process. Maintenance technology is part of the theory of building performance that has been developed by Preiser and Vischer (2004). In focusing the maintenance aspect of RWH, it will contribute into the advancement of building performance theory. Furthermore, the assessment framework will become one of the parameter in focused evaluation.

b. Policy Maker

The result of the study will become a reference point for the MHLG in upgrading the guidelines for implementation of RWH system. The actual condition of RWH system will reflect the true scenario of the system, as well as making some indicators of the real life performance of RWH. It also supports the government agenda in realizing the maintenance culture particularly for the government property. It will also highlight, the maintenance aspect of RWH, which cannot be ignored and it has to be performed by the professional team.

c. Practitioner

Since RWH system is in the government agenda, the building industry consultant should also involve as a state holders. The maintenance data can be used by the consultant in improving their design for the future similar project in nature. To some extent, the consultant can use the assessment framework (that is developing in this research) for the purpose of evaluating their design performance. These will portray the good image of the consultant as putting their self in tracking the performance of RWH, which is not limited to design responsibility only.

1.9 Summary

This chapter discussed the background and basic concepts of this research. These include the research objectives, research foundation, previous research about RWH and techniques of data collection and analysis. Research statement and research question also has been highlighted to determine the research objectives and importance of the study.

The following chapter two will discuss on the concept of RWH, RWH practice in the world and in Malaysia. The RWH implementation issue in Malaysia also will be highlighted before the end of this chapter.

CHAPTER TWO

RAINWATER HARVESTING PRACTICE AND IMPLEMENTATION

2.1 Preface

All over the world, rainwater harvesting (RWH) systems has been used for thousand years ago especially for the areas where water supply has been limited by climate or infrastructure. Either internationally or locally, this system not only seen as a solution to solve water problems but it also to support sustainable building which has been widely promoting in every country. The benefits of harvesting rainwater are not only domestic or agricultural, but they extend to the control of local floods, the replenishment of underground aquifers and the prevention of soil erosion (Dlamini, 2004).

In Malaysia, the Green Building Index (GBI) has set up green rating tool for building in order to promote sustainability in built environment. RWH is one of the rating tools under water efficiency and carry 10% of the total score for non-residential building and 12% for residential building (GBI, 2011).

The purpose of this chapter is to introduce the RWH practices in context locally and internationally. It covers the previous research about RWH and discussion on the concept of RWH including the background and element of RWH. It follow by identify the RWH practice in the world and in Malaysia and the RWH implementation issue in Malaysia before summarizing all the key points.

2.2 An Overview of Rainwater Harvesting System in Malaysia

Malaysia is blessed with an ample supply of water tanks to abundant rains. However, increasing usage of water by industry, in agriculture, commercial and by household users is straining the existing water supply infrastructure. Alternative water supply may help to overcome the situation.

According to Sehgal (2005), at present Malaysia is primarily depend upon rainwater that falls over the hills and in the countryside and which is then collected into large reservoirs and as ground water. This water is then pumped into treatment plants and from there distributed through the water mains and a network of pipes. However the history of rainwater harvesting in tropical parts of Asia can be traced back to about the 9th or 10th century to the small-scale collection of rainwater from roofs and simple brush dam constructions in the rural areas of South and South-East Asia. Rainwater collection from the eaves of roofs or via simple gutters into traditional jars and pots has been traced back to almost two thousand years in Thailand. Rainwater harvesting has also long been used in the Loess Plateau Regions of China.

Perhaps there is need to review the water harvesting techniques in realm of modern technology by considering the fact that clean water is also being delivered right on roof tops as rain but in absence of proper water management it run off into storm water drains. This further ends up causing flood and soil erosion on its way to the rivers and sea. In fact, the rainwater falling on rooftops is one of the purest forms of natural water that nature provides us, yet we simply let it flow away.

Malaysia receives plenty of rainfall throughout the year and because of that Malaysia experiences a wet equatorial climate regime. In fact, there is no distinct dry season in any part of the country (Weng *et al.,* 2006). Malaysia has an average rainfall around 3,000 mm a year - Peninsular Malaysia averaging 2,420 mm; Sabah averaging 2,630 mm and Sarawak averaging 3,830 mm (Salmah and Rafidah, 1999).

The main rainy season in the east runs between November and February, while August is the wettest period on the west coast. East Malaysia has heavy rains (November to February) in Sabah and in Sarawak. Based on an average annual rainfall of about 3,000 mm per year, Malaysia is endowed with an estimated total annual water resource of some 990 billion cubic meters (BCM) which is one BCM is equal to one million mega liters (Keizrul, 2002).

Presently, the existing water supply systems have improved but the demand is increasing due to the population growth and expansion in urbanization, industrialization and irrigated agricultural. The prolonged dry period due to global weather change can be considered as another factor effecting water supply. The available water resources are limited and/or seasonal which made the experts working in the water sector to search for solution to the water shortage (Thamer *et al.,* 2007). A systematic support to local innovations on rainwater harvesting could provide substantial amounts of water and reduce demand on water supply systems.

Based on the mentioned potential and statistic, Sehgal (2005) suggest the following benefits of RWH, namely independent and ample supply of water in the dwelling; water received is free of costs and the use of this water significantly reduces water bills for purchased water from municipal supply; costs incurred for purifying the water for potable use are nominal; and for users located in the rural areas, an independent supply of water avoids the cost of installing a public water supply system. On the whole, the benefit of rainwater harvesting is in the form of environmental and governmental benefit (Sehgal, 2005).

a) Environmental benefits

Harvesting rainwater is not only water conserving, it is also energy conserving since the energy input requires to operate a centralized water system designed to treat and pump water over a vast service area is by-passed. By capturing water directly, we can significantly reduce our reliance on water storage dams. This places less stress on these water storage facilities and can potentially reduce the need to expand these dams or build new ones. Avoiding having to build additional dam reservoirs consequently avoids ecological damage to the area to be submerged. Rainwater harvesting lessens local soil erosion and flooding caused by the rapid runoff of water from impervious cover such as pavements and roofs as some rain is instead captured and stored. A reduced level of storm water requires smaller sized storm water drainage systems and also helps in reducing soil erosion into the waterways, preventing damage to the surrounding areas. Secondary use of grey water (water once used in showers and rainwater itself) further reduces the need for processing effluent water in treatment plants before discharge into the waterways.

b) Governmental benefits

Reduce the burden for new investment to build, operate and maintain additional water supply systems such as reservoirs, water treatment plants and distribution systems necessary to meet the ever-increasing demands for water. It also saves on land area committed to store water in artificial lakes built for the purpose.

2.3 Previous Research About Rainwater Harvesting

Rainwater harvesting (RWH) system is a technology used for collecting and storing rainwater from catchment area such as rooftop or other purpose built catchments, the collection of sheet runoff from man-made ground or natural surface catchments and rock catchments for domestic, industry, agriculture and environment use. This system has been categorized as one of traditional technology water supply system (Gould, 1999). The systems can be categorized as small, medium and large scale (Gould, 1999). Normally, the size of rainwater harvesting was based on the size of catchment area (Thamer *et al.,* 2007). The water then can be utilized for both potable and non-potable requirements.

In scientific term, RWH refers to collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of loses through evaporation and seepage and all other hydrological studies and engineering interventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit as a watershed (Agrawal and Narain, 1999). Shaaban and Huang (2007) basically described the category of RWH as in Figure 2.1.

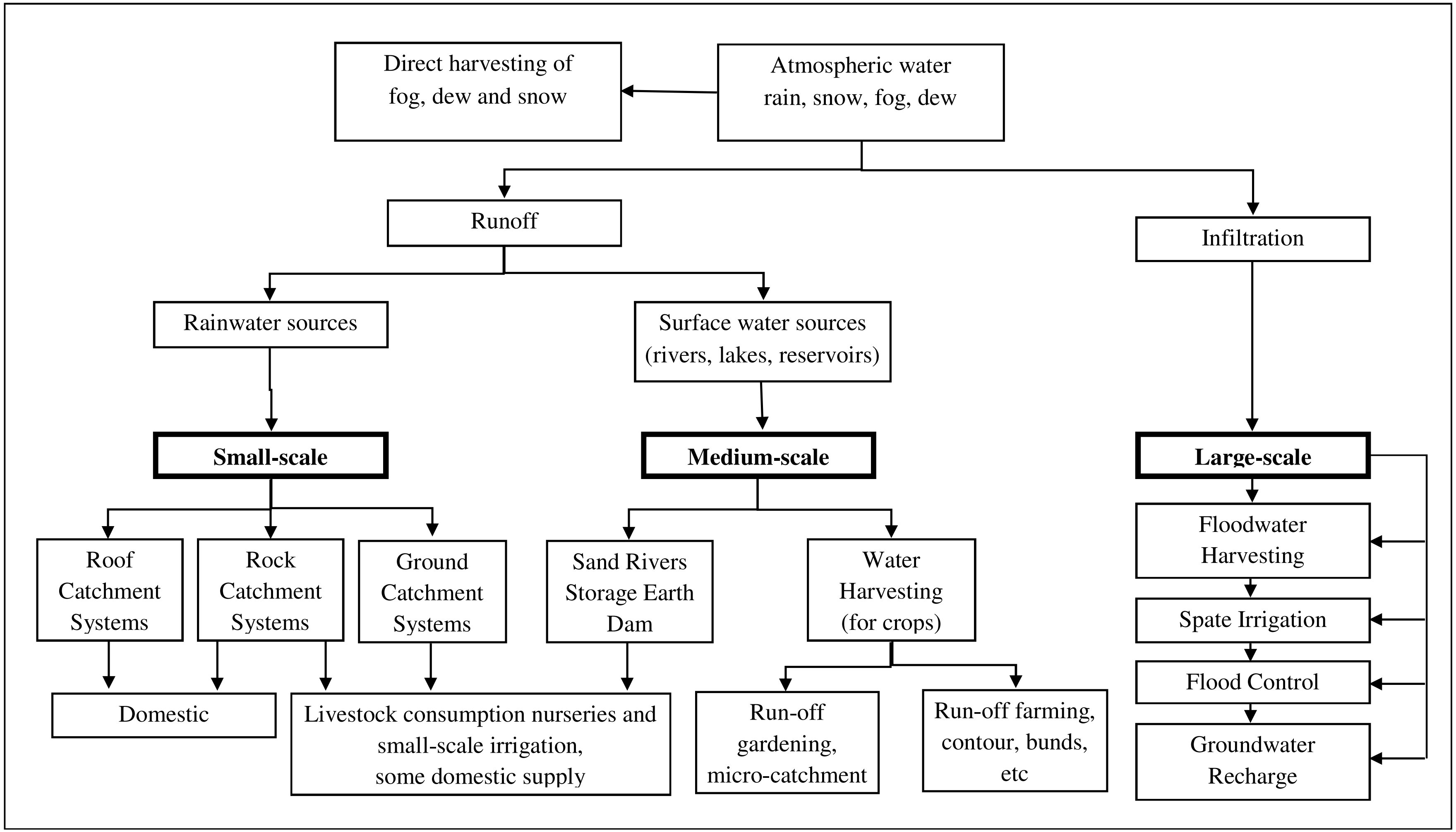

Figure 2.1: Rainwater Collection Category
Source: Shaaban and Huang, 2007

In Malaysia, the system has been used especially in rural area for few decades by our ancestors. However, only in 1998 after long drought and Malaysia facing serious water crisis, the Minister of Housing and Local Government (MHLG) has expressed the government's interest for houses to be designed to include facility for collecting rainwater (Shaaban and Huang, 2007). In 1999, the MHLG has produced a 'Guideline on Installing a Rainwater Collection and Utilization System'. This can be seen as the initial phase of the rainwater harvesting policy in Malaysia. The main purpose of this guideline is to reduce the dependency on treated water and provides a convenient buffer in times of emergency or a shortfall in the water supply. It also proposed the construction of 'mini dams' or rainwater tanks in urban areas instead of continuing to build giant dams upstream (Othman *et al.,* 2007). This guideline is intended as an 'ideal manual' for reference for those who want to install a rainwater harvesting and utilization system (MHLG, 2008).

After five years implementation of this guideline in 2004, the MHLG has prepared another cabinet paper to the National Water Resources Council to encourage government buildings to install a rainwater collection and utilization system. The Council has later announced that rainwater utilization is to be encouraged, but not mandatory. The Department of Irrigation and Drainage (DID) and The Ministry of Energy, Green Technology and Water (KeTTHA) were the two government agencies that implement the rainwater harvesting system in the early stage. The acceptance on rainwater harvesting system in the beginning is not good enough. Only few areas like Sandakan and Shah Alam that have introduced rainwater harvesting system in new housing developments (Othman *et al.,* 2007).

National Hydraulic Research Institute of Malaysia (NAHRIM) was established under Ministry of Natural Resources and Environment in 2004 is also one of the agencies that carried out pilot projects for rainwater harvesting system. The projects are (i) double storey terrace house located at Taman Wangsa Melawati, Kuala Lumpur, (ii) Taman Bukit Indah Mosque, Ampang and (iii) Headquarters of the Department of Irrigation and Drainage, Kuala Lumpur (Shaaban and Huang, 2007). In supporting of the Government's interest in Rainwater harvesting system, NAHRIM also actively involved in designing and installing rainwater harvesting system for several schools (Othman *et al.,* 2007).

In 2005, the Federal Constitution has transferred all matters related to water supply services from State List to Concurrent List (Othman *et al.,* 2007). This enable the Federal Government involvement in the water services sector and to establish regulated water services industry. Due to this, KeTTHA has come up with two new water related laws namely Water Services Industry Act 2006 and Water Services Commission Act 2006. Through this act, the ministry is actively involved in the water saving programs which encouraging rainwater harvesting system implementation.

In term of previous researches either locally or internationally, generally there are related to rainwater harvesting system based on seven main areas namely the rainwater usage, rainwater quality, the design of RWH, parties involved in RWH, advantages and disadvantages of RWH, the application of RWH in building and RWH technology. Figure 2.2 is shown the seven main areas of RWH. National Hydraulic Research Institute of Malaysia (NAHRIM) is an active agency in carry out research about RWH in Malaysia collaboration with few parties such as research Institute and ministry. Table 2.1 shown the previous researches in relation to the seven areas described above.

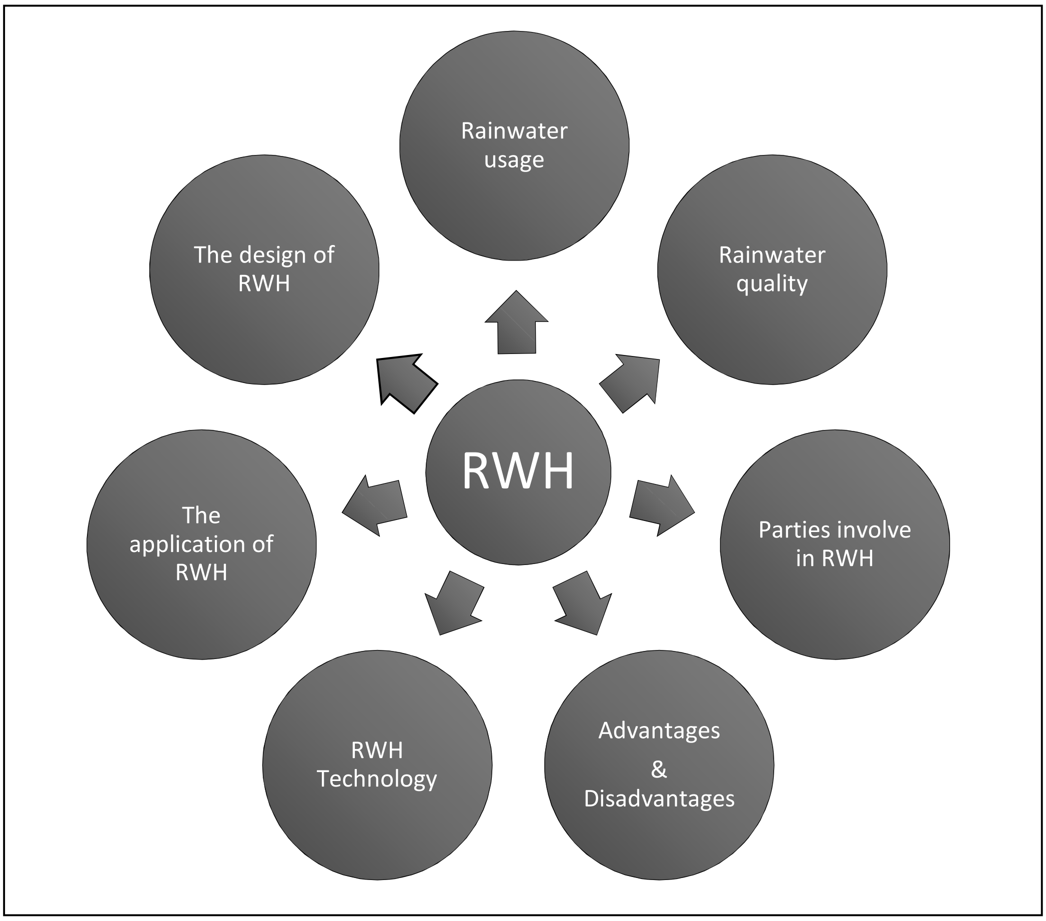

Figure 2.2: Main areas of previous researches about RWH

Table 2.1: Previous research about RWH in relation to RWH research area

No.	Author	Agency / Institution Involve	Year	Research Title	Reasearch Area
1	H. T. Ishaku, M. R. Majid and F. Johar	Dept. of Urban and Regional Planning, Faculty of Built Environment, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia	2012	Rainwater Harvesting: An Alternative to Safe Water Supply in Nigerian Rural Communities	• The application of RWH
2	Md. Manzurul Islam, F.N.F. Chou, M.R. Kabir, C.H. Liaw	Department of Hydraulic and Ocean Engineering, National Cheng Kung University, 1 University Road, Tainan, Taiwan 70101	2010	Rainwater: A Potential Alternative Source for Scarce Safe and Arsenic Contaminated Water in Bangladesh	• Rainwater quality • RWH Technology
3	O.O. Aladenola, O. Adeboye	Department of Bioresources Engineering, Faculty of Agriculture and Environmental Sciences, McGill University, Montreal, QC, Canada	2010	Assessing the Potential for Rainwater Harvesting	• RWH Technology • The application of RWH
4	E. Ghisi	Laboratory of Energy Efficiency in Buildings, Department of Civil Engineering, Federal University of Santa Catarina, Florianopolis, SC, 88040-900, Brazil	2009	Parameters Influencing the Sizing of Rainwater Tanks for Use in Houses	• RWH Technology • The design of RWH
5	Che-Ani A.I, Shaari N, A.Sairi, M.F.M. Zain, M.M. Tahir	Dept. of Architecture, Faculty of Enginerring and Buit Environment, Universiti Kebangsaan Malaysia (UKM), 43600 UKM Bangi, Selangor, Malaysia	2009	Rainwater Harvesting as an Alternative Water Supply in the Future	• RWH Technology • The application of RWH
6	B. Helmreich, and H Horn	Institute of Water Quality Control, Technische Universität München, Am Coulombwall, 85748 Garching, Germany	2009	Opportunities in Rainwater Harvesting	• Rainwater quality • RWH Technology

7	M. Sturm, M. Zimmermann, K. Schütz, W. Urban and H. Hartung	Technische Universität Darmstadt, Institut WAR, Chair of Water Supply and Groundwater Protection, Petersenstr, 13, 64287 Darmstadt, Germany	2009	Rainwater harvesting as an alternative water resource in rural sites in central northern Namibia	• The design of RWH • RWH Technology
8	Ming-Daw Su, Chun-Hung Lin, Ling-Fang Chang, Jui-Lin Kang and Mei-Chun Lin	Dept. of Bioenvironmental Systems Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, 10617, Taiwan	2009	A probabilistic approach to rainwater harvesting systems design and evaluation	• The design of RWH • Rainwater usage
9	Moore D.R., Mclean S.N.	School of Architecture and Built Environment, The Robert Gordon University	2008	Appraisal of the Requirements for Establishing Domestic Roof Rainwater Harvesting Schemes in Bangladesh	• The design of RWH • RWH Technology • Rainwater usage
10	Thamer Ahmed Mohammad, Megat Johari Megat Mohd. and Noor, Abdul Halim Ghazali	Department of Civil Engineering, Faculty of Engineering, Universiti Putra malaysia	2007	Study on Potential Uses of Rainwater Harvesting in Urban Areas	• Potential of RWH • Advantages of RWH • Rainwater Quality
11	Ahmad Jamaluddin Shaaban and Huang Yuk Feng	National Hydraulic Research Institute of Malaysia (NAHRIM)	2007	NAHRIM’s Experiance in Rainwater Utilisation Systems Research	• The application of RWH • Advantages of RWH
12	Baharuddin Abdullah	Head, Department of Water Quality and Environment, NAHRIM	2007	Water Quality Monitoring of NAHRIM Rainwater Station	• Rainwater Quality
13	Kamaruddin Che Lah and Rosnani Mahmod	Majlis Perbandaraan Seberang Perai	2007	Project Experiance on Rainwater Harvesting System	• The application of RWH
14	Ahmad Jamaluddin Shaaban, Huang Yuk Feng and Kamarul Azlan Mohd Nasir	National Hydraulic Research Institute of Malaysia (NAHRIM) and Universiti Teknologi Malaysia (UTM)	2007	Potential and Effectiveness of Rainwater Harvesting in Enhancing the Effectiveness of on-site Detention (ROSD) Facilities in Controlling Surface Runoff at Taman Wangsa Melawati, K.Lumpur	• Rainwater usage • The application of RWH
15	Othman M.S.; Suhaimi A.R.; Rasyikah M.K.; Ahmad Jamaluddin	National Hydraulic Research Institute of Malaysia (NAHRIM), Universiti Putra Malaysia (UPM), Universiti	2007	Policies and Incentives for Rainwater Harvesting in Malaysia	• The Application RWH • RWH Technology • Parties involve in RWH

	S.; Huang Y.F.; and Farah M.S.	Teknologi Mara (UiTM) and private lawyer			
16	Abd Mutalib Mat Hassan and Rozman Mohamad	Department of Irrigation and Drainage (JPS)	2007	Rainwater Harvesting – DID Experiance	• The Application RWH
17	Tan Choo Lan	Department of Building Control, Ministry of Housing and Local Goverment	2007	Policies, Implementation and Public Awareness on Rainwater Harvesting Systems	• The Application of RWH
18	Ruslan Hassan	Universiti Teknologi MARA (UiTM)	2007	Rainwater Harvesting: Reliability Analysis for Large Building: Factory, Government and Commercial Complexs	• RWH Technology • The Application RWH
19	Fayez A. Abdulla and A.W. Al-Sharee	Water Resources and Environmental Engineering Program, Civil Engineering Department, Jordan University of Science & Technology, PO Box 3030, Irbid 22110, Jordan	2006	Roof rainwater harvesting systems for household water supply in Jordan	• Rainwater Quality • Rainwater Usage
20	Tze Liang Lau, Taksiah A. Majid, Kok Keong Choong, Nor Azazi Zakaria and Aminuddin Ab. Ghani	Universiti Sains Malaysia (USM)	2005	Study on a High Rise Building Incorporated with Rainwater Harvesting Storage Tank Towards Building a Sustainable Urban Environment in Malaysia	• The design of RWH • The Applications of RWH

Othman *et al.* (2007) has work out the policies and legal aspects of RWH implementation and concluded about adoption of RWH in Malaysia as;

1. It is recommended that a combination of the methods such as RWH practice should not only supplementary but it should be mandatory on the people and parallel to it enacting legislations and providing detailed guidelines to their system in order to be more authoritative and organized.
2. It is recommended that rainwater harvesting is introduced, initially on a small scale, to assess public reaction. Since Malaysians are known to be slow in accepting drastic changes, of measures could cause rainwater harvesting to fail. Monetary or economic incentives like cash or tax rebates and subsidiaries in purchasing or installing rainwater harvesting devices should be introduced to attract interest of members of the public.
3. Furthermore, education and awareness campaigns should start from the early stages to instill a sense of awareness. This may be included in the water and energy conservation topics under the environment subject in the school curriculum. As a matter of fact, the younger generation is the generation of the future. Thus, they should be equipped with proper knowledge to which is energy and water efficient, as well as environmentally sustainable.

Rainwater and floodwater harvesting have the potential to increase the productivity of arable and grazing land by increasing the yields and by reducing the risk of crop failure. They also facilitate afforestation, fruit tree planting or agroforestry. With regard to tree establishment, rainwater and floodwater harvesting can contribute to the fight against desertification. Most of these techniques are relatively cheap and can therefore be a viable alternative where irrigation water from other sources is not readily available or too costly. Unlike pumping water, water harvesting saves energy and maintenance costs. Using harvested rainwater helps in decreasing the use of other valuable water sources like groundwater. Remote sensing and Geographical Information Systems can help in the determination of areas suitable for water harvesting (Prinz *et al.,* 1998).

Rainwater harvesting should suit its purpose, be accepted by local population, and be sustainable in local environment. In dry areas (and without storage facilities), field crops with deep rooting and drought resistant trees constitute the most promising application (Boers, 1997).

The decision making process concerning the best method applicable in particular environmental and geo-physical conditions depends on kind of crop to be grown in prevalent socio-economic and cultural factors. Local availability of labor and material are the most important factors. The accessibility of the site has also to be considered for construction of water harvesting structures and distance from village. There are number of studies reports that rainwater harvesting can be economically profitable (Rodriguez, 1996) for example in Highland Balochistan, Pakistan - wheat grown under micro-catchment water harvesting is more viable and profitable than any of the traditional methods.

Prinz and Singh (1999) have work out the comparison between water harvesting techniques and the construction of large or medium dams shows that:

a. Through the introduction of water harvesting, water resources in upstream watershed can be managed more efficiently.

b. Water harvesting can supplement irrigation water supply during water scarcity or low water availability periods. Its proximity to cropping area can be an important point in improving water use efficiency and avoiding field losses.

c. Water harvesting may be of small scale but certainly have edge over dams due to its suitability for immediate local environment, they are labor intensive (local employment generating), democratic and participatory in nature.

d. With the small scale of water harvesting technology, no foreign investment is needed (but banking facilities are sometimes needed).

e. Some of the benefits of large dams like generating hydropower energy, supplying drinking water for big cities and others, cannot be offered by water harvesting.

f. Water harvesting to be successful requires local capacity building and agriculture extension services, training and credit facilities for resources users, co-operation and extensive participation.

Based from discussion above, it shows that the research focus is less emphasizes on the post-construction stage for example maintenance part of rainwater harvesting system. The equal importance has to be taken into consideration on maintenance as to minimize the abandon and 'white elephant' rainwater harvesting project.

2.4 The Concept of Rainwater Harvesting

Rainwater harvesting is simply collecting, storing and purifying the naturally soft and pure rainfall that fall upon the roof. Rainwater may be utilized for both potable and non-potable requirement such as drinking, cooking, laundry and landscape irrigation. The application of an appropriate rainwater harvesting technology can make possible through the utilization of rainwater as a valuable and necessary water resource. Rainwater harvesting (RWH) system is an economical small-scale technology that has the potential to augment safe water supply with least disturbance to the environment, especially in drier regions (Ishaku *et al.*, 2012). It also necessary in areas having significant rainfall but lacking of centralized government supply system. It is also suitable to use in areas where good quality fresh surface water or groundwater is lacking.

The concept of rainwater harvesting varies from region to region however the overall concept for adoption RWH is précised well by Southface Energy Institute (2002), mentioned as under;

a. Save money
b. Save water
c. Save energy
d. Reduce erosion and storm water run-off and increase water quality

Save money, avoid the increasing economic and environmental costs associated with purchasing water from the centralized water system. Operating costs are lower than the cost of purchasing water from the centralized water system.

Save energy, by reducing water use, energy demands to pump water from the water treatment plant to the service area are reduced too. The number of newly built polluting power plants will also decrease as a result of collecting rainwater.

Save water, reduce the demands on scarce surface and ground water sources. Reuse water instead of pulling from the water table (or a freshwater source). Centralized water systems and wells pull from the water table.

Reduce erosion and storm water run-off and increase water quality, capturing the rain that falls on roofs reduces flash floods and household storm water runoff. Less storm water run-off may reduce the storm water collection fee for the household and will certainly improve the health, quality, biodiversity of our watersheds, and replenish the water table (or our freshwater supply).

2.4.1 The Background of Rainwater Harvesting

Gathering of rainwater by using roofs, reservoirs and other collectors is called rainwater harvesting. It is not a modern concept, according to Mahmud *et al.* (2008) in ancient Egypt and Rome, rainwater was harvested by reservoir and canal, and was used for domestic purposes, cultivation, irrigation and in primitive small industries. For centuries throughout the world, people have still relied on rainwater harvesting to supply water for household, landscape, livestock, and agricultural uses. Before large, centralized water supply systems were developed, rainwater was collected from a variety of surfaces, most commonly roofs and stored on site in tanks known as cisterns. With the advent of large, reliable community treatment and distribution systems and more affordable well drilling equipment, rain harvesting systems have been all but forgotten, even though they offer a source of pure, soft, and low sodium water.

However a renewed interest in this time-honored approach has emerged due to the escalating environmental and economic costs of providing water by centralized water systems or by well drilling; health concerns regarding the source and treatment of polluted waters; a perception that there is cost efficiencies associated with reliance on rainwater.

The tropical region of world and heavy monsoon rains regions make rainwater harvesting a viable option for flushing and drinking water. The common people's experience may not be adequate and systematic to suit a preconceived notion of a system, but people do know that their forefathers, albeit in a limited way, did rely on rains during heavy showers.

Many countries in the region such as India, United States, Japan, China, Germany and Australia have proven systems of rainwater harvesting really works (Misra, 2011). Efforts to promote rainwater harvesting should build on these experiences gradually in improving tank design, fittings and costing to suit socio-economic environment around the globe.

However the demonstration and promotion of rainwater harvesting systems that build on common and existing experiences is likely to meet general acceptance. In fact more focus has been given on the household systems and the storage of rainwater to meet the total needs but there is need to establish the water saving criterion in commercial buildings too.

2.4.2 The Element in Rainwater Harvesting System

Rainwater harvesting system has been implemented in many countries such as Canada, USA, Japan, China, India, Pakistan, Germany, Belgium and Australia to support the increasing water demand. The integration between rainwater harvesting system and existing conventional water supply systems will help to meet the demand and contribute in the sustainability of the water supply.

There are six main elements in rainwater harvesting system as in Figure 2.3. There are catchment area, gutter and downspout, filtration system, storage system, delivery system and treatment.

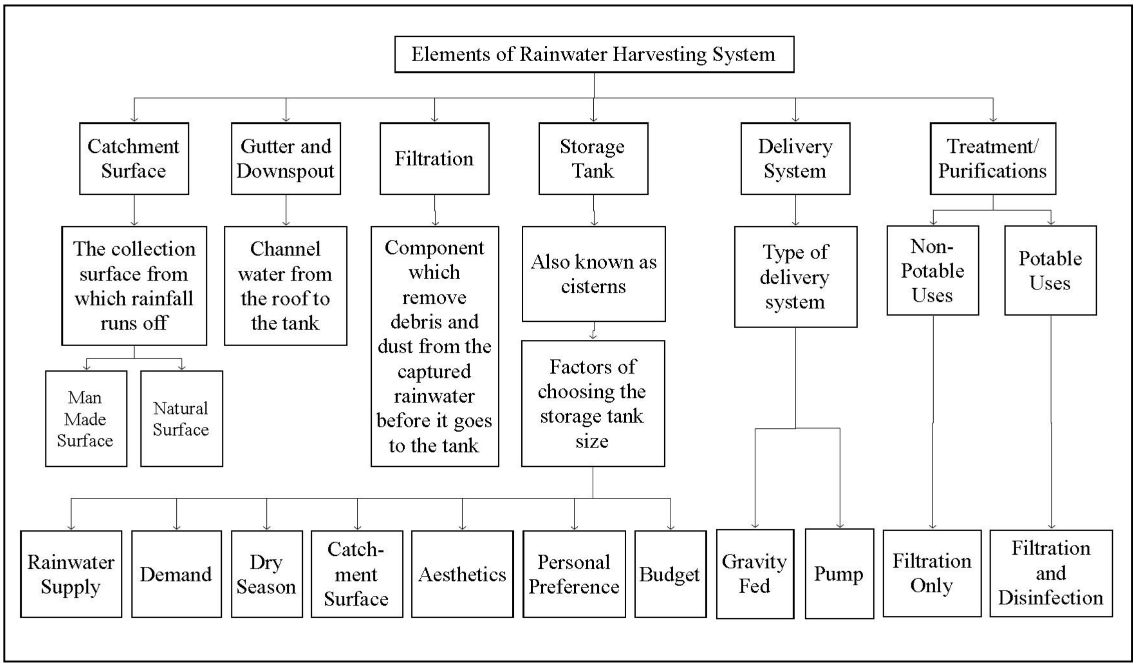

Figure 2.3: Elements of Rainwater Harvesting (RWH) System
Source: Shaaban and Huang, 2007

a) Catchment Surface

The catchment surface of a rainwater harvesting is the surface which receives rainfall directly. Obviously the roof of a building is the first choice for catchment surface. Besides that, it also can be a paved area like a terrace or courtyard of a building. According to Guidelines for Installing a Rainwater Collection and Utilization System 1999 by MHLG, the roof surfaces should be chemically inert materials, such as concrete tiles, metal deck and others, in order to avoid adverse effects on water quality. Besides that, maintenance of the rainwater utilization equipment is very importance. The trash and animal excreta in catchment surface must be cleaned off regularly to prevent down pipe clogging.

b) Gutter and downspout

Conveyance system is including the down pipes and gutter that carry rainwater from the catchment area to the harvesting system. Down pipes and gutter may be of any material like polyvinylchloride (PVC), asbestos or galvanized iron (GI). Besides that, when using the roof of a building as catchment surface, it is important to consider about size of catchment area, slope of the roofs, and intensity of rainfall. The location and size of gutter and down pipes should be able to capture all the water at that point.

In addition, gutters should be installed with the slope towards the down pipes; also the outside face of the gutter should be lower than the inside face to encourage drainage away from the building wall. In general, the debris and leaves inside the gutter need to be cleaned always.

c) Filtration

A roof act as a catchment surface to collect rainwater, at the same time can also be a natural collection surface to the dry leaves, dust, debris, twigs, insert bodies and other airborne residues. The filtration system is necessary for rainwater system to prevent leaves, dirt or sand coming together into the down pipe and the rainwater storage tank. This entire system is function to keep the collected rainwater quality in a useable level.

There are many types of filtration system, it can be a chamber or a first flush diverters. The simplest first-flush diverter is a PVC standpipe (Figure 2.4). The standpipe fills with water first during a rainfall event and the balance of water is routed to the tank. The standpipe is drained continuously via a pinhole or by leaving the screw closure slightly loose. In any case, cleaning of the standpipe is accomplished by removing the PVC cover with a wrench and removing collected debris after each rainfall event (Texas Water Development Board, 2005).

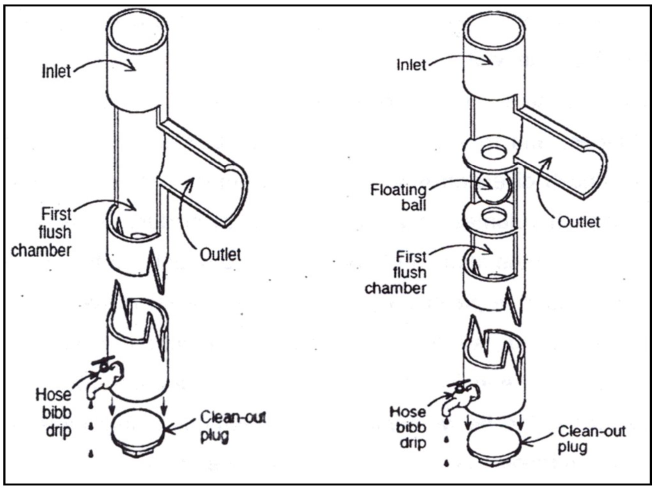

Figure 2.4: Examples of first flush diverters
Source: The Texas Manual on Rainwater Harvesting, 2005

d) Storage tank

Storage tank is the rainwater component which has taken most space. The size of storage tank is dictated variably. The quantity of water to be stored in rainwater system is depends on the size of the catchment area and the size of storage tank. The storage tank has to be designed according to the water requirements, rainfall and catchment availability. The tanks should be located as close to supply and demand points as possible to reduce the distance water is conveyed. Besides that, the tank location also can be very flexible, like elevated, above ground, and underground.

e) Delivery System

Delivery system is a component which delivers the collected rainwater to water taps for daily usage, like toilet flushing, vehicle washing, garden watering and others. According to Southface Energy Institute, the following are five elementary considerations for RWH;

a. Type of Cistern
b. Location of Cistern
c. Conveyance System
d. Distribution system

Type of Cistern

The size of the cistern depends on the amount of water to be collected and cost restraints. Choose a cistern that fits the needs of the water harvesting system. Collecting a small volume of water is better than collecting none. All cisterns should be watertight, durable, and have a clean, smooth interior. The cover needs to be tight fitting to prevent evaporation. A cistern with a lid allows for easy access to attach a faucet and to occasionally clean inside. It is best to place the cistern out of direct sunlight to prevent algae and bacteria growth, which can clog the system. The use of two or more smaller cisterns enables service on one unit at a time without disrupting the entire system.

i. Location of cistern

- Place the cistern at a high point on the lot and elevate approximately three to four feet on a sturdy, load-bearing foundation or structure. This creates enough pressure to use gravity for running the water through a hose, soaker hose, or drip irrigation system to the landscape. Foundations can be made of bricks, concrete, or a wood frame. A full fifty-five gallon cistern will weigh around five hundred pounds.
- Above ground cisterns are less expensive than a below ground cistern and easier to maintain. With this system it is easy to take advantage of gravity to guide water throughout the irrigation system.
- Below ground cisterns are good for colder climates. Storing water below ground can have aesthetic appeal while keeping the water out of the sun.

Underground systems require a more complicated design and a pump to achieve gravity irrigation. Below ground systems tend to be used primarily in commercial sites due to the additional cost of pumping.

ii. Conveyance system

- Install continuous leaf screens, made of one quarter inch wire mesh in a metal frame, above the gutters to prevent debris from entering the system.
- Place a basket strainer (for example a screen or wire basket) at the top of the downspouts (optional). Make the downspout out of four inch diameter Schedule forty PVC pipe or comparable piping. Angle bends should not exceed forty-five degrees. Slope the piping at one-quarter inch slope per foot minimum.
- Adapt the gutter to PVC piping with a downspout adapter.
- Place pantyhose or other filtering system before the head of the cistern to filter out debris from the roof.

iii. Distribution system

- Place a faucet near the bottom of the cistern with a hose connection. Do not place at the very bottom because sediment will build up here.
- Drill a hole into the cistern for the connection and install a ball valve. Seal the area completely around the hole with aqua or water resistant sealant. (Sealant can be purchased at a hardware or pond supply store).

- Enough pressure is generated to run soaker hoses and drip irrigation systems from a cistern that is elevated four feet. A pump may be needed to create enough pressure to run sprinklers, which require a higher amount of pressure.

2.5 Rainwater Harvesting Practice in The World

a. Canada

Seters (2008) has brief about the status of RWH in Canada as, the ancient practice of collecting rainwater from roofs and using it to satisfy daily water needs has undergone a renaissance in the Greater Toronto Area (GTA) over the past few years as municipalities and building owners seek new ways to conserve water and reduce runoff. Seters (2008) further adds that, the most common uses of rainwater harvesting (RWH) system include toilet flushing, landscape irrigation, vehicle washing and laundry, but if the water is treated, the systems can also be used to supply water for drinking, bathing and dishwashing. Industries may also use harvested water for cooling and in various production processes.

Seters (2008) stressed that there are several environmental and economic benefits associated with the practice of rainwater harvesting. These include:

i. *Lower municipal energy costs:* Roughly one third of municipal energy use is spent pumping and treating water, much of it for uses such as irrigation and toilet flushing that does not require treated water.

ii. *Reduced greenhouse gas emissions and air pollution:* Less energy used in pumping water translates directly into lower emissions of pollutants and gases that contribute to global climate changes.

iii. *Delayed expenditures on new water treatment plants or existing plant expansions:* Water treatment plant expansions in Canada cost billions of dollars each year. In some municipalities, restrictions on the availability of suitable water supplies may provide an additional incentive to use rainwater.

iv. *Improved storm water management:* Utilizing rainwater to supplement municipal supplies reduces flooding, stream erosion and the pollution of waterways from storm water and combined sewer runoff.

v. *Lower consumer water bills:* Supplementing potable supplies with rainwater can reduce water bills by as much as 50% in homes and up to 80% in industrial buildings.

Adding the views about incentives and policies of local government for RWH (Brandes *et al.,* 2006) adds that in Canadian urban areas, RWH is considerably underutilized. Most large Canadian cities receive an average of 260 to 1,500 mm of precipitation annually, and have the potential to harvest this precipitation to lower domestic municipal water use by up to 50%. Report further adds that between 1994 and 1999, approximately 26% of Canadian municipalities reported water shortages due to seasonal drought.

Application RHW in High Rise Apartment in Toronto Canada

Seters (2008) study the performance of RWH mechanism in newly completed commercial and residential buildings and conducted study on buildings having RWH system. The first case study is taken as Minto Development's new high-rise residential apartment building located at 150 Roehampton Avenue in Toronto. The building is sixteen stories high with 148 suites. As the storm sewer serving Roehampton Avenue has limited capacity, the City of Toronto has requested that on-site storm water detention be implemented to maintain or reduce pre-development flows. Specifically, the city has required that the allowable discharge to the street sewer not exceed the peak runoff rate under the pre-development condition for the two year event. In addition, an overland flow route must be provided to direct runoff in excess of the five year event to an overland flow outlet. The flow volume difference between the two and five year events was to be detained on site.

b. United States

Lye (2003) records that rainwater harvesting systems are much more common in the United States, especially where there are chronic water shortages state surveys suggest that there are may be as many as 100,000 systems in use across the United States.

Texas, for instance, has had property tax relief for commercial and industrial facilities using RWH since 1993, and in 2001 a sales tax exemption was introduced for all RWH equipment (TRHEC, 2006).

The City of Austin currently offers $500 for residential RWH systems and $5,000 for systems installed in buildings owned by public agencies or organizations in the non-profit sector. The Texas Manual on Rainwater Harvesting (third edition) is an excellent example of how the technology has been adopted and can be appropriately implemented under various circumstances.

CofA (2007) adds that the cities of Portland and Albuquerque, and the States of Arizona, Ohio, Washington and Kentucky also have guidelines for designing and installing RWH system. In Santa Fe, New Mexico RWH system must be installed on all new residential buildings greater than 2,500 square feet. The State of Virginia provides a tax rebate for RWH system up to $2000, but no more than half of the cost of the system.

c. Europe

In Europe, RWH is more widely accepted and practiced than in North America. Germany has been especially proactive in this regard. In 1980, Germany legalized rainwater utilization and by 1988 Hamburg became the first German city to provide subsidies for RWH adoption. RWH systems have since become part of mainstream building practice and the subsidies are no longer offered (Koenig, 2004).

(Brandes *et al.*, 2006), adds that by year 1993, in Germany Hessen has become the first state to change its building regulations, giving local governments and communities the ability to enforce the use of RWH technology. The cities of Baden-Wurttemberg, Saarland, Bremen, Thüringen and Hamburg soon followed Hessen policy.

De Gouvello *et al. (*2005) reports about Belgium, that the country has national legislation which requires all new construction to incorporate RWH systems for flushing toilets and external water uses.

(CWWA, 2002) declares that tax credits or rebates on RWH equipment are also offered in the United Kingdom and France while RWH practice in the UK remains in its infancy, markets for the technology have grown by 300% over the past couple of years.

d. Australia

RWH systems are also being installed across Australia, with some help from government incentive schemes. South Australia has the highest percentage of households (51%) with cisterns, of which 36% use the harvested rainfall as drinking water (Diaper, 2004).

Through community water grants the Australian Government Water Fund (AGWF) gives communities up to $50,000 towards projects that will save, recycle, or improve their local water resources as part of a five year $200 million program. Further encouragement is given through state-wide programs mandating energy and water efficiency measures in new buildings.

e. India

The Central Groundwater Authority, Ministry of Water Resources, New Delhi has invited the attention of residential societies, institutions, hotels, industrial establishments and farm houses located in the notified areas in and around New Delhi to adopt the roof top rainwater harvesting system for groundwater recharge in their premises by 31st December, 2001 and if not adopted within the specified period as given above, the existing tube wells in the premises would be sealed and would also attract penal action under section fifteen of the Environment Protection Act, 1986. The notification, if followed in the right spirit would help in building up necessary storage for assured water supply in future to overcome the problem of water shortages in different parts (Sharma, 2007).

f. Pakistan

Study of Akram (2009) highlight the issues of RWH in Pakistan and its mode of adoption in arid areas of Pakistan. According to Akram, seventy million hectares of Pakistan fall under arid and semi-arid climate including desert land. Cholistan is one of the main deserts covering an area of 2.6 million hectares where water scarcity is the fundamental problem for human and livestock population as most of the groundwater is highly saline. Rainfall is the only source of freshwater source, which occurs mostly during monsoon (July to September). Therefore, rainwater harvesting in the desert has crucial importance. The Pakistan Council of Research in Water Resources (PCRWR) has been conducting research studies on rainwater harvesting since 1989 in the Cholistan desert by developing catchments through various techniques and constructing ponds with different storage capacities ranging between 3000 m^3 and 15000 m^3. These ponds have been designed to collect maximum rainwater within the shortest possible time and to minimize seepage and evaporation losses. As a result of successful field research on rainwater harvesting system, PCRWR has developed ninety-two rainwater harvesting systems on pilot scale in Cholistan desert. Each system consists of storage reservoir, energy dissipater, silting basin, lined channel, and network of ditches in the watershed.

g. Other Countries

Many countries around the world are facing water shortages. Optimization of water usage and the conservation of water as a natural resource can help to overcome water shortage. Rainwater can be used for potable and non-potable uses. The potable uses include drinking, bathing, and cooking and washing. Usually, the rainwater used for this purpose must be treated to remove the contaminants. Non-potable uses include flushing toilets, watering garden and washing floor and treatment of rainwater is not required for these purpose. (Mohammed *et al.*, 2008).

Study of Appan (2000) mention that many countries around the world are still promoting the usage of harvested rainwater for potable and non-potable uses. Examples of these countries are USA, Germany, Australia, China, and Japan. The volume of rainwater collected is different from place to place. For example and based on pilot project in Zambia, Africa, a volume of ten m^3 of rainwater was collected.

Study of Pendey *et al.* (2003) has focus on the issues of climate environment on RWH. The research of Pendey reveals that the, alteration of environment due to global weather change brings about extreme climate events such as drought and flood. But observation showed that drought and flood affected the water resources utilization for various purposes. Therefore many countries adopting strategies to conserve the available water resources including promoting the usage of rainwater harvesting technique for landscaping and agriculture. Recently, many regions around the world adopted rainwater harvesting to reduce the impact of climate change on water supply. These regions are India, South America, Arabian Peninsula, North America, Europe, and Asia-Pacific.

Needless to say that water is perhaps the scarcest commodity of the twenty first century. Highlighting the need of adoption of RWH in India Sharma (2007) mention that**,** on global scale it is assessed that over the next two decades, water use by human beings will increase by 40% and that 17% more water will be needed to grow more food for the increasing population. The world water vision commission drew attention to the "gloomy arithmetic of water" as water demand will out strip its availability. Study further reveals that the scenario of water in India is equally gloomy. When India gained independence in 1947, the per capita availability of water was 6000 cubic meters and had only 1000 bore holes in the country but today with population crossing one billion mark, the per capita availability has fallen to 2300 cubic meters which is further expected to go down to 2000 cubic meters by the year 2015 though the number of bore holes have increased to more than six million.

2.6 Rainwater Harvesting Practice in Malaysia

The volume of rainwater collected from rainwater harvesting system varying from place to place and depends on weather. In a tropical country like Malaysia it is easy to collect two m^3 in a single rain. While in Zambia, Africa only ten m^3 was collected annually from a roof of almost the same size.

Ministry of Housing and Local Government (MHLG) introduced Rainwater harvesting system after the 1998 drought. The 'Guidelines for Installing a Rainwater Collection and Utilization System 1999' can be seen as the initial phase of the rainwater harvesting policy in Malaysia. The main purpose of these guidelines is to reduce the dependence on treated water and provides a convenient buffer in times of emergency or a shortfall in the water supply. It also proposed the construction of 'mini dams' or rainwater tanks in urban area instead of continuing to build giant dams upstream (Othman *et al.,* 2007). This guideline is intended as an 'ideal manual' for reference for those who want to install a rainwater harvesting and utilization system (MHLG, 2008).

After five years of this guidelines, namely in 2004, the Ministry of Housing and Local Government has prepared another cabinet paper to the National Water Resources

Council to encourage government buildings to install a rainwater collection and utilization system. The Council has later announced that rainwater utilization is to be encouraged, but not mandatory. The Department of Irrigation and Drainage and The Ministry of Energy, Green Technology and Water (KeTTHA) are the two government agencies that implement the rainwater harvesting system in the early. The acceptance on rainwater harvesting system in the beginning is not good enough. Only few areas like Sandakan and Shah Alam that has introduced rainwater harvesting system in new housing developments (Othman *et al.,* 2007).

National Hydraulic Research Institute of Malaysia (NAHRIM) was established under Ministry of Natural Resources and Environment in 2004 is also one of the agencies that carried out pilot projects for rainwater harvesting system. The projects are (i) double storey terrace house located at Taman Wangsa Melawati, Kuala Lumpur, (ii) Taman Bukit Indah Mosque, Ampang and (iii) Headquarters of the Department of Irrigation and Drainage, Kuala Lumpur (Shaaban and Huang, 2007). In support of the Government's interest in Rainwater harvesting system, NAHRIM also actively involved in designing and installing rainwater harvesting system for several schools (Othman *et al.,* 2007).

In 2005, the Federal Constitution has been transferred all matters related to water supply services from State List to Concurrent List (Othman *et. al.,* 2007). This enable the Federal Government involvement in the water services sector and to establish regulated water services industry. Due to this, Ministry of Energy, Green Technology and Water (KeTTHA) has come up with two new water related laws; Water Services Industry Act 2006 and Water Services Commission Act 2006. In the new act, the Ministry is actively involved in the water saving programs which encouraging rainwater harvesting system implementation. Figure 2.5 shows the development of rainwater harvesting implementation development in Malaysia since 1975 until 2006.

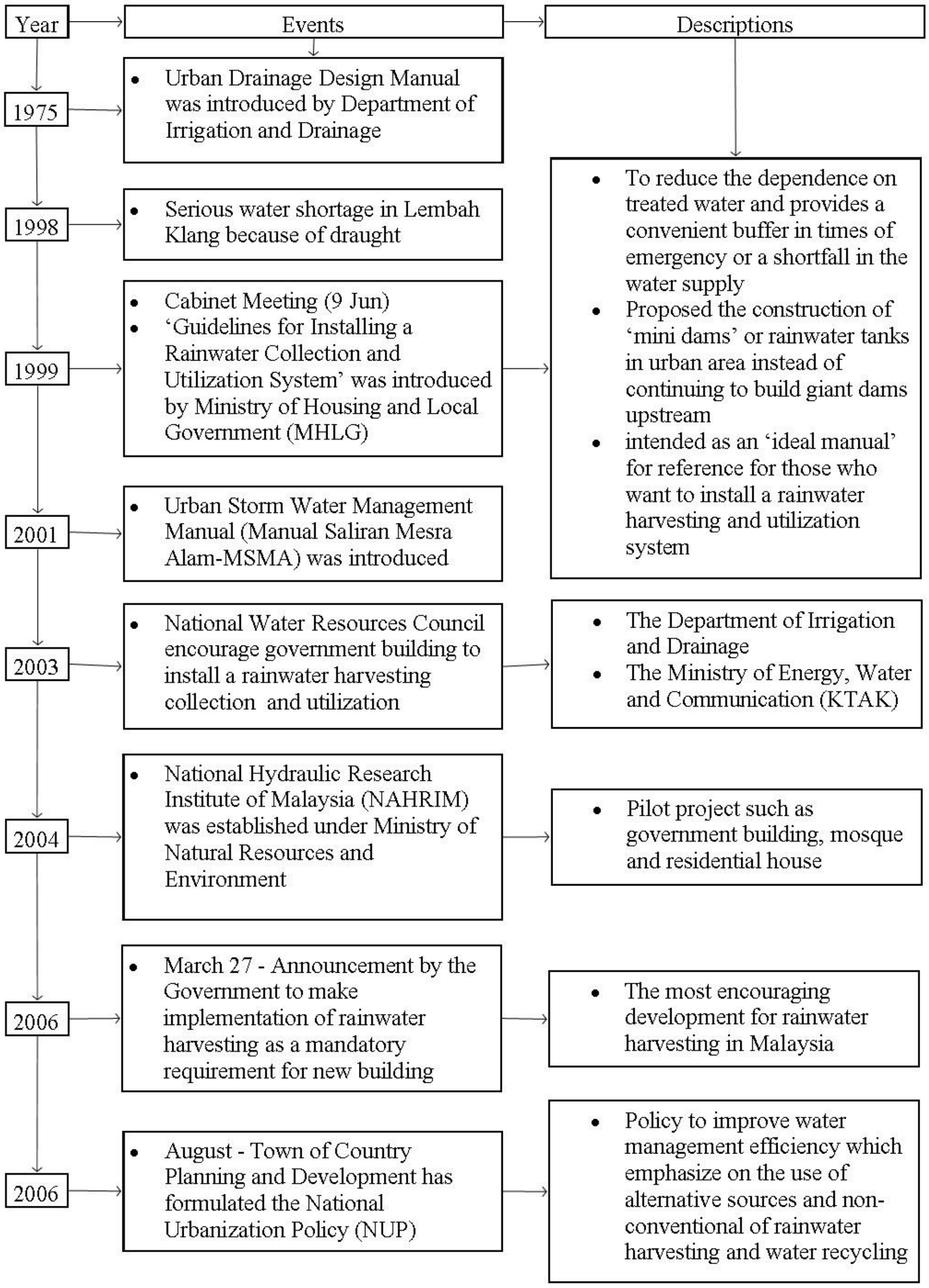

Figure 2.5: Development of Rainwater Harvesting System Implementation in Malaysia
Source: MHLG, 2008

To date, a few pilot projects have been conduct by the certain agencies such as local authorities, National Hydraulic Research Institute of Malaysia (NAHRIM) and private agencies. Table 2.2 show the list of rainwater harvesting projects in Malaysia since 1998 to present. Most of the projects involved are located in urban areas. Government buildings implement this system to support the Council and it was easy for the Council to monitor the development of this system. From the list, there are only two private buildings involved in rainwater harvesting project implementation. They are Flextronics factory and One Utama Shopping Complex.

Table 2.2: List of Rainwater Harvesting Projects in Malaysia

No.	Location		Projects	Management
1.	Selangor	1	Flextronics Factory	Private
		2	One Utama Shopping Complex	Private
		3	PKNS Housing Development – Kota Damansara	Private
		4	Bukit Indah Mosque, Ampang	Government
		5	Bungalow – Gombak	Government
		6	Zoo Negara, Hulu Kelang	Government
		7	Phase 5 Mix Development, Puncak Alam	Private
		8	Housing – Taman Seri Pristana	Private
		9	Api-api District Mix Development, Taman Bendahara	Private
		10	Kuala Selangor City Development, Taman Desiran Malawati	Government
		11	Ijok District Development, Taman Industri Alam Jaya	Government
		12	Meteorologi Building (RADAR), Bukit Gila, Sg. Buloh	Government
2	Kuala Lumpur	13	JPS Headquarters, Jalan Sultan Salahuddin	Government
		14	Sek.Men.Keb.Bukit Jalil	Government
		15	Bungalow-Taman Melawati	Government
3	Pahang	16	JPS (M&E Dept), Kuantan	Government
		17	Kg. Salak Complex, Pulau Tioman	Government
		18	Police Station, Pulau Perhentian Kecil	Government
		19	Bangunan MARA, Pulau Perhentian Kecil	Private
		20	Mardi, Cameron Highlands	Government
		21	JPS, Bera	Government
		22	JPS, Raub	Government
4	Perak	23	Institut Tanah dan Ukur Negara, Tanjung Malim	Government
		24	JPS, Ipoh	Government
5	Seberang Perai, Pulau Pinang	25	Seberang Perai Tengah Multifunction Hall	Government
		26	Municipal Court, Butterworth	Government
		27	Food Court Kampung Jawa, Butterworth	Government
		28	Seberang Perai Local Authority Branch Building	Government
		29	Kota Permai Market	Government
		30	Taman Selamat Market	Government
	Pulau Pinang	31	Balik Pulau Market, Bus Terminal, Hawker Complex Project	Private
6	Kedah	32	JPS, Langkawi	Government
		33	Buffalo Park, Langkawi	Government
7	Negeri Sembilan	34	Housing – Taman Bukit Kepayang	Private
		35	Housing – Taman Jayamas	Private

8	Johor	36	Housing – Taman Rebana	Private
		37	Housing – Taman Sri Seruling	Private
		38	Uni.Tun Hussein Onn, Batu Pahat	Private
9	Kelantan	39	JPS, Pasir Puteh	Private
		40	Institut Pengurusan Air Negara, Kota Bharu	Government
10	Terengganu	41	JPS, Dungun	Government
		42	JPS Hulu Terengganu	Government
		43	Pusat Latihan Veterinar Cermin Kiri, Jerangau	Government
11	Sabah	44	Terrace house, Sandakan	Private
12	Sarawak	45	JPS, Miri	Government
13	Labuan	46	Taman Rekreasi Pulau Papan's Inn	Private

Source: MHLG (2008) and DID (2010)

2.7 Rainwater Harvesting Implementation Issues in Malaysia

In Malaysia, rainwater harvesting system was officially introduced after the 1998 long drought by Ministry of Housing and Local Government (MHLG). During its early introduction and up to date, rainwater harvesting systems seems to be inappropriate because of the responsibility rests on the State Water Board to operate and runs water supply for residential areas and commercial. Malaysia has more than 95% coverage of piped water in rural areas and 99% for urban areas which unfortunately stop the development of rainwater harvesting system (Weng *et al.,* 2006). However, it is not the main factor that makes this issue happened. There are other reasons why rainwater harvesting system cannot be successfully developed in Malaysia. Figure 2.6 shows some of the reasons. Most of all, the traditional drainage manual of 1975 encourages maximum drainage rather than retaining rainwater (Weng *et al.,* 2006).

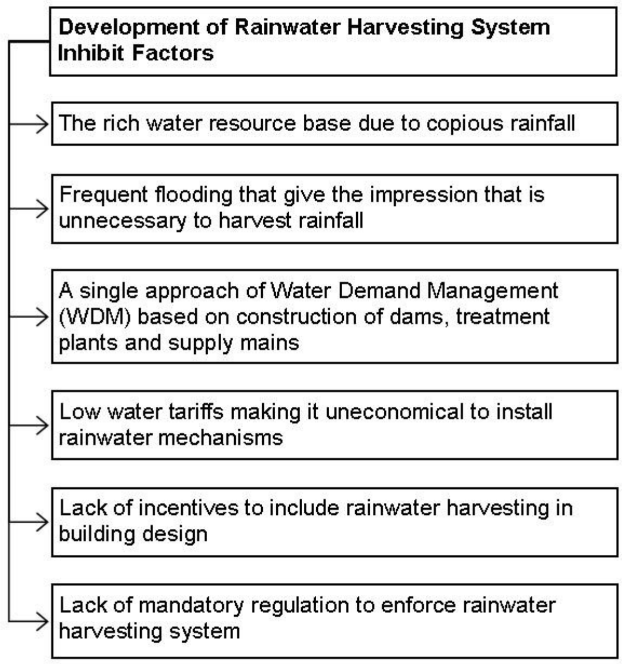

Figure 2.6: Development of Rainwater Harvesting System Inhibit Factors
(Adapted from Weng *et al.*, 2006)

Othman *et al*. (2007) describe the development of RWH policy in Malaysia and are summarized as under;

1. The 1999 "Guidelines for Installing a Rainwater Collection and Utilization System" can be seen as the initial phase of the rainwater harvesting policy in Malaysia. Introduced after the 1998 drought, it aims at reducing the dependence on treated water and provides a convenient buffer in times of emergency or a shortfall in the water supply. It also proposes the construction of "mini dams" or rainwater tanks in urban areas instead of continuing to build giant dams upstream.

2. After five years of introduction of the Guidelines, the Ministry prepared another cabinet paper to the National Water Resources Council to encourage government buildings to install a rainwater collection and utilization system. The Council has later announced that rainwater utilization is to be encouraged, but not

mandatory, in all federal and state government buildings. There is a need for rainwater utilization campaign and to provide a solution for prevention of mosquito breeding.

3. To date, two federal government buildings have been equipped with the rainwater harvesting system, namely the Department of Irrigation and Drainage and the Ministry of Energy, Water and Communication. With a few exceptions as in Johor and Penang, many local governments have not implemented rainwater harvesting in their locality. Few types of council like in Sandakan and Shah Alam has introduced it in new housing developments.

However, Othman *et al*. (2007) further highlight the latest development towards issues of policy making and implementation of RWH in Malaysia, which are precisely as under;

1. After the creation of the Ministry of Natural Resources and Environment in 2004, the National Hydraulic Research Institute of Malaysia (NAHRIM) was established under the wing of the Ministry. It aims at conducting research in all aspects of water hydraulic and water environment, rainwater harvesting.
2. To date, NAHRIM had started three main pilot projects that involve a government building, a mosque and a residential house. It is also actively involved in designing and installing rainwater harvesting systems for several schools.
3. In August 2006, the Town of Country Planning and Development has formulated the National Urbanization Policy (NUP). The policy in particular stresses that cities need to improve water management efficiency which emphasize on the use of alternative sources and non-conventional of rainwater harvesting and water

recycling. Under this policy the relevant agencies for the system implementation are the Ministry of Energy, Green Technology and Water (KeTTHA) the Water Supply Department as well as both State and Local Authorities.

4. To date the Ministry of Technology, Water & Communication has initiated a water saving campaign with the Federation of Malaysian Consumer Association (FOMCA) and makes rainwater harvesting an important component in the water saving efforts. In its long-term plan, the Ministry aims at installing rainwater harvesting systems in new government buildings and schools.

5. The most encouraging development for the success of rainwater harvesting in Malaysia came about after the announcement by the government to give full support of the system in March 27, 2006. It is certainly a right step towards a more sustainable development in Malaysia.

6. The government has finally come to realize that although initial steps were taken since 1999, not much progress has been made in conserving treated water. It is hoped that by making rainwater harvesting mandatory, Malaysia will have less water-related crises in the future.

2.8 Summary

This chapter has highlighted the rainwater harvesting (RWH) system practice and implement in context either locally or internationally. The previous research about RWH identified in seven main areas namely the rainwater usage, RWH quality, the design of RWH, parties involved in RWH, advantages and disadvantages of RWH, the application of RWH and RWH technology. It then covered the review on RWH practice in the world and also in Malaysia before discussed on the implementation issues in Malaysia.

The following Chapter three discusses on the conceptual development of RWH evaluation starts on the RWH maintenance evaluation practices before proceed with developing RWH maintenance evaluation framework.

CHAPTER THREE

THE CONCEPTUAL DEVELOPMENT OF RAINWATER HARVESTING (RWH) MAINTENANCE EVALUATION

3.1 Preface

The key point for assessing the maintenance performance of RWH is to evaluate the condition of the system in relation to this respect. Building evaluation is the systematic assessment of building performance relative to define objectives and requirements. The assessment process is a mean of getting RWH system right for the people who own, manage and use them.

A well-conceived and well-directed evaluation program can be extraordinarily effective in delivering real benefits of RWH. These benefits can be as significant and promising higher returns on investment in RWH implementation in their buildings and providing good quality of potable and non-potable water to the peoples. In carrying out the evaluation, it is compulsory to determine the conceptual framework to be adopted as measuring elements. This also will lead to a better position of assessing the subject under study. Therefore, this chapter deals extensively in discussing the variables that form the conceptual framework for assessing maintenance performance of RWH system in Malaysia.

3.2 The Rainwater Harvesting Maintenance Evaluation Practices

Study of Seters (2008) highlights the following issues of maintenance consideration for rainwater harvesting (RWH) system;

a. Typical maintenance activities associated with rainwater harvesting systems include purging first flush sedimentation tanks, cleaning drain and debris filters, pump maintenance and valve and system pressurization checks. If the water system is intended for potable supply, regular inspection of treatment filters and water sampling would also be required.

b. The frequency of maintenance and inspection activities will vary depending on the complexity of the system. The RWH system evaluated in this study would require seasonal cleaning of the inlet debris filter and monthly system checks. Sedimentation tanks should be cleaned once a year, or less frequently depending on the volume of sediment accumulation.

c. Since the initiation of monitoring, the RWH system has encountered a number of operational problems. The primary setback was a loss of pressure in the system due to a cracked draw pipe below grade. Greater care taken during construction of the system may have helped to avoid some of the unanticipated problems encountered at the site.

d. Minor leaks were detected in the cisterns both at the School and the newly constructed apartment complex. Both tanks have since been repaired. All seams/joints in pre-cast tanks should be thoroughly purged with a non-toxic sealant or concrete to avoid leaks. Seamless tanks may be an option in other applications.

e. Most rainwater harvesting systems are under warranty for at least a year after installation. To avoid unanticipated costs, systems should be closely monitored and, if necessary, repairs undertaken prior to the end of the warranty period.

3.2.1 Building Performance Evaluation

According to Preiser and Vischer (2004) Post-occupancy performance evaluation tries to answer four broad questions:

a. How is this building working
b. It is intended
c. How can it be improved
d. How can future buildings be improved

Answer to these vital questions can include the buildings assessed client, industry and management procedures for future buildings construction and renovation. In spite of the significant accumulation of knowledge based on user feedback studies and post-occupancy evaluation (POE), unfortunately professionals designer engage in building design, procurement and construction are unwilling to engage POEs as a systematic basis to improve their design. Whereas Building Performance Evaluation (BPE) is an innovative approach to the planning, design, construction and occupancy of buildings. It is based on feedback and evaluation at every phase of building delivery, ranging from strategic planning to occupancy, through the building life cycle.

Preiser and Vischer (2004) further add that, BPE covers the useful life of building from move-in to adaptive reuse or recycling. BPE came into being as a result of knowledge accumulating from years of post-occupancy studies of buildings, the results of which contained important information for architects, builders and other involved in the process of creating buildings information that is infrequently accessed and rarely applied in most building projects. BPE is a way of systematically ensuring that feedback is applied throughout the process, so that building quality is protected during planning and construction and, later, during occupation and operations.

Different theoretical approaches to BPE were first presented in the book of Building Evaluation (Preiser, 1989). Since, then there is not only increased interest and activity in this area of concern, both in the private and public sectors – for example, Learning from our buildings (Federal Facilities Council, 2001). But post-occupancy evaluation also continues to expand and its importance grows many folds in industrialized nations around the world.

However the National Council or Architectural Registration Boards (NCARB), (2003) has published a book of Improving Buildings Performance, which allows architect to study and be tested in the field of endeavor, as part of professional development and continuing education.

3.2.1.1 Building performance levels, a development of hierarchy of users; needs and priorities

Lang and Burnette (1974), has developed the hierarchical system approach to set the priorities on building performance of users' needs by and synthesized into the habitability framework. However Preiser (1983) and Vischer (1989) also worked on similar ideas. The outcome of this researches could be summarized as:

1. Health, safety, and scrutiny performance.
2. Functional, efficiency and work flow performance.
3. Psychological, social, cultural and aesthetic performance.

3.1.1.2 Development in Building Assessment Techniques

According to Preiser and Vischer (2004), the human comfort rating is usually the summing up of a wide variety of perceptions and judgments over a given time period; on the other hand, a new situation, or one that causes particular concern to users, may be subjected to short-term judgment that is not indicative of the long term operation of the building.

There is an ever-increasing variety of diagnostic measuring instruments available for gathering follow-up data on building performance in areas such as indoor air quality and ventilation performance, thermal comfort and humidity, lighting and visual comfort, and noise levels and acoustic comfort.

Preiser (1999) has developed the Building performance evaluation model which is based on the post-occupancy evaluation (POE). Whereas Federal Facilities Council (2001) mention that building performance evaluation is the process of systematically comparing the actual performance of buildings, places and systems to explicitly documented criteria for their expected performance.

In addition to above tools for building evaluation other techniques of introducing feedback into the building design and construction process are through checklists, building codes and standards requirements, and design guidelines emanating from other sources are also available for better evaluation of buildings. However, this is not to say that in each of these cases some discretionary judgment on the part of the evaluator is not required to ensure that the process moves forward.

In order to evaluate the building, the necessary data is required to be gathered by adopting proper measure for these purposes. The data-gathering techniques in BPE have to be valid and standardized the results need to become replicable. International Building Performance Evaluation (IBPE) Consortium has taken the efforts to create a standardized 'universal tool kit' of data-gathering instruments, which can be applied to any building type anywhere in the world (Preiser and Schramm, 2002).

3.1.1.3 Office and Commercial Building Performance

According to Preiser and Vischer (2004), business performance related to building is contingent upon effective use and management of all resources to enhance competitive advantages. The resource value of finance, human resources, and technology is widely recognized, but for supporting building infrastructure (or real state) that houses these resources is not obvious to many corporate managers, who see building-related expenses as a drain on profit.

Preiser and Vischer (2004) further stressed that operational buildings are simultaneously a physical asset, a functional facility, and a business resource. Therefore, it follows the measurement of building performance during occupancy will be multidimensional. But recently, a business resource view has emerged, which focuses on measuring performance in terms of the relationship between operational facilities and business outcomes. This view coincides with the facility management approach to optimizing building performance over the life of the building, and using feed-back from a wide range of sources to ensure responsiveness to market needs.

Morgan (2002) has highlighted the drive of measures of building performance as buildings provide environments for a wide range of business activities. Some building facilities are a critical and integral part of the business (for example hotels, research laboratories, prisons, hospitals and schools), while others are more generic business resources (for example office space). A building represents a unique resource, in that it is a capital asset that requires a long-term finding decision, and, at the same time, on operational asset used by organizations as a factor of production. But as a productive environment for business enterprises, facilities are often the largest asset group an organization may have and the second largest expenses after staff costs. However the right economic conditions, they provide capital appreciation as well as a recurrent income stream.

The economic condition related to building and its performance is well pronounced by Then (1994) as three business drivers such as people, property and technology exists to explore the performance of all business resources.

Discussion above can be précised as, that without a proper management and maintenance regime and good customer service, buildings can progressively deteriorate in value and have a shortened effective economic life span. Buildings are also ubiquitous assets, appearing on the balance sheet of both the private and public sectors.

3.2.2 Building Condition Survey

According to Oakleaf Group (2009) condition surveys are essential for building evaluation and should be nationally recognized. These are used across the country by the public and private sector, reporting:

a. Current building condition.
b. Costs to bring up to standard.
c. Future planned maintenance costs over a chosen period.
d. Recommendations, concerns, further action.
e. Data provided for existing property/facilities management systems and data imputing.
f. Data for business case building.

However data is gathered using hand held electronic gathering tools that provide data consistency between surveyors and have in-built checking and productivity functionality. The tools mirror a standard pro-forma style and are used to record the condition of each element/sub element.

According to Anglia Building Surveying (2009), a Condition Survey is a mid-range inspection and record of the current condition of premises. It differs from a commercial building survey as it is normally less detailed and is not intended to diagnose or offer advice on any defects that may be revealed. A Condition Survey, and the subsequent Schedule of Condition that is prepared from the inspection, is useful for a variety of reasons:

a. A Condition Survey is often required, and is always recommended, at the beginning of a commercial lease. The Condition Survey is useful to both the Tenant and the Landlord as a basis for dilapidations negotiations, which may occur both during the term of and at the end of a lease.
b. Condition Surveys are also a useful means of recording the nature and condition of a property for a number of other reasons, for example, prior to building works or other activities by a third party which might affect your premises.

However in these cases, the condition survey provides a clear record of the pre-existing condition, which can underpin a claim for loss or damage. Equally, a Condition Survey provides a sound defence against an unfair claim.

According to Kerns (2009), a condition survey provides an assessment of physical property conditions. The survey should identify deficiencies, and maintenance issues including, but not limited to structural, mechanical, electrical, plumbing, fire protection, site layout, site utilities, storm water management, soil erosion and life safety systems. To facilitate an informed decision making process, a condition survey should result in a clear understanding of the current condition of operating systems by a client. But the extent of a condition survey can vary depending upon the client's need for information. Kerns (2009) reveals that building condition survey can be further divided into two components as mentioned below;

a. A Preliminary Condition Survey**;** preliminary Condition Survey entails the review of existing documentation such as construction drawings, specifications, reports and calculations.
b. A Detailed Condition Survey**;** in a detailed Condition Survey, on site interviews, maintenance history review, review of local municipal records, code compliance research, testing of operating systems, design and performance criteria definition, load capacity calculations and preparation of schematic drawings are generally areas addressed in the findings and recommendations report.

3.3 Developing Rainwater Harvesting Maintenance Evaluation Framework

Highlighting the importance of maintenance for RWH, Seters (2008) mention that maintenance is important for performance and protection of the rainwater harvesting (RWH) systems. Maintenance helps to prevent the system from damage or avoid malfunction of RWH. In order to get satisfactory quality of water, the system requires adequate maintenance to ensure that water quality does not cause any illness to user. The study further reports that in order to keep the system works efficiently.

Maintenance is required throughout the functional life of the system. However it is the responsibility of property owner's to maintain the system until it is abandoned.

Carvajal (1987) has defined that maintenance of rainwater harvesting is a periodic duty. The maintenance of rainwater harvesting can easy to conduct by owner and it is necessary to all elements in rainwater harvesting. In addition, monitoring the water quality and upgrading of systems is also necessary.

Based on Sekaran and Bougie (2009), a framework is a conceptual model of how one theorizes or makes logical sense of the relationships among the several factors that have been identified as important to the problem. Therefore the conceptual framework in this study forms as a basis for assessing the maintenance performance of RWH. There are two layers of variables, namely concept and dimensions. This kind of variables arrangement is to be operationalize the concept of assessing the performance, and termed as 'operational definition' as suggested by Sekaran and Bougie (2009) in quantitative study. The conceptual framework is depicted in Figure 3.1.

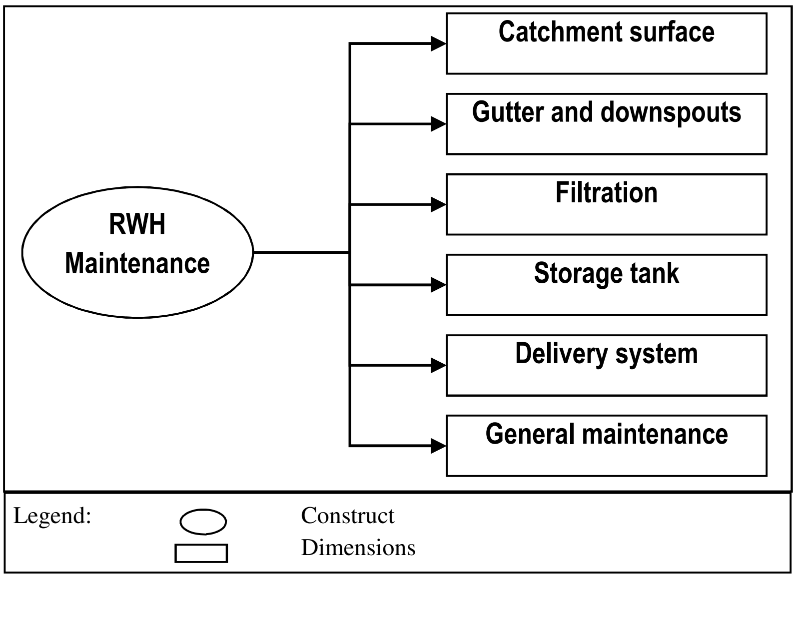

Figure 3.1: Conceptual Framework of Rainwater Harvesting Maintenance

The conceptual framework shows the concept of RWH maintenance is assessing by six dimensions namely catchment surface, gutter and downspouts, filtration, storage tank, delivery system and general maintenance. All dimensions are the elements of RWH based on Texas Water Development Board (2005) and Center for Science and Environment (2003).

a) Catchment surfaces

According to Palmier and Schvartzman (2009), high quality water will be achieved when the rooftop catchment provide with the surfaces covered with asphalt, concrete, butyl rubber, plastic, tarpaper or sheet metal from. That covering will prevent the collected water form atmospheric impurities and contamination and thus produces high quality water. Furthermore, the study adds that, the rooftop should be clean and the collector must be provide with the trap of netting as known as first flush to catch the debris or rubbish avoid enter the water tank.

Noh *et al.* (2009) reveals that the rooftop catchment should be keep clean from any solid and debris to ensure the system will be collect the high quality water and avoid pollution to the water stored in the tank. Furthermore the study has also highlighted the important maintenance features of RWH. The study adds that, the maintenance for element of rainwater harvesting is important and highly desirable to ensure that system will remain operational for longer term. The timely maintenance and inspection must be periodic to ensure the proper function of system. However maintenance is also necessary to remove suspending solid, any debris or rubbish for better performance of system.

Expressing the views about quality of rainwater Helmreich and Horn (2008) advocates that, the quality of rainwater not only depends on the first- flush treatment and regular water quality inspection but also on long term monitoring and the maintenance and arrangement of the water collection zone is crucial.

b) Gutter and downspouts (collector drain)

The gutter and downspouts must be properly sized, sloped and installed in order to maximize the quantity of harvested water (Fayez and Amani, 2006). The collector drains are subject to blockage because of presence of debris or rubbish in the systems. In order to secure the good function of collector drains it is recommended to install screen at the end receiving. The screen will trap undesirable material such as insects, plants and other debris. Provision of screen also prevents the contamination of the water in the storage tank. The collector drains and screen should be inspected and cleaned monthly and periodically (Texas Water Development Board, 2005).

c) Barrel and tank

The barrel should be maintained to avoid the clogging, mosquitoes nesting and overflow. Usually the maintenance work of barrel includes cleaning and to check for accumulation of debris or rubbish. Besides that, the filter also should be installed in barrel to ensure the collection of good quality rainfall. A filter or screen should be durable, easy to clean and replaceable. However Mosley (2005) adds that in order to prevent the mosquito entry in barrel there should be a no gaps in the storage tank inlets where mosquitoes can enter or exit.

d) Cistern and storage tanks

Storage tank or water tank should be cleaned annually. Fayez and Amani (2006) believed above ground tanks easier to drain for cleaning and usually cost less than below ground tanks. The storage tank must checked and keep clean from any debris and accumulation of sediment, this will help to obtain good quality of water. Cleaning agents such as chlorine bleach solution can be used during cleaning of storage tank. The cisterns should be maintained and ensured that it is safe for user to use the water from the cisterns. The cistern also should be visited at least twice per year. The visit should be preferentially for end of rain season around April and also for end of dry season. The water collection must be testing to ensure that water is safe to use and drink. The cisterns must be have own maintenance schedule to ensure that system can operate in a long term and it can avoid the water pollution.

e) Pipelines and outlet

Pipelines in rainwater harvesting system should be kept as clean as possible to prevent blockage or accumulation of sediments. Poly vinyl chlorides (PVC) are good to use material for pipelines in RWH, use of PVC pipe eliminate the chance of corrosion and are easy to maintain in a long term. However the outlets should be inspect and cleaned periodically. In addition, the possible area in system should be covered properly to prevent the possible contamination.

f) General maintenance

General maintenance and repair of rainwater harvesting ensure that systems can function properly. Rainwater harvesting requires schedule maintenance because the system is exposed to various environmental condition and vandalism. For example system is exposed to natural environmental conditions such as accumulation of fallen leafs, atmospheric dust, and dry wood. However act of vandalism could account as theft of system components

The discussion above can be summarized as that rainwater harvesting system is manageable for maintenance. The components of system such as tank, gutter and screen should be cleaned annually. The schedule maintenance can make the system more efficient in collecting and use of the rainwater.

Carvajal (1987) has also marked the schedule maintenance of rainwater harvesting system and mention that, schedule maintenance of RWH ensures the system and its element can function properly and more efficiently. However, the maintenance work should be carrying out separately for each element. This approach of maintenance practice can provide more easy access to maintenance and also prevent the chance to overlook the maintenance work of any element.

a. The first part of rainfall should be diverted from the storage tank because it maybe contains undesirable materials, which have accumulated on the roof and also from other surface between rainfalls. Generally, in first ten minutes captured rainfall average intensity is unfit for the drinking purpose.

b. Care should be taken to cover the surfaces of rainfall collection, to reduce the insect such as mesquites, lizard, and other pest using the cistern as a breeding ground. It can be prevent than corrective action about that problem with treating or removing water at a later time.

   Gutter and down pipes need to be periodically inspected and cleaned carefully. Periodic maintenance must be carried out on any pumps used to lift water to selected areas in the house or building.

3.4 Summary

Measuring maintenance performance is among the key success factors in providing effective RWH in the building. This chapter solely deals with identifying in concept of RWH maintenance and variables that going to be used in assessing the maintenance performance of RWH in Malaysia. In short, the conceptual framework consists of six variables. After considering these variables, it is then time to conduct a field work based on the conceptual framework. Therefore, the next chapter, Chapter four is discussing about research methodology adopted in maintenance of rainwater harvesting (RWH) system in Malaysia. It will touch about the entire research process, population, data collection and method of data analysis.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Preface

Research is a detailed and meticulous study of something to find out more information about its method is a way of doing something. To ensure the correct measurement has been done, it is important to clearly understand the research methods to be applied. The methods of research can be divided into two types, which are the qualitative and quantitative methods. The qualitative method is the method that describes the phenomena in words instead of numbers or measures. It emphasized the meanings, experiences (often verbally described), description and others. The quantitative method can be defined as the method that describes phenomena in numbers or measures instead of words. It is based on the time of collecting facts and study inter-relationship of the data (Creswell, 2009).

In this chapter, it is going to discuss about the research methodology adopted in maintenance of rainwater harvesting (RWH) system in Malaysia. It also will cover the research design, research process, population, formulation of research instrument and method of data collection and analysis.

4.2 Research Design

Naoum (2007) look at the research design as a blueprint that describes how to achieve the objectives. There are several key steps in the action plan that must be taken into account before any answers can be obtained in order to produce conclusion of the research work done.

4.2.1 Research Process

The research process according to Naoum (2007) can be divided into three parts. The first part is selecting a topic, writing the dissertation proposal and reviewing the literature. The second part is deciding on the research approach, deciding on the research technique and constructing the questionnaire or designing format for secondary data collection. Finally for part three is coding the data measurement, analyzing the results, structuring and writing the dissertation and dissertation supervision including assessment.

From the study of Nachmias and Nachmias (1996) and Sekaran and Bougie (2009), re-examination or re-evaluation the research process is important to avoid the rejection of the tentative hypothesis which might not due to its invalidity but to deficiencies in performing research operations.

Figure 4.1 shows the research process of this research as specified by Naoum (2007). This process becomes the main part of this research to determine the successful of the study and the objectives achievement.

According to Sekaran and Bougie (2009), data collection can be divided into two categories; that are primary and secondary. It starts with the secondary, which is literature review. From the literature review, a research framework has been established to determine the main parts of RWH system. The frameworks are used as a tool in implementing research instruments that has become a primary data for this research.

The instruments are split into two, which are condition survey and questionnaire survey. Details about these instruments are explained in the Formulation of Research Instrument.

Results for both instruments is combined in findings to generate a cross-combination two parameters in single explanation namely RWH Maintenance Performance Quadrant. The quadrant becomes the final contribution for this research.

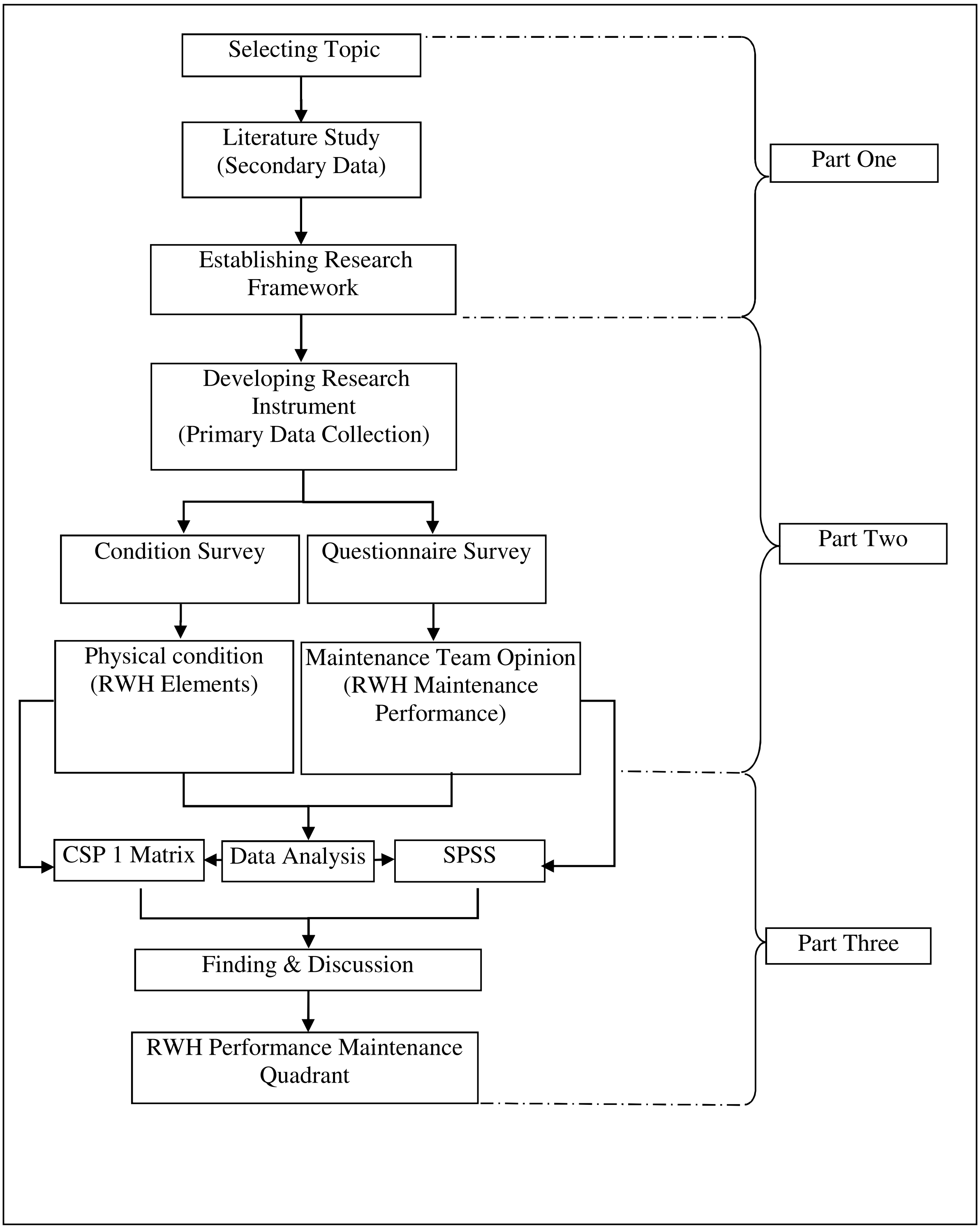

Figure 4.1: Research Process

4.2.2 Population

In general, there are various RWH projects in Malaysia. As explain in research scope in Chapter one, this research only concentrates into the RWH projects that managed by NAHRIM, DID and LA. For this reason, this research goes to the full extent of RWH projects list by the respective government agencies updated until April 2010. Therefore, as the research scope for this research is concerned, it used full population as sampling. In other words, this research has the population, which comprises of RWH projects by NAHRIM, DID and LA. All of twenty-eight projects by those agencies are considered and information and data collection are collected via letter/email and telephone. However, only sixteen were replied and granted their permission to enter their building. Moreover, second attempt within a month after the first contact have been made to the respective projects but still received no feedback. After finalizing this effort, the population of this research is shown in Table 4.1. The table listed the projects by the state and also reports the status of data collection for each project and date of inspection has been carried out.

Table 4.1: Population for this research and data collection status

STATE	NO.	PROJECT	STATUS	DATE OF INSPECTION
Selangor	1	Zoo Negara, Hulu Kelang, Selangor	Done	21/7/2010
	2	Bangunan Metorologi (RADAR) Di Bukit Gila, Sg. Buloh, Selangor Darul Ehsan.	No response	-
Pahang	3	JPS (M&E) Kuantan, Pahang Darul Makmur.	Done	27/7/2010
	4	JPS Daerah Bera, Pahang	Done	26/7/2010
	5	JPS Daerah Raub, Pahang	Done	26/7/2010
	6	Mardi, Cameron Highlands, Pahang	Done	23/7/2010
	7	Police station, Pulau Perhentian Kecil, Pahang	No response	-
	8	Bangunan MARA, Pulau Perhentian Kecil, Pahang	No response	-
	9	Bangunan Komplek Kg. Salak, Pulau Tioman, Rompin, Pahang	No response	-
Kuala Lumpur	10	Sek. Men. Keb. Bukit Jalil, Jln. 3/155A, Bukit Jalil, Kuala Lumpur.	No response	-
	11	JPS Headquarters, Jalan Sultan Salahuddin	Done	6/8/10
Perak	12	Institut Tanah dan Ukur Negara (INSTUN) Tanjung Malim, Perak	No response	-
	13	JPS (M&E), Ipoh	Done	23/7/2010
Kedah	14	JPS Langkawi, Kedah	Done	4/7/10
	15	Buffalo Park, Langkawi, Kedah	Done	4/7/10
Terengganu	16	JPS Daerah Dungun, Terengganu.	Done	27/7/2010
	17	JPS Daerah Hulu Terengganu, Terengganu.	No response	-
	18	Pusat Latihan Veterinar Cermin Kiri, Jerangau, Dungun Terengganu.	No response	-
Kelantan	19	JPS Jajahan Pasir Puteh, Kelantan.	No response	-
	20	Institut pengurusan Air Negara Kota Baharu, Kelantan.	No response	-
Johor	21	Universiti Tun Hussein Onn Fasa 1 Projek Komitted, Batu Pahat, Johor.	No response	-
Pulau Pinang	22	JPS Seberang Perai Tengah, Pulau Pinang.	Done	16/7/2010
	23	JPS Balik Pulau	Done	16/7/2010
	24	Taman Permai Market, Seberang Perai	Done	25/5/2010
	25	Taman Selamat Market, Seberang perai	Done	25/5/2010
	26	Municipal Court, Butterworth	Done	26/5/2010
	27	Seberang Perai Local Authority Branch Building, Jln Betik	Done	26/5/2010
Sarawak	28	JPS Bahagian Miri, Sarawak	No response	-

4.2.3 Formulation of Research Instrument

There are two instruments used for this research namely condition survey and questionnaire survey. All these instruments are developed based on outlined conceptual framework as depicted in Figure 3.1 in chapter three. The sample of questionnaire form is shown in Appendix A. Two instruments are used in this study as to capture two different information for the RWH maintenance performance quadrant (this quadrant is explained in data collection and analysis section in chapter five). Condition survey is to capture the physical condition of the RWH elements, meanwhile Questionnaire survey to capture maintenance team's opinion about RWH maintenance performance of their respective building.

For condition survey, it is carried out based on Condition Survey Protocol (CSP1 Matrix). Refer to Che-Ani *et al.*, 2011 this matrix used by the Building Surveying Division, Royal Institution of Surveyors Malaysia (RISM) as a basis to develop CP BS101: Code of Practice for Building Inspection report. The CSP1 matrix was developed as a rating tool for a reasonable property condition assessment. The matrix is also suitable for all types of buildings because the data input relies on the condition and damage assessments. The system gathers two sets of data, namely, the condition of the building and the seriousness of the building defect's that can be analysed to provide a rating of the building's overall condition (Che-Ani *et al.*, 2011). Basically this CSP1 Matrix emphasizes on the data analysis and reporting procedure of the particular condition survey works.

The procedure of CSP1 Matrix, namely condition assessment protocol 1, priority assessment, the matrix, the descriptive value according to score and overall building ratings are shown in the Table 4.2, 4.3, 4.4, 4.5 and 4.6 respectively in Appendix B. Each numerical score (1 to 5) is accompanied by a scale value and description.

For questionnaire survey, it comprises of two sections, which are demographic profile and maintenance of RWH system. For demographic profile, it covers respondent profile, how long were their involvement in RWH maintenance, age of building, age of RWH system, type of RWH system used, approximate catchment area and number of trees around the building. In the aspect of maintenance for RWH system, it covers maintenance approach implemented, method of implementing RWH maintenance, frequency of routine inspection, performance of RWH system in the building, main problem in maintaining RWH system, RWH element frequently needs to be repaired, common defects that occurred in RWH system, their opinion on RWH system helps in saving water consumption and frequency of RWH system breakdown in a year.

4.2.4 Method of Data Collection and Analysis

Data can be collected in a variety of ways, in different settings, and from different sources. This research used two methods of data collection as depicted in Figure 4.1, which are condition survey and questionnaire survey. Each method used a different type of data analysis. Details will be discussed in the next page.

4.2.4.1 Condition survey

The systems were used as a case study to test the reliability of the CSP1 Matrix. The inspection was carried out from May until August 2010 in fair and clear weather conditions. The inspection was carried out during a two hour period each sites, and visual inspection was the primary survey method. The inspection started by examining the systems exterior. A top down and clockwise surveying technique was adapted for this inspection. This procedure is one of the surveying techniques suggested by Hollis and Gibson (2000) and Hoxley (2002) and is designed to prevent surveyors from overlooking any defects.

All of the information gathered for the CSP1 Matrix is recorded in the Schedule of Building Condition Form, shown in Table 4.7 in Appendix C. For reporting purposes, the CSP1 Matrix comprises a photograph box, a defect plan tag and an executive summary, as shown in Figures 4.2, 4.3, 4.4, Appendix D.

The description of each defect is concise and straightforward. Standard terms are used where applicable. The main idea is to describe what the defect is. In the Schedule of Building Condition form, the description of each defect is accompanied by an image in the photograph/sketch box and its location in the defect plan tag. The key information in the CSP1 Matrix is the Schedule of Building Condition. The colour code adopted allows quick identification of a defect's categorisation. Three colours were used which green for good, yellow for fair and red for dilapidated. This allows a client who wants to know whether the inspector found any defects that might need serious attention by easily scan the 'red'-rated defects.

4.2.4.2 Questionnaire survey

Data collection methods for questionnaire survey include *interviews* – face-to-face interviews, telephone interviews, computer-assisted interviews, and through the electronic media; *questionnaires* – that are personally administered, sent through the mail, or electronically administered; *observation* – of individuals and events with or without videotaping or audio recording (Sekaran and Bougie, 2009).

Interviewing, administering questionnaires and observing people and its environment are the three main data collection methods in survey research. Although interviewing has the advantage of flexibility in terms of adapting, adopting, and changing the questions as the researcher proceeds with the interviews, whereas questionnaires has the advantage of obtaining data more efficiently in terms of researcher time, energy, and costs (Sekaran and Bougie, 2009). Based on this argument devoted by Sekaran and Bougie, this research opts for administering questionnaires via personally administered questionnaire survey.

A questionnaire is a pre-formulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives (Naoum, 2007; Sekaran and Bougie, 2009). Questionnaires are an efficient data collection mechanism when the researcher knows exactly what is required and how to measure the variables of interest. The questionnaire used in this research is attached in Appendix A.

The questionnaires distributed to the respondents on the day of site visit and were collected immediately after the survey completed. The target respondents for each site are three, which are two from technical person, and one from management person. This survey is to get the maintenance aspect of RWH from maintenance staff perspective view.

Analysis technique for the questionnaires is using the software of Statistical Package for Social Sciences (SPSS) version 15. The result of the analysis will be presented in the form of tables and charts.

4.2.4.3 Combination of Analysis- RWH Maintenance Performance Quadrant

Basically the data for this research comprises from the condition survey and questionnaire survey. By combining this two data, it is then simplified as to define the RWH maintenance performance via RWH Maintenance Performance Quadrant. This quadrant is developed based on "*Johari Window"* devised by Joseph Luft and Harry Ingham in 1955.

The "*Johari Window"* is a simple and useful tool for understanding and training self-awareness, personal development, improving communications, interpersonal relationships, group dynamics, team development and intergroup relationships. This quadrant especially relevant due to emphasis on, and influence of, 'soft' skills, behaviour, empathy, cooperation, inter-group development and interpersonal development (Chapman, 2003). However, this is the first attempt for this study to apply the basic concept of *"Johari Window"* in built environment field in developing "The RWH Maintenance Performance Quadrant". The quadrant was following the concept of

"Johari Window" namely cross-combination the finding of two parameters in single explanation.

In other words, it provides well explain scenarios under this study. For this quadrant, the finding of both condition survey and questionnaire survey are divided into two situations namely good and bad (refer Figure 4.5). For condition survey, good practice is defined as acceptable (where the CSP1 Matrix indicates the score of 1 and 2) and bad practice is dilapidated (where the CSP1 Matrix indicates the score of 3). For questionnaire survey, good is defined as high (where 5 point likert scale indicates score of 3 to 5) and bad as low (where 5 point likert scale indicates score of 1 to 2). The combination of this finding is portray within the four situations namely good practice, need improvement (organization), need awareness (organization) and bad practice as shown in Figure 4.5.

	QS–HIGH	**QS–LOW**
CS–ACCEPTABLE	**GOOD PRACTICE**	**NEED IMPROVEMENT (ORGANIZATION)**
CS–DILAPIDATED	**NEED AWARENESS**	**BAD PRACTICE**

Figure 4.5: RWH Maintenance Performance Quadrant

4.3 Summary

This chapter discussed the methodology adopted in this research. The nature of data in this research has two fold, namely secondary data from literature study for establishing the framework and primary data for measurement purposes. Two instruments have been used as a measurement tools in getting the result, which are condition survey and questionnaire survey. Condition survey has been carry out at sixteen projects located in Peninsular Malaysia manage by NAHRIM, DID and LA meanwhile questionnaire survey has been distribute to the respondents at the day of site visit and were collected immediately after the survey completed for each projects. Method of data analysis for condition survey is using CSP1 matrix meanwhile questionnaire survey analyzed using SPSS software. Findings for both instruments were combined in RWH Maintenance Performance Quadrant to define the RWH maintenance performance. Next chapter will discuss about the findings of the study as well as discussion about the scenarios created under study.

CHAPTER FIVE

DATA ANALYSIS AND FINDINGS

5.1 Preface

This chapter discusses on the data analysis and findings of this research. In general, quantitative methods dominated this research for the data output. As mentioned in previous chapter, two instruments have been used as primary data collection and two different methods of analysis applied for both instruments. Condition survey generated the result using CSP1 matrix and questionnaire survey analyzed using Statistical Package for Social Sciences (SPSS) version 15. Significances to have both instruments is crucial due to result of Condition survey is to capture the physical condition of the RWH elements, meanwhile Questionnaire survey to capture maintenance team's opinion about RWH maintenance performance of their respective building. This is important in determining the performance of RWH system maintenance in Malaysia.

5.2 Condition Survey

The condition survey covers sixteen buildings that implement the RWH system in Peninsular Malaysia. The survey is carrying out from May to August 2010, in clear weather condition for all projects. The findings for condition survey shown in Table 5.1 summarize the result according to its location. The detail schedule of building condition for each project is attached in Appendix E.

The result for CSP1 Matrix (in Table 5.1) shows overall rating for all the buildings are planned maintenance, condition monitoring and serious attention. Based on condition survey result, on overall twelve projects are rated as good which the total score for this rating is between 1 to 4 (refer table 4.6, Appendix B). For fair and dilapidated, there are only two buildings for each rating respectively. The total score for fair is 5.1 and 7.3. Meanwhile for dilapidated, the total score is 16 and 20. In general, based from condition survey assessment, the condition of RWH system can be considered in good condition, with 75% (twelve buildings) of all sixteen buildings portrayed the findings of good overall rating condition for CSP1 Matrix.

From the Table 5.1, JPS Seberang Perai Tengah (SPT) shows the lowest score; 1 which is rated as good condition. This is because the building is newly operated, around May 2009. All the RWH elements still in good condition except for the gutter are sagging due to poor construction, as shown in Figure 5.1. The details of defects for this project is in Appendix F also include the plan of defects.

Photograph/ Sketch No. 1

Level		Not Applicable	
Location		Roof	
Element/ Component		Gutter	
CSP1			
Condition	**Priority**	**Matrix**	**Color**
1	1	1	(green)
Defect Description			
Sagging			
Possible Causes			
Poor construction			
Remarks			

Figure 5.1: Photograph/sketch box of JPS SPT defects

For fair condition, Pasar Awam Taman Permai, Seberang Perai shows the highest score, 4.7. The main problem RWH system at the building is gutter, which is similar to JPS SPT condition. Most of gutter bracket were corrode due to low quality material. Figure 5.2 shows one of the defects.

Photograph/ Sketch No.2	**Level**		Not Applicable	
	**Location**		Roof	
	Element/ Component		Gutter	
	CSP1			
	Condition	**Priority**	**Matrix**	**Color**
	3	3	9	
	Defect Description			
	Rusty gutter bracket			
	Possible Causes			
	Low quality material			
	Remarks			

Figure 5.2: Photograph/sketch box of Pasar Taman Permai defects

For the dilapidated condition, Municipal Court and Food Court, Seberang Perai hit the highest score for CSP1 Matrix, 20. The RWH system in this building is malfunction due to pump problem and low water pressure. After a year of using the system, the Maintenance Department MPSP has decided to stop the system and switch to the local water supply from JBA. This decision was taken due to lack of funding and also lack of RWH expertise. Figure 5.3 shows one of the defects.

Photograph/ Sketch No. 3	**Level**		Not Applicable	
	**Location**		Ground	
	Element/ Component		Pump	
	CSP1			
	Condition	**Priority**	**Matrix**	**Color**
	5	4	20	
	Defect Description			
	No pump			
	Possible Causes			
	Removes by maintenance dept			
	Remarks			

Figure 5.3: Photograph/sketch box of Municipal Courts and Food Court defects

Table 5.1: Summary of Condition Survey Protocol (CSP) 1

NO	BUILDING NAME	DATE OF INSPECTION	WEATHER	CSP1 MATRIX			OVERALL BUILDING RATING			
				1 (PM)	2 (CM)	3 (SA)	TOTAL MARKS	NO.OF DEFECTS	TOTAL SCORE	OVERALL RATING
A	JPS HQ, KL	6/8/2010	Good	7	-	-	8	7	**1.1**	**Good**
B	JPS Langkawi, Kedah	4/7/2010	Good	1	8	-	46	9	**5.1**	**Fair**
C	Buffalo Park, L'kawi, Kedah	4/7/2010	Good	4	3	-	16	7	**2.3**	**Good**
D	JPS (M&E) Ipoh, Perak	23/7/2010	Good	2	1	-	6	3	**2**	**Good**
E	Stesen MARDI, Cameron Highlands	23/7/2010	Good	3	2	-	6	5	**1.2**	**Good**
F	JPS SPT, Pulau Pinang	16/7/2010	Good	1	-	-	1	1	**1**	**Good**
G	JPS Jln Betik, SP, Pulau Pinang	26/5/2010	Good	1	2	-	9	3	**3**	**Good**
H	JPS Raub, Pahang	26/7/2010	Good	3	3	-	22	6	**3.7**	**Good**
I	JPS Bera, Pahang	26/7/2010	Good	3	2	-	14	5	**2.8**	**Good**
J	JPS (M&E) Kuantan, Pahang	27/7/2010	Good	4	1	-	19	5	**3.8**	**Good**
K	JPS Balik Pulau, Pulau Pinang	16/7/2010	Good	1	2	-	10	3	**3.3**	**Good**
L	JPS Dungun, Terengganu	27/7/2010	Good	2	-	-	3	2	**1.5**	**Good**
M	Zoo Negara, Selangor	21/7/2010	Good	1	-	-	4	1	**4**	**Good**
N	Pasar Awam Tmn Permai, SP, P.Pinang	25/5/2010	Good	3	-	-	22	3	**7.3**	**Fair**
O	Pasar Awam Tmn Selamat, SP, P.Pinang	25/5/2010	Good	-	8	-	128	8	**16**	**Dilapidated**
P	Municipal Court & Food court, SP, P.Pinang	26/5/2010	Good	-	4	-	72	4	**18**	**Dilapidated**

5.3 Questionnaire Survey

Results for questionnaire survey in the conduct of the survey, a total of forty-eight respondents were interviewed and the data were collected using a constructed questionnaire. The questionnaire comprises of two parts, Part A which captures data pertaining to the respondents' demographic profile and Part B which elicits information regarding the maintenance of Rainwater Harvesting (RWH) System. Two categories of respondents were covered in the survey; the Technical and Management categories where it involves several types of building which is JPS Seberang Prai, JPS Ipoh, JPS Raub, JPS Dungun, JPS Bera, JPS Langkawi, JPS HQ, JPS Kuantan, JPS Balik Pulau, Zoo Negara, Mardi Cameron Highlands, Buffalo Park and Pasar Awam Taman Permai. Data collected were analysed by using SPSS software and the results are presented in this chapter.

5.3.1 Internal consistency of the scale

In any survey work high quality of the data obtained is crucial in the decision making process. Low quality data may lead to wrong or biased conclusion. In other words, the quality of the data collected is strongly related to how the instrument used to collect the data was constructed and handled. In this survey one of the instruments used is questionnaire. Hence, to determine whether the outcome of this study is highly reliable, therefore, it is pertinent that the quality of the data collected is assessed. For this purpose, the Alpha's coefficients were calculated for the attributes, related to variables, were being investigated. The results are presented in Table 5.2. From the results obtained, the values of

Alpha coefficients calculated were found to hover at about 0.8. Thus, we can conclude that the data obtained have some amount of consistency of the scale.

Table 5.2: Reliability coefficients

Variables	**Number of Items**	**Alpha's Coefficient**
6. Difficulties in maintaining RWH System	6	0.854

5.3.2 Profile of respondents

The largest category of the respondents comprises of the Technical constituting from 32 (66.7%) of the total interviewed. Meanwhile, respondents comprised of the Management constituting of 16 (33.3%). The distributions of the categories of respondents can be seen in Figure 5.4 below.

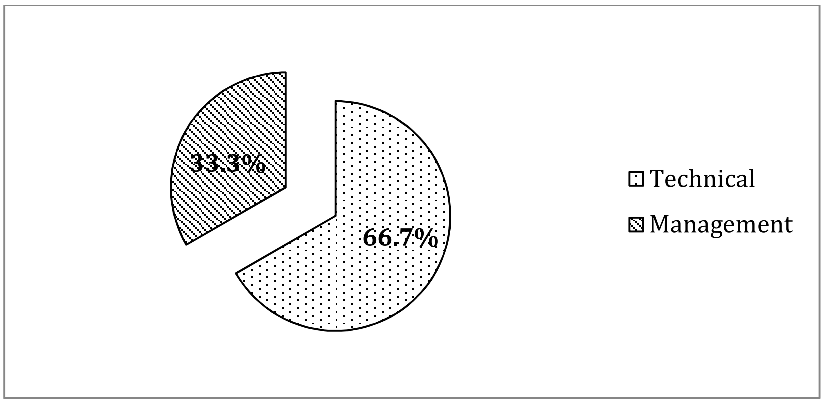

Figure 5.4: Category of respondent

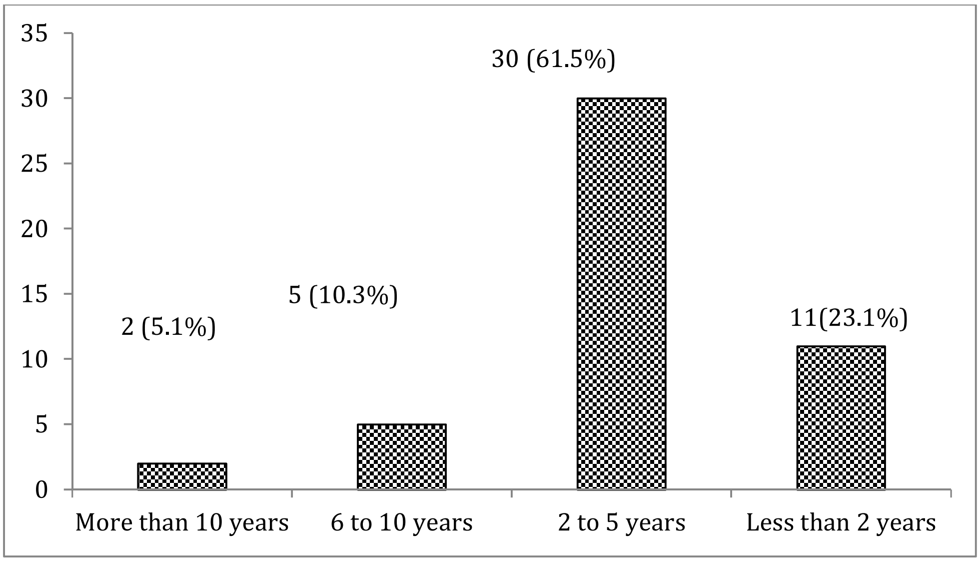

Figure 5.5: Involvement in maintaining RWH System

As illustrated in Figure 5.5 above, most of them 61.5% (30) have involved two to five years in maintaining RWH System for the building. For less than two years, there is 23.1% (11). Only 5.1% (2) have involved more than ten years in maintaining RWH System for the building. The result implies that majority of the respondents (37) have experienced enough, at least two years in maintaining RWH System.

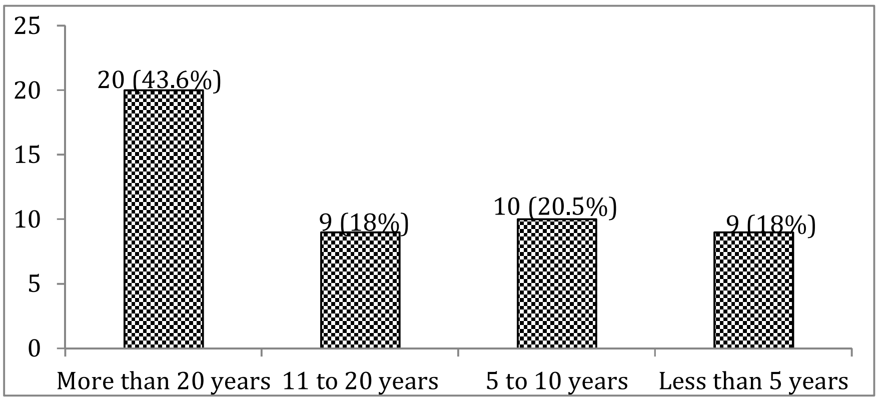

Figure 5.6: Operation of the building

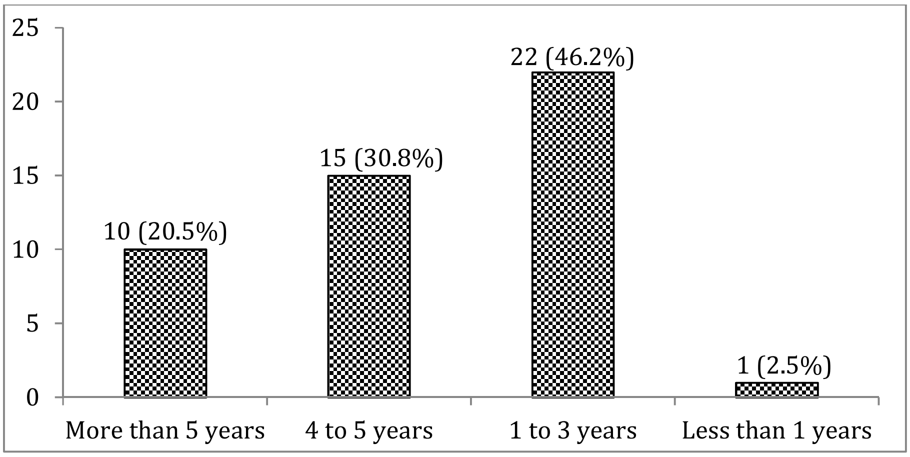

Figure 5.7: RWH system installation

Based on Figure 5.6, most of the building 43.6% (20) has been operated more than twenty years. For five to ten years, there is only 20.5% (10). Meanwhile, for the building which has been operated between eleven to twenty years and less than five years, the proportion of the respondents is the same. Furthermore, most of the RWH system 46.2% (22) has been installed in the building between one to three years. For more than five years installation, there is only 20.5% (10) and for less than one year's installation, there is only 2.6% (1). This can be clearly seen in Figure 5.7. From both of the result, it could be concluded that most of the system installed (79.5%) is for the new building which is operating less than five years. Only certain old building operating more than five years (20.5%) has been retrofit to implement the RWH system.

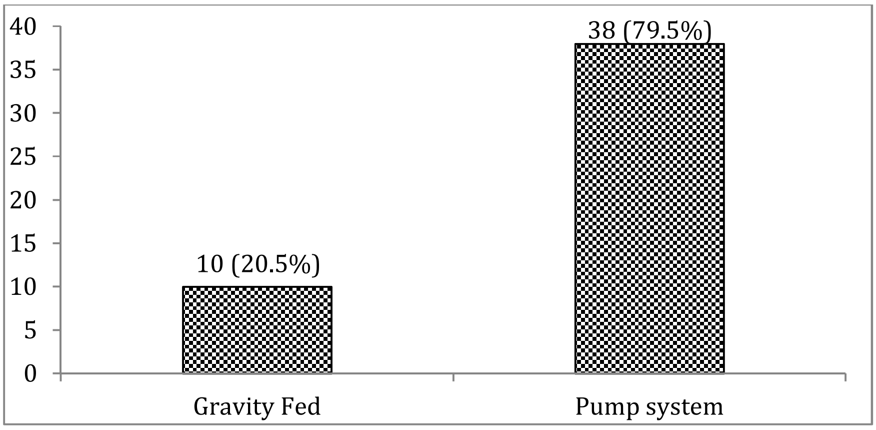

Figure 5.8: Type of delivery system.

There are two types of delivery system used for RWH system in the building which is gravity fed and pump system. As shown in Figure 5.8 above, most of the building 79.5% (38) used pump system as delivery system for RWH system. Meanwhile, there is only 20.5% (10) used gravity fed. Gravity system is less maintenance compare to pump system and an extra maintenance works need to be carry out for the system using pump.

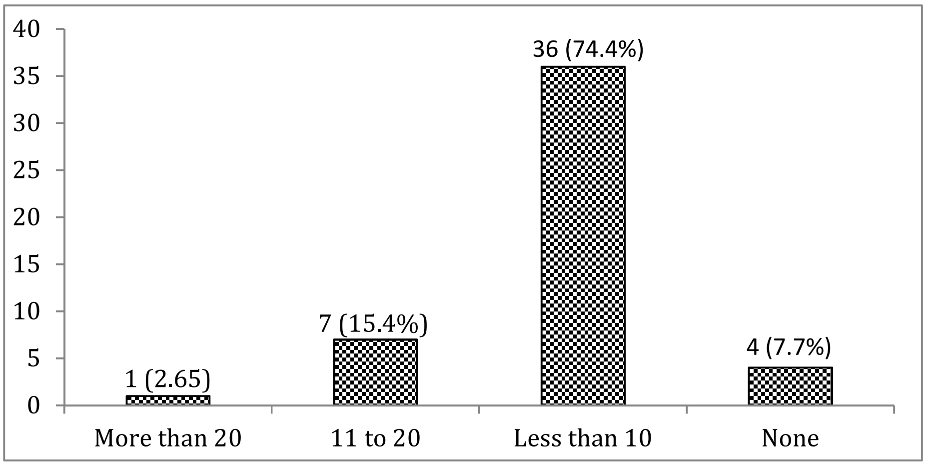

Figure 5.9: Numbers of tree

Figure 5.9 above shows estimated numbers of tree around the building in ten metre radiuses. Majority of respondents 74.4% (36) estimated numbers of tree less than ten.

Meanwhile, 15.4% (7) estimated numbers of trees around eleven to twenty trees and only 2.6% (1) estimated more than twenty trees. More trees around the building need more maintenance works which affect from their leaves or root.

5.3.3 Maintenance of RWH System

Part B of the questionnaire contains about the maintenance of the system itself. The results gain from this part reflects the opinion of respondents in maintaining RWH system in their building.

5.3.3.1 Maintenance approach implemented for RWH in the building

Table 5.3: Maintenance approach

Maintenance Approach	**Percentage (%) n=48**
Preventive maintenance	0.0
Predictive maintenance	0.0
Corrective maintenance	0.0
Condition based maintenance	100.0

Based on Table 5.3, 100.0% (48) said maintenance approach implemented for RWH in the building is condition based maintenance. The rest maintenance approaches are not implemented for RWH in the building. This result shows there is no schedule or routine maintenance has been carrying out at all building. The system only maintained after having problems or breakdown. This result was support by statistic on routine inspection where the most frequent of routine inspection being carried out for RWH system at the building are others which are 66.7% (32). Others can be yearly or none. This is followed by monthly routine inspection 17.9% (8). As for daily and every 3 days routine inspection, the proportions are the same where only 7.7% (4). This can be clearly seen in Table 5.4 below.

Table 5.4: Routine inspection

Routine Inspection	**n**	**Percentage (%)**
Daily	4	7.7
Every 3 days	4	7.7
Weekly	0	0.0
Bi-weekly	0	0.0
Monthly	8	17.9
Others	32	66.7

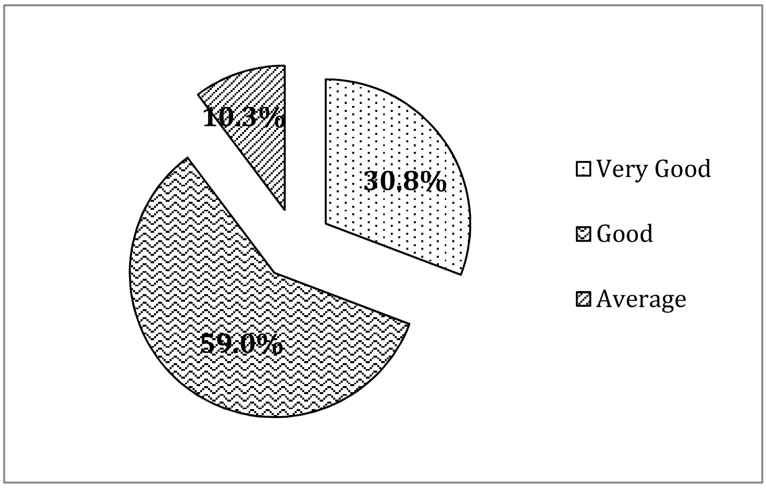

Figure 5.10: Performance of RWH System

However, the performances of RWH System in the building as in overall are good. This is illustrated in Figure 5.10 above where 59.0% (28) respondents indicate the performances of RWH system are good. Moreover, 30.8% (15) indicate very well. And only 10.3% (5) are average in term of performance of RWH system. Conclusion from the result is even though there is no preventive maintenance carried out for the system, but it still functioning well.

Unfortunately, there are problems in maintaining RWH System in the building. Most of them 84.6% (41) believe that the main problems are limited budget allocation. This can affect performance of maintenance work and necessarily the system itself. Second, 7.7% (4) believe because of lack of skilled personnel and 5.1 % (2) believe other problems. And only 2.6% (1) believe because lack of knowledge in RWH maintenance (Refer Table 5.5).

Table 5.5: Problem in maintaining RWH System

Problem	**n**	**Percentage (%)**
Lack of skilled personnel	4	7.7
Limited budget allocation	41	84.6
Lack of knowledge in RWH maintenance	1	2.6
Others	2	5.1

According to Table 5.6 below, majority of them 41.9% (20) claim the part of RWH element that needs to be repaired most are gutter and downspout. Second, 22.6% (11) claims that part needs to be repaired are pump. Third, 17.7% (8) claim that filtration are part needs to be repaired. The lowest parts are storage tank where there is only 8.1% (4) claim. Cost of maintenance can be estimate based on this statistic.

Table 5.6: Part of RWH element

RWH element	**n**	**Percentage (%)**
Roof/catchment surface	5	9.7
Gutter and downspout	20	41.9
Filtration	8	17.7
Storage tank	4	8.1
Pump	11	22.6

Similarly, 66.7% (32) claimed that the common defects that occurred for the RWH System in the building are clogged or water backing up at gutter and downpipe. This is the reason gutter and downspout needs to be repaired. And second, 51.3% (25) claim that the defects are due to the pump not working properly. Third, 30.8% (15) claim that excess debris or sediment present on rooftop. The lowest, 23.1% (11) claim that leakage at tank is defects that occurred from the RWH System in the building. Refer Table 5.7.

Table 5.7: Defect occurred for RWH System

Defects	**n**	**Percentage (%)**
Excess debris or sediment present on rooftop	15	30.8
Clogged or water backing up at gutter and downpipe	32	66.7
Leakage at tank	11	23.1
Pump is not working	25	51.3
Others	12	25.6

Although, there is a problem in maintaining RWH System, with part needs to be repaired and also common defect occurred for the RWH System, still 94.9% (46) believe that this RWH system really helps in saving water consumption. There is only 5.1% (2) denies it. This can be seen in Table 5.8.

Table 5.8: Saving water consumption

Saving water consumption	**n**	**Percentage (%)**
Yes	46	94.9
No	2	5.1

Furthermore, based on Table 5.9, frequency of breakdown happened to the RWH System in a year registered mean of 1.64 which considered as bad practice.

Table 5.9: Breakdown

Breakdown	Mean	Standard Deviation
Frequency of breakdown to RWH System	1.64	0.707

Besides, the degree of difficulties in maintaining RWH System for the building also registered mean score around 1.18 to 1.67 which indicate as low. The highest degree of difficulties are access to the catchment area with mean score 1.67 and the lowest degree of difficulties are get the replacement part with registered mean of 1.18. Measurements of likert's scale using 5 points of scale from very difficult to least difficult. Refer Table 5.10

Table 5.10: Degree of difficulties

Difficulties	Mean	Standard Deviation
Get the replacement part	1.18	0.451
Clearing the catchment area	1.54	0.756
Get the competent person to repair the system	1.54	0.720
Access to the catchment area	1.67	0.838
Access to the catchment storage tank	1.31	0.614
Space to carry out maintenance work	1.23	0.485

5.3.4 Demographic influence on preferred coaching behaviours

Analysis of the results was based on univariate analysis, with follow-up univariate comparisons. Mean for each variable and for each demographic sub-group were subjected to univariate analysis of variance (ANOVA). The demographic of interests were involvement in maintaining RWH System, operation of the building and RWH System installation.

5.3.4.1 The relationship between difficulties and involvement in maintaining RWH System

Table 5.11: Summary of result of univariate ANOVA

Difficulties	Involvement	N	Mean	Std. Deviation	*F*	*p-value*
Get the replacement part	More than 10 years	2	1.000	0.000	0.653	Not significant
	6 to 10 years	4	1.000	0.000		
	2 to 5 years	24	1.167	0.381		
	Less than 2 years	9	1.333	0.707		
Clearing the catchment area	More than 10 years	2	1.500	0.707	2.58	Not significant
	6 to 10 years	4	1.250	0.500		
	2 to 5 years	24	1.375	0.495		
	Less than 2 years	9	2.111	1.167		
Get the competent person to repair the system	More than 10 years	2	1.000	0.000	3.182	$p<0.05$
	6 to 10 years	4	1.250	0.500		
	2 to 5 years	24	1.417	0.584		
	Less than 2 years	9	2.111	0.928		
Access to the catchment area	More than 10 years	2	1.500	0.707	6.311	$p<0.05$
	6 to 10 years	4	1.250	0.500		
	2 to 5 years	24	1.417	0.504		
	Less than 2 years	9	2.556	1.130		
Access to the catchment storage tank	More than 10 years	2	1.500	0.707	5.002	$p<0.05$
	6 to 10 years	4	1.000	0.000		
	2 to 5 years	24	1.125	0.338		
	Less than 2 years	9	1.889	0.928		
Space to carry out maintenance work	More than 10 years	2	1.500	0.707	1.256	Not significant
	6 to 10 years	4	1.000	0.000		
	2 to 5 years	24	1.167	0.381		
	Less than 2 years	9	1.444	0.726		

The difficulties and involvement in RWH System is shown in Table 5.11. The univariate ANOVA found a significant difference for the three degree of difficulties which are *get the* *competent person to repair the system, access to the catchment area* and *access to the catchment storage tank* on the involvement in maintaining RWH System. As a result, involvements in maintaining RWH System do influence the degree of difficulties in maintaining RWH System.

5.3.4.2 The relationship between difficulties in maintaining RWH System and operation of the building.

Table 5.12: Summary of result of univariate ANOVA

Difficulties	**Operation**	**N**	**Mean**	**Std. Deviation**	***F***	***p-value***
Get the replacement part	More than 20 years	17	1.235	0.562	0.604	Not significant
	11 to 20 years	7	1.000	0.000		
	5 to 10 years	8	1.125	0.354		
	Less than 5 years	7	1.286	0.488		
Clearing the catchment area	More than 20 years	17	1.471	0.624	2.646	Not significant
	11 to 20 years	7	1.143	0.378		
	5 to 10 years	8	2.125	1.126		
	Less than 5 years	7	1.429	0.535		
Get the competent person to repair the system	More than 20 years	17	1.647	0.786	3.339	$p<0.05$
	11 to 20 years	7	1.000	0.000		
	5 to 10 years	8	2.000	0.756		
	Less than 5 years	7	1.286	0.488		
Access to the catchment area	More than 20 years	17	1.647	0.702	3.637	$p<0.05$
	11 to 20 years	7	1.143	0.378		
	5 to 10 years	8	2.375	1.188		
	Less than 5 years	7	1.429	0.535		
Access to the catchment storage tank	More than 20 years	17	1.353	0.702	1.566	Not significant
	11 to 20 years	7	1.000	0.000		
	5 to 10 years	8	1.625	0.744		
	Less than 5 years	7	1.143	0.378		
Space to carry out maintenance work	More than 20 years	17	1.235	0.562	0.782	Not significant
	11 to 20 years	7	1.000	0.000		
	5 to 10 years	8	1.375	0.518		
	Less than 5 years	7	1.286	0.488		

The univariate ANOVA result for operation of the building on difficulties in maintaining RWH System is presented in Table 5.12. The ANOVA proved that there is significant difference for the two degree of difficulties which are *get the competent person to repair the system* and *access to the catchment area* on operations of the building. Therefore, operations of the building have influence on difficulties in maintaining RWH System.

5.3.4.3 The relationship between difficulties in maintaining RWH System and RWH system installation.

Based on Table 5.13, the univariate ANOVA found that there is significant difference for one degree of difficulties which is *get the replacement part* on RWH System installation. This means that the longer the RWH system has been installed in the building, the degree of difficulty in maintaining RWH System for the building getting higher especially for replacement parts. As a result, RWH System installation does influence the degree of difficulties in maintaining RWH System.

Table 5.13: Summary of result of univariate ANOVA

Difficulties	**RWH System Installation**	**N**	**Mean**	**Std. Deviation**	***F***	***p-value***
Get the replacement part	More than 5 years	8	1.625	0.744	4.315	$p<0.05$
	4 to 5 years	12	1.000	0.000		
	1 to 3 years	18	1.111	0.323		
	Less than 1 years	1	1.000	.		
Clearing the catchment area	More than 5 years	8	1.500	0.756	0.814	Not significant
	4 to 5 years	12	1.333	0.492		
	1 to 3 years	18	1.722	0.895		
	Less than 1 years	1	1.000	.		
Get the competent person to repair the system	More than 5 years	8	1.875	0.835	1.107	Not significant
	4 to 5 years	12	1.333	0.651		
	1 to 3 years	18	1.556	0.705		

	Less than 1 years	1	1.000	.		
Access to the catchment area	More than 5 years	8	1.750	0.886	0.819	Not significant
	4 to 5 years	12	1.417	0.515		
	1 to 3 years	18	1.833	0.985		
	Less than 1 years	1	1.000	.		
Access to the catchment storage tank	More than 5 years	8	1.625	0.916	1.383	Not significant
	4 to 5 years	12	1.083	0.289		
	1 to 3 years	18	1.333	0.594		
	Less than 1 years	1	1.000	.		
Space to carry out maintenance work	More than 5 years	8	1.375	0.744	0.722	Not significant
	4 to 5 years	12	1.083	0.289		
	1 to 3 years	18	1.278	0.461		
	Less than 1 years	1	1.000	.		

5.4 Discussion of Findings: Quadrant Analysis

Both findings as discussed before are combined to determine the Maintenance Performance Quadrant of RWH in Malaysia as show in Figure 5.3 below. The result from condition survey is based on Summary of Condition Survey Protocol (CSP) 1 (Table 5.1) meanwhile the result from questionnaire survey based on part B of questionnaire which are frequency of RWH breakdown (Table 5.9) and difficulties in maintaining RWH (Table.5.10).

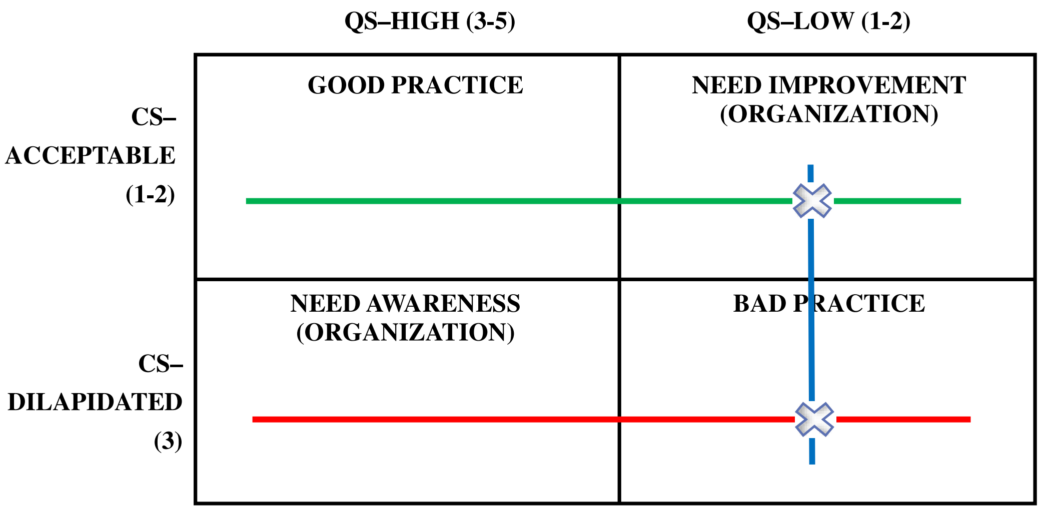

Figure 5.11: Maintenance Performance Quadrant of RWH in Malaysia

Findings gained from condition survey shows 14 buildings (87.5 %) score 1 and 2 rated as good and fair for overall rating meanwhile only 2 buildings (12.5%) score 3 which rated as dilapidated (Refer Table 5.1: Summary of Condition Survey Protocol (CSP) 1). Results for good and fair rating falls under acceptable box and represent the green line as shown in quadrant and dilapidated falls under dilapidated box and represent the red line.

Cross result for questionnaire survey represent in blue line shows the frequency of RWH system breakdown and the degree of difficulties in maintaining RWH System registered mean score around 1.18 to 1.67 as shown in Table 5.9 and 5.10 which falls under low box.

Combination of both results demonstrates a cross-combination finding that shows the situation of maintenance performance of RWH;

1. Most of the buildings (14) - Need Improvement (organization)

   Means the maintenance of RWH for that building is good but there is some improvement needs to be taken for their organization for example in terms of planned maintenance and allocation of budget. This is to make sure the performance of the system up to the maximum standard and the systems functionality satisfied.

2. Some of the buildings (2) - Bad Practice

   Means the maintenance of RWH for that building totally needs to revamp in term of organization and the system itself. The maintenance approaches for the RWH system have to re-plan and the system needs to have major repaired, as the status of the system is dilapidated.

5.5 Summary

Two instruments used in this research to assess maintenance performance of RWH in Malaysia. Condition survey has been carrying out in 16 buildings throughout Semenanjung Malaysia, and the data was analysing using CSP1 matrix. The results show only two buildings rated as dilapidated meanwhile majority (14) buildings rated as good and fair. Questionnaire survey distributed to three respondents for each building. Total 48 respondents throughout Semenanjung Malaysia was analysed using SPSS. The results of difficulties in maintaining RWH system in the building shows mean score below than 2.0, which consider as low. Both results demonstrated cross-combination finding via maintenance performance quadrant at the end of analysis and shows majority of building need improvement in terms of their organization meanwhile only two building had bad practice, which needs total to revamp in terms of the RWH system itself or their organization.

The next chapter is going to elaborate the findings from this study of the objective that have been set as well as provide recommendations for further improve the maintenance performance of rainwater harvesting (RWH) in Malaysia.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Preface

This research is about the maintenance of rainwater harvesting (RWH) system in Malaysia. As discussed in chapter 2.3, there is no previous research studied about a maintenance aspect of the system. All the data and information stated in this report is purely from data collection on existing scenario. This study also is the first attempt in assessing the maintenance aspect of the RWH system in Malaysia. Therefore, the findings from this study cannot be compared with other findings and solely discuss based on available sources.

The aim of this research is to improve the maintenance management of RWH system in Malaysia. At the end of the study, it is going to achieve 3 objectives namely (i) to overview the RWH practice and implementation issue in Malaysia, (ii) to develop the assessment framework for RWH in Malaysia and (iii) to assess the maintenance performance of RWH in Malaysia. This in turn is going to reflect the achievement of this study as well as establishing whether the research process is achieved or not. Therefore this chapter is going to highlight the objective achievement. Apart from this, the recommendation is also listed, based on the key findings from this study.

6.2 Objectives Achievement

This research embarks on three objectives that are based on the problem statement, namely "Maintenance of Rainwater Harvesting (RWH) System in Malaysia". In relation to this statement, the primary research question had been developed, namely "What is the instrument that can be used in assessing the maintenance of RWH?" The research question is actually reflecting the last objective of this study. It is then driving the whole research process towards one primary aim and it is elaborated below.

a. To overview the practice and implementation issues of RWH system in Malaysia

The first objective is achieved via the groundwork of study. It is solely based on the secondary data collection, namely the literature review. The literature review is carried out with reference to published documents such as journal paper and government agency publication. As discussed in chapter two (2.6 and 2.7), objective one is then achieved.

b. To develop the assessment framework for RWH system in Malaysia.

Same as objective one, objective two also achieved via literature review. After considering the data sources, this research form up the conceptual framework as depicted in Figure 3.1 and further elaborated in chapter three. It highlights the variables that are used in assessing the maintenance of RWH in Malaysia. The conceptual framework become assessment framework and it consists of six variables that measuring the maintenance performance of RWH in Malaysia. There are:

I. Catchment surface
II. Gutter and downspouts
III. Filtration
IV. Storage tank
V. Delivery system
VI. General maintenance

With forming this framework, objective two is achieved.

c. ***To assess the maintenance performance of RWH system.***

After establishing the assessment framework of RWH maintenance, it is then be used for this research instruments in producing the checklist for condition survey and in designing questionnaire for questionnaire survey. Results from condition survey are to capture the physical condition of RWH elements and results from questionnaire survey to capture maintenance team's opinion about RWH maintenance performance in their building.

Both results are combined to demonstrate a cross-combination finding via maintenance performance quadrant of rainwater harvesting (RWH) system in Malaysia which condition survey results represents x-axis and questionnaire survey results represents y-axis in the quadrant (as shown in figure 5.11 in chapter five). The intersection point becomes the finding for this research and detail descriptions have been made to clarify the maintenance performance of RWH system in Malaysia, thus showing the achievement of second objective as well as answering the research question in this study.

There are two primary key in this research, namely to assess the current scenario related to the maintenance of RWH system in Malaysia and to build an assessment framework that can be used by maintenance organization as an instrument to assess the maintenance performance of RWH system in their respective building.

For the academic researcher, this research contributes to the development of technology from aspect RWH system and maintenance performance. To date, there is very limited study on RWH which cover the maintenance aspect in their research. The conceptual framework established in this study could be used as a guide in expands further study about RWH maintenance performance.

For practitioner, finding of this study reveal the existing scenario of RWH system in Malaysia and the maintenance performance quadrant of RWH can be used as an instrument for their organization in assessing the RWH maintenance performance in their building.

6.3 Main Conclusion of The Study

This research started with literature reviews about RWH. The assessment framework of this study namely the conceptual framework of RWH maintenance has been developed as to guide this research and to drive the overall research flow.

Two instruments used in this research to assessed maintenance performance of RWH in Malaysia. Instruments, condition survey and questionnaire survey became main data collection of the study. This is important to ensure the successful of this research.

One of contribution of this research is production of Maintenance Performance Quadrant of RWH which was developed to assess the RWH maintenance performance in Malaysia. Results from instruments demonstrate a cross-combination finding via this quadrant at once demonstrates the finding of this research.

From the findings, it can be conclude that performance of RWH maintenance in most of the buildings (case study) that with RWH system installed in the building need improvement in term of the organization meanwhile only two building had a bad practice which means either the RWH system itself or the organization, both need to be revamp and gives serious attention to make sure the performance of RWH up to the standard.

6.4 Recommendation for Further Research

Discussion on this part is going to be a closing of the research works. Five recommendations are going to propose for further research about maintenance of RWH system. The recommendations are as follows.

1. This study focuses only for projects that managed by government agencies which are NAHRIM, DID and local authority. Bigger sampling should be carrying out for comparable study for example including projects under private agencies. The result between this two agencies can be compare in determine the maintenance performance of RWH.

2. Similar research should be carried out using different type of building such as residential building. The result obtained should be different from finding of this research as the maintenance of RWH system for residential building is under owner's responsibilities.

3. In term of questionnaire survey, similar study should be carried out using different respondents for example from perspective view of the users or stakeholder. Results found from that study could be compared with present study.

4. While this study focuses on maintenance performance of RWH in term of elements condition and perspective view of maintenance parties who involved directly with RWH system, extend study should be carry out focusing on the RWH system technology itself to helps to prolong the life span of the system. For example using the sustainable elements or adapting intelligent concept into the system in order to make the system more sophisticated and advanced.

5. Based on the finding of this research, main problem in maintaining RWH is the organization itself. An in-depth study is needed to identify the factor of depreciation performance of maintenance organization in government agencies either management level or technical support. The study should emphasis on planned preventive maintenance.

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APPENDIX A

A STUDY ON MAINTENACE OF RAINWATER HARVESTING (RWH) IN MALAYSIA

Questionnaire Form

THANK YOU in advance for your cooperation towards this survey. I believe your valuable information can help me to gather all necessary information for my thesis.

Instruction to Respondent

1. This questionnaire survey is solely for academic purpose. Therefore it is really hope that the respondents can provide their best response in relation to every single question.

2. Any means of identification i.e. name, respodent identity, etc. is treated in a strictest confidence. A written approval has to be obtained from respondent prior to disclose any particulars regarding the respondents' identification.

3. This questionnaire comprises of 2 section namely:

   Section A: Demographic Profile
   Section B: Maintenance of RWH System

4. Your answerwould be based on the RWH System installed in the selected building.

5. If you are happy to help in this important study I would be so much grateful and thank you for taking the time to complete this survey (I know you are often to fill out questionnaires).

Yours sincerely,

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SECTION A: DEMOGRAPHIC PROFILE

1. Building Name :...

2. Estimated GFA :..

3. Respondent profile:

   ☐ Technical
   ☐ Management
   ☐ Others

4. How long have you involved in maintaining RWH System for the building?

   ☐ More than 10 years
   ☐ 6 to 10 years
   ☐ 2 to 5 years
   ☐ Less than 2 years

5. How long the building has been operated?

   ☐ More than 20 years
   ☐ 11 to 20 years
   ☐ 5 to 10 years
   ☐ Less than 5 years

6. How long the RWH system has been installed in the building?

   ☐ More than 5 years
   ☐ 4 to 5 years
   ☐ 1 to 3 years
   ☐ Less than 1 years

7. kindly indicate water consumption bill for the building per month?

   ☐ More than RM500
   ☐ RM101 to RM300
   ☐ RM301 to RM500
   ☐ Less than RM100

8. What is the type of delivery system used for RWH system in this building?

   ☐ Gravity Fed
   ☐ Pump system

9. Approximate RWH catchment area (roof surface)

   ☐ More than 500 m^2
   ☐ 101 to 300 m^2
   ☐ 301 to 500 m^2
   ☐ Less than 100 m^2

10. Estimate numbers of trees around this building in 10m radius

   ☐ More than 20
   ☐ Less than 10
   ☐ 11 - 20
   ☐ None

SECTION B: MAINTENANCE OF RWH SYSTEM

11. Kindly indicate maintenance approach implemented for RWH in the building

- [ ] Preventive maintenance
- [ ] Predictive maintenance
- [ ] Corrective maintenance
- [ ] Condition based maintenance

12. Kindly indicate method of implementing the maintenance approach for RWH System

- [ ] In house maintenance i.e using own staff
- [ ] Outsource maintenance management
- [ ] Others (Please specify..)

13. Kindly indicate frequency of routine inspection being carried out for RWH System at the building

- [ ] Daily
- [ ] Every 3 days
- [ ] Weekly
- [ ] Bi- weekly
- [ ] Monthly
- [ ] Others (Please specify..)

14. Kindly indicate the performance of RWH System in the building

- [ ] Very Good
- [ ] Good
- [ ] Average
- [ ] Poor
- [ ] Very Poor

15. What is the main problem in maintaining RWH System in the building?

- [ ] Lack of skilled personnel
- [ ] Limited budget allocation
- [ ] Lack of knowledge in RWH maintenance
- [ ] Others (Please specify..)

16. Which part of RWH element frequently needs to be repaired?

- [ ] Roof/ catchment surface
- [ ] Gutter and downspout
- [ ] Filtration
- [ ] Storage tank
- [ ] Pump

17. Kindly indicate common defects that occurred for the RWH System in the building

- [ ] Excess debris or sediment present on rooftop
- [ ] Clogged or water backing up at dutter and downpipe
- [ ] Leakage at tank
- [ ] Pump is not working
- [ ] Other (Please specify..)

18. Do you think this RWH system really helps in saving water consumption?

- [ ] Yes
- [ ] No

19. Kindly indicate frequency of breakdown happened to the RWH System in a year.

Very low ⬭ ⬭ ⬭ ⬭ ⬭ Very High

20. Kindly rate the degree of difficulties in maintaining RWH System for the building.

20.1	Get the replacement part	Very low ⬭ ⬭ ⬭ ⬭ ⬭ Very High
20.2	Clearing the catchment area	Very low ⬭ ⬭ ⬭ ⬭ ⬭ Very High
20.3	Get the competent person to repair the system	Very low ⬭ ⬭ ⬭ ⬭ ⬭ Very High
20.4	Access to the catchment area	Very low ⬭ ⬭ ⬭ ⬭ ⬭ Very High
20.5	Access to the catchment storage tank	Very low ⬭ ⬭ ⬭ ⬭ ⬭ Very High
20.6	Space to carry out maintenance work	Very low ⬭ ⬭ ⬭ ⬭ ⬭ Very High

Comments/ Opinions/ Suggestions/ Remarks:

....

....

....

....

END OF QUESTIONNAIRE SURVEY
YOUR COOPERATION IS HIGHLY APPRECIATED

APPENDIX B

Table 4.2: Condition Assessment Protocol 1

Condition	Scale Value	Description
1	Good	Minor Servicing
2	Fair	Minor Repair
3	Poor	Major Repair/Replacement
4	Very Poor	Malfunction
5	Dilapidated	Damage/Replacement of Missing Part

Source: Che-Ani *et al.,* 2011

Table 4.3: Priority Assessment

Condition	Scale Value	Description
1	Normal	Functional; cosmetic defect only
2	Routine	Minor defect, but could become serious if left unattended
3	Urgent	Serious defect, does not function at an acceptable standard
4	Emergency	Element/structure does not function at all; or presents risks that could lead to fatality and/or injury

Source: Che-Ani *et al.,* 2011

Table 4.4: The matrix

Scale		Priority Assessment			
		E 4	**U 3**	**R 2**	**N 1**
Condition Assessment	**5**	20	15	10	5
	4	16	12	8	4
	3	12	9	6	3
	2	8	6	4	2
	1	4	3	2	1

Source: Che-Ani *et al.,* 2011

Table 4.5: The descriptive value according to score

No	Matrix	Score
1	Planned Maintenance	1 to 4
2	Condition Monitoring	5 to 12
3	Serious Attention	13 to 20

Source: Che-Ani *et al.,* 2011

Table 4.6: Overall building ratings

No	Building Rating	Score
1	Good	1 to 4
2	Fair	5 to 12
3	Dilapidated	13 to 20

Source: Che-Ani *et al.,* 2011

APPENDIX C

Table 4.7: Schedule of Building Condition

Source: Che-Ani *et al.,* 2011

BUILDING CONDITION ASESSMENT

Schedule of Building Condition (CSP1 Matrix)

NO.	AREA	DEFECTS	Condition Survey Protocol (CSP) 1				
			Condition Assessment (a)	Priority Assessment (b)	Matrix Analysis (c) (a x b)	Photo No./ (Sketch No.)	Defects Plan Tag
	Total marks (d) (Σ of c)						
	Number of defects (e)						
	Total score (d/e)						
	Overall building rating						

APPENDIX D

Photograph/ Sketch No.		Level			
		Location			
		Element/ Component			
		CSP1			
		Condition	Priority	Matrix	Color
		Defect Description			
		Possible Causes			
		Remarks			

Figure 4.2: Photograph/sketch box

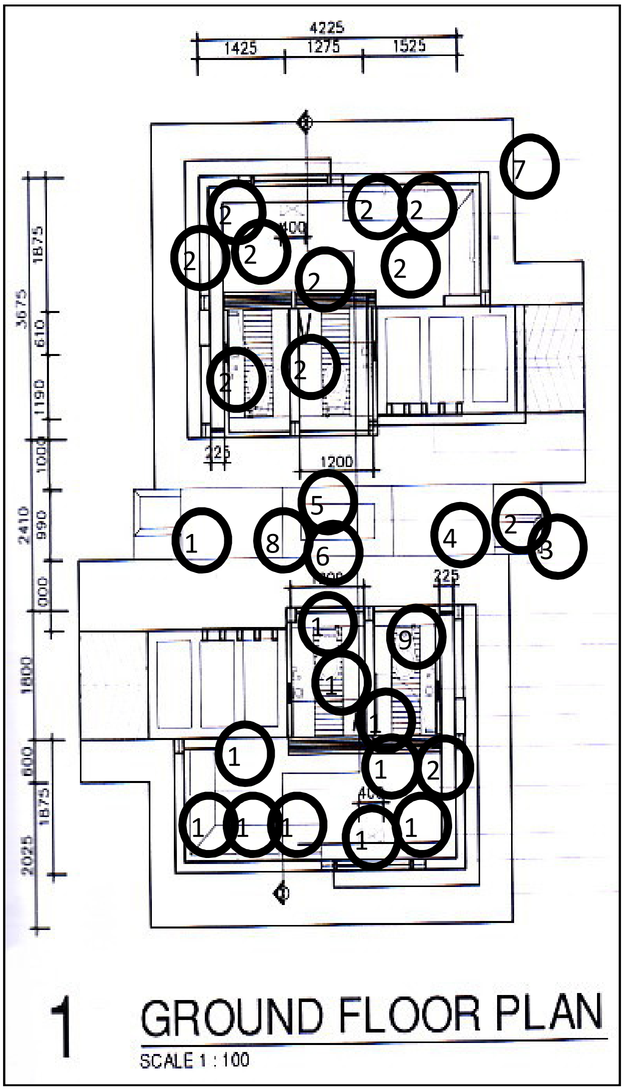

Figure 4.3: Defect plan tags
Source: Che-Ani *et al.*, 2011

BUILDING CONDITION SURVEY FOR ECSTRACT
PULAU LANGKAWI, KEDAH DARUL AMAN

CONDITION SURVEY PROTOCOL (CSP) 1

EXECUTIVE SUMMARY

1.0 Property Information

Building Address : ECSTRACT™ Pulau Langkawi, Kedah Darul Aman
Owner Name : Ministry of Science, Technology and Innovation (MOSTI)
Date of Inspection : 26.06.2009
Weather : Clear and Fair

2.0 Condition Survey Protocol (CSP) 1 Matrix

No.	Matrix	Score	Color Code	Finding(s)
1.	Planned Maintenance	1 to 4	Green	25
2.	Condition Monitoring	5 to 12	Yellow	4
3.	Serious Attention	13 to 20	Red	0
Total Defects				**29**

3.0 Overall Building Rating

No.	Building Rating	Score
1.	Good	1 to 4
2.	Fair	5 to 12
3.	Dilapidated	13 to 20

Total marks : 127
Number of defects : 29
Total score : 4.38
Overall building rating : Good.

4.0 Recommendation

This building is in Good condition.

However, the total score is close to 5, indicating that, if the defects identified in this inspection are [illegible]
[illegible]

Therefore, it is recommended that periodical inspections be carried out on this building and that any actions recommended by this report are carried out to prevent further dilapidation to the building.

Figure 4.4: Executive Summary