FACILITATE DECISION MAKING OF OPTIMUM UTILIZATION URBAN ROOFTOP RWH, CASE STUDY KOLKATA METROPOLITAN AREA

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ABSTRACT

The study is done for assessment of Rooftop Rain Water Harvesting (RRWH) for non potable uses in a humid urban catchment. In this study, an user response survey was conducted, with 390 sample size, in five types of building uses; Residential, Educational, Medical, Institutional and mixed use Commercial, with variable roof sizes and situated in four different zones of KMA, having wide variation in piped water supply. A database of 32 years of daily rainfall data has been analyzed , in order to find out demand for different end uses for various building, supply from roof runoff, demand supply ratio, priority of different socio-economic factors for each type of building using AHP analysis, user's opinion on choice of end-use using regression analysis and finally developed a DSS model. Analysis also revealed that the highest acceptance of RRWH are in favor of the Medical uses building, the lowest being mix-Commercial building. Further factors like toilet flushing is found to be most potential end use options, followed by landscaping and cleaning. The regression model clearly show that the variables like ground condition, scale of development, degree of contact, storey's of building and water scarcity are key to decision making.

KEYWORDS : *Roof top Rain Water Harvesting (RRWH), non potable use, Decision support system (DSS), Analytical Hierarchy Process (AHP), End-use potential, Urban Local Bodies (ULB).*

1.0. INTRODUCTION

Once thought to be a never-ending renewable resource, clean, fresh water supplies are rapidly depleting, causing drought and drought-like conditions around the world. "Today, one billion people lack access to safe and affordable sources of clean water, and over 2.4 billion people lack adequate sources for sanitation" (UN Water, 2006). The state of West Bengal receives an annual rainfall close to 1700mm. During some events it causes water logging for more than two days. West Bengal especially KMA is frequently perceived as 'wet regions' which should not have any difficulties relating to the availability of water. The existing ground water table is at 1.8 m. The city might boast of excess water supply at present, but the scenario is set to undergo a dramatic change by 2025. The demand-supply ratio could drop to 100:75 from the present 101:125, if the usage pattern is not altered and steps not taken to conserve water (study by JU August 2009). Some pockets of Kolkata Metropolitan Area faces serious water crisis during every summer.

However a serious thought for the rain water management for the city should be given to counteract this conflicting situation. Moreover there are increasing pressures on the water resources in KMA and parts of West Bengal. The urban development has been sporadic in nature and the distribution of infrastructure is not evenly spread (Ghosh, 2010). The shortfalls of integrated surface water management in the ULBs has called upon problems related to water quantity (floods and droughts) and quality (pollution of ground water and surface waters), and water resource management. At present traditional methods of water management in urban areas focus primarily on so called "end of pipe" approaches. However, urban water systems normally are very complex and they need to be fully integrated into the process of urban planning. Though Governments are working frantically to develop solutions to these shortages and have introduced the issue of water conservation for the community. There is an urgent need to take action due to:

1. Increasing water usage due to population growth

2. The effects of climate change (including extended periods of drought)

3. The huge cost to develop new water infrastructure (such as water treatment plant and rain water management systems)

Growing water shortage or unexpected drought can be met with the utilization of *non- conventional resources* as harvesting *Rain Water*. The feasibility of harvesting rainwater is based on many factors, i.e. precipitation frequency, water consumption needs, prices of local water and wastewater treatment, and the cost of installation and maintenance (Sen, 2012). Storm water has become a vulnerable issue in terms of provision of large number of drainage infrastructure within urban environments; through it can be turned into a reliable and sustainable water resource.
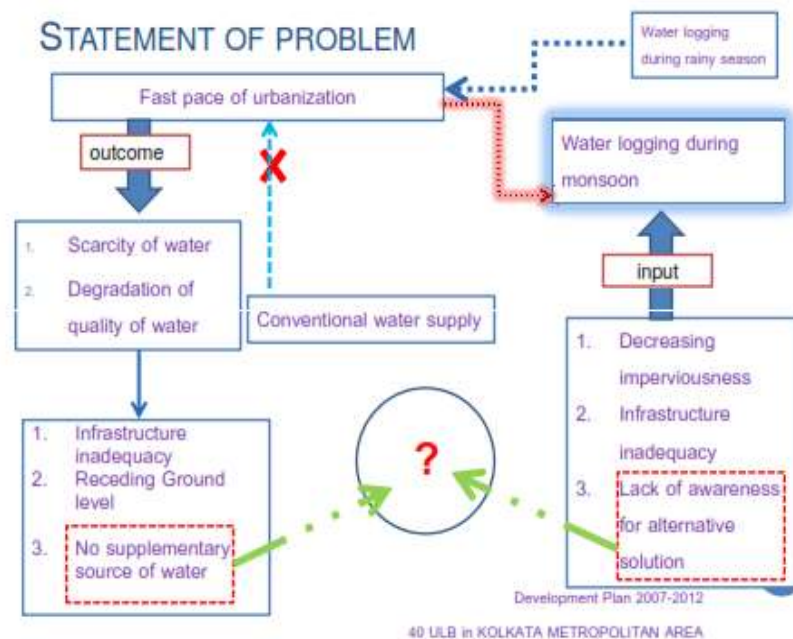
Source: Draft Development Report (2005-09) for forty numbers of ULBs in KMA, DFID, India

Present water usage of Metropolitan area cannot be considered sustainable because too much water of high quality is taken from the eco-systems and too much polluted water is discharged (Terpstra, 1998). Utilization of natural resources and of the environment should be attuned to availability for future generations. The general principle of sustainability is put into practice to address three issues: running out of resources; polluting of the ecosystem; and disrupting the natural systems.

The humid tropics are having some typical characteristics of urban development. As the water is found in abundance in this part the residents never cares for water conservation. The goal of the thesis is to measure the factors responsible for the implementation of rain water harvesting for non potable uses in a humid urban catchment. As the thesis considers only the municipal uses of water; the other urban water uses like industrial, irrigation is assumed to remain outside the system boundary. Public rejection of Rooftop Rainwater Harvesting has been assumed to be based on misunderstanding of the technologies of water treatment and misconceptions of health risks.

The objectives of this thesis are manifold

1. Reviewing literature available on rooftop rainwater harvesting and its applicability at plot level
2. Finding the probability of rainfall and its distribution pre-monsoon, Monsoon and Post Monsoon Period in humid west Bengal
3. Identify the need for non potable water uses in various type of building
4. Identify the factors responsible for reuse of harvested rainwater in urban catchment
5. Developing a conceptual model for re-use of rooftop rainwater in decision making process for different building uses

1.1. Significance of the study

The majority of previous studies on RWH in the past (some of these are described in literature review) have taken either a social or technical viewpoint. This study intends to contrast these studies by presenting a feasibility of RRWH in a Humid Region. This study finaly derives a DSS Model for deriving type of endues of harvested rainwater in a system environment. In order to appropriately implement RWH into a development of any scale, the available resources as well as site specific constraints need to be understood. Furthermore, user

behavior plays a major role in the performance of RWH systems. This study is based on the actual survey for the development of RRWH in the study areas. Consequently it is based on a real time process. The author did not spend more than three weeks at a time in any of the study area. There is a possibility that dynamic change in societal and cultural issues might influence and re-direct the focus of further research. This study has not intervened for treatment of rainwater as a potable water resource.

2.0 LITERATURE REVIEW

In Kolkata, centralised water supply systems depend on surface water sources like rivers and lakes. Where surface water sources fail to meet the rising demand, groundwater reserves are being tapped, often to unsustainable levels. According to a World Bank study, of the 27 Asian cities with populations of over 1,000,000, Calcutta fourth worst (Source: Background Paper - International Conference on New Perspectives on Water for Urban & Rural India - 18-19 September, 2001, New Delhi.). Anyhow, there is a growing demand for alternative water systems, wherever the conventional systems are not affordable in terms of money or in terms of natural water resources. Surrounding the Rain water runoff system, there are other systems that compose the system environment. These can of course be grouped in different ways, but here three entities are chosen to represent the context of the Rain water runoff systems: the environment, society and the urban water system.

Gould (1999) clearly summarized the history of rainwater harvesting. Water harvesting is a term describing techniques for collecting, concentrating, and conserving water from various sources for various purposes. Agarwal (2001) defined Rain Water Harvesting as the art, technique, and science of collecting rainwater where it falls, while Paceyand Cullis (1986) referred to rainwater harvesting as the principle of using precipitation from a small catchment.

Generally, rainwater-harvesting methods are classified based on the characteristics of the runoff producing and storage elements of the system. At the simplest level, the various methods can be divided into two groups (CSE, 2003):

- Rooftop Rain Water harvesting method: Rainwater is collected from roof of buildings, concentrated in gutters and conveyed by pipes to a storage system for domestic uses, groundwater recharging, and/or micro irrigation.
- Non-rooftop rainwater harvesting, including micro-catchment and macro-catchment. Micro catchment includes contour ridges, furrow dyke, strip planting, stone bunds, etc. Macro catchment includes terraced systems, hillside conduit system, dam used for recession planting, etc.
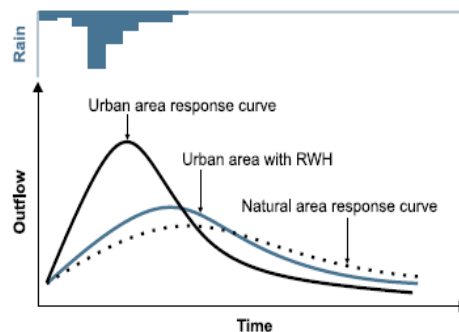

Figure 2.2: principal flow response curve from an urban catchment with and without rainwater harvesting in place, showing the effect of slower flow through the landscape (contributed by K. König)

2.1 Factor responsible for choosing the option for RWH

The harvested rainwater is a resource. The factor responsible for choosing the option for RWH is given below:

1) The rainfall pattern: Areas where the total annual rainfall occurs during three or four months are examples of places where groundwater recharge is usually practiced. In places where rain falls throughout the year with a short dry period, a small sized tank is reliable enough for storing rainwater.

2) The sub-surface geology: The most important factor of sub-surface geology for recharging the water is the structure should be permeable. Wherever sub-strata are impermeable, recharging will not be feasible.

3) Groundwater salinity: In places where the groundwater is saline or not of potable standards, the alternate system could be that of storing rainwater (DGIS, 2001).

4) Density of population in a given area determines whether to reuse or recharge harvested Rainwater.

5) **Availability of water** and availability of alternative sources of water, e.g. surface water are influencing factor in the choice of the system.

6) Human induced (deterioration of) quality of the groundwater (need for improvement by surplus water of good quality).

7) Quantity of excess water during the monsoon season that has to be drained and could potentially is recharged.

8) Depth of the recharged aquifer and technical means to lift the water, etc. will possibly improve the existing groundwater quality, especially in urban areas.

Pattern of RWH

- *Occasional* – Rain water is collected occasionally with a small storage capacity, which allows the user to store enough water for a maximum of, say, one or two days.

- *Intermittent* - This type of pattern is one where the requirements of the user are met for a part of the year. A typical scenario is where there is a single long rainy season and, during this time, most or all of the users' needs are met. During the dry season, an alternative water source has to be used.

- *Partial* - This type of pattern provides for partial coverage of the water requirements of the user during the whole of the year.

- *Full* - With this type of system the total water demand of the user is met for the whole of the year by rainwater only.

  There is a wide range of tried and tested Rain water harvesting reuse techniques used around the world. These include Aquifer storage and recovery; Urban lakes; wetlands; lakes and ponds uses for swimming , snowmaking, Fishing, boating, and other noncontact recreational activities and non-potable reuse; The choice of end use depends on Space availability, Options available locally, Local traditions for water storage, Cost of purchasing new tank, Cost of materials and labour for construction, Materials and skills available locally, Ground conditions, Style of RWH – whether the system will provide total or partial water supply, Sizing the system.

There are many decentralized water solutions described in the literature. Burkhard et al. (2000) present a broad review of techniques in rainwater management, domestic wastewater management, and water and waste re-use. Local Rain water harvesting management solutions, such as infiltration basins, swales, and infiltration trenches, are suitable where there is sufficient open space (Burkhard et al. 2000; Harremoës 1997). In addition, local water reuse solutions, such as rainwater, liquid waste, and greywater reuse systems, have the potential to reduce total water consumption; however, their economic feasibility depends significantly on the scarcity of water resources (Burkhard et al. 2000; Harremoës 1997). The planning of decentralized, integrated water, Rain water harvesting, and wastewater management is a complex process involving land use planning and control legislation. Smerdon et al. (1997) elaborate on methods to plan and implement decentralized water supplies and sewerage for single units, clusters of houses, villages, and towns. The literature contains several examples of demonstration projects at the scale of a single dwelling (Berndtsson, 2004), neighborhood (Hofman, 2014), and town (Ward et al. 2012).

From the literature review the following gap has been identified

- Socio cultural and Socio economic behavior of the stakeholders towards acceptance of RWH
- Feasibility of RWH for different building uses in metropolitan catchments depends on the selection of correct end use of harvested Rain water.
- Regional and local policies and other institutional mechanism to support RWH
- a Specific DSS model to assess impediments for Acceptance of RWH in the study area
- Interdependencies between demand and supply of rain water at specific plot level.

This study had integrated socio economic factor to formulate policy for acceptance of roof top rain water harvesting at plot. It has also devised mechanism for proper end use of harvested rainwater at different plot level.

3.0 DEVELOPMENT OF INDICATORS

Since one single indicator cannot describe sustainable systems, thus a number of indicators must be chosen, and a framework for making them cover all the important aspects of sustainability are needed (Maclaren 1996). In a discussion on rain water sustainability the concept of integrated rain water management is valuable (Niemczynowicz 1999). The indicators are formulated with local conditions in mind. In general, indicators shall be formulated to facilitate an assessment of the degree of fulfillment (Bossel 1998, 1999), and they shall be measurable (Lundqvist 2000; Spangenberg 2002), something which does not necessarily imply quantitative measures. The indicators presented here are not suggested in order to be quantitative or measurable on a common scale, but to reflect relevant issues within their own frames of logic In Table below, a number of indicators are listed with the intention of illustrating possible characteristics comprised by the six basic

orientors of system sustainability. The set of indicators presented here, both illustrate the approach as well as summarize relevant indicators generated in previous research. The indicators in the columns reflect either the internal rain water system, or the interaction between the rain water system and its different superior systems.

AHP Analysis

Components	Indicator	Variable	Question no
C1	Judgment Strategies	Association/Participation	
		People's risk perceptions/ Health	32,29
		Scientific knowledge/ awareness	15
C2	Cost	Cost Recovery	30
		Investment Level	30
		Capacity to Pay	14
C3	Co Existence	Flexibility	23,
		Skeptical about durability	30
		Adaptability	30
C4	Adaptability	People priorities	30
		Disgust emotion	30
		Scope/Demonstration projects	30
C5	Performance	Safety	30
		Operation and maintenance	25,27
		Level of infrastructure	9
C6	.Policy framework and legislation	Service Delivery	13,7,11,7
		Compensation	31
		Water availability	12

Regression Analysis

Variable	Question No
Space availability	18
Options available locally	20,17,21,22,24,26
Style of RWH	1
Ground conditions	19
Scale of development	4
Stories of the building	3
Water Scarcity	15
Degree of Contact	25
Number of WCs more than 1per 500sqft	5

Demand Supply Balance

Variable	Question No
Rainfall	Data availed from IMD
Roof area	18
Outcome	Total supply
Total number of non potable water consumer	2
Period of operation	3
Type of demand as per end use	8,28
Outcome	Total Demand as per different end use

4.0 DATA COLLECTION

A 32 years daily rainfall data was collected from IMD for Airport station, Dumdum. The data ranges from 1982 to 2013. The user response survey was conducted in December, 2010 – March, 2011, through 400 set of questionnaires of open end, structured and using five-point Likert-type scale designed to identify respondents' preferences. Survey participants were interviewed through a convenient sampling approach in urban area of KMA with sample sizes conforming to the population ratio of each ULB. Finally a qualified sample size of 390, or a response rate of 97.5% was achieved. The questionnaire survey has been conducted in five types of building uses. Namely Residential, Educational, Medical, Institutional and mixed use Commercial.

Introduction to Study Region

Kolkata Metropolitan Area (KMA), the largest urban agglomeration in eastern India, extends over 886.67 sq. km. and envelopes 3 Municipal Corporations (including Kolkata Municipal Corporation), 39 Municipalities and 24 Panchayat Samitis. Kolkata includes the city proper, urban and rural area. Kolkata is within the Ganges Delta (Latitude- 22° 33' N, Longitude- 88° 30'E) and is situated on an average of 9m from sea level. Due to this location advantage Kolkata enjoys a humid tropical climate. Consequently, the city sits on alluvial deposits and within a considerable seismic zone, and thus is prone to earthquakes.

The metropolitan region suffers from scarcity in clean water and flooding, in periodic cycles, depending on the climate, topography and condition of the river Hooghly, its tributaries, distributaries and canals that flow through the area.

Selection of the study area

The recently released Perspective Plan 2025, by the Kolkata Metropolitan Development Authority which provides an outline for urban planning till 2025, envisages that the per capita availability shall be 150 litres per day. The water is supplied via six service districts identified by the water treatment plants in the specified areas — Palta, Kolkata, Garden Reach, Sonarpur, Howrah and Serampore. The supplied water had been unable to reach 100% household. Greater Kolkata consists of Kolkata Municipal Corporation of parts of Kolkata metropolitan development officer and Kolkata Municipal Corporation. There are two other municipal and 40 municipalities in KMA. Out of 40 municipalities, 4 municipalities have been selected for study- Bally, Srerampur , Panihati and South Dumdum.

Bally

Total area of bally municipality is 11.81 and total population is 275000(as per 2011 census). The localities which has been surveyed are Balibazar , Chaitalpara , Pathakpara, Badamtala, Ghoshpara, Ramcgandrapur , Sahebbagan . There are lots of water bodies in this north western part of bally. Rate of water supply by municipality is 36.61 LPCD
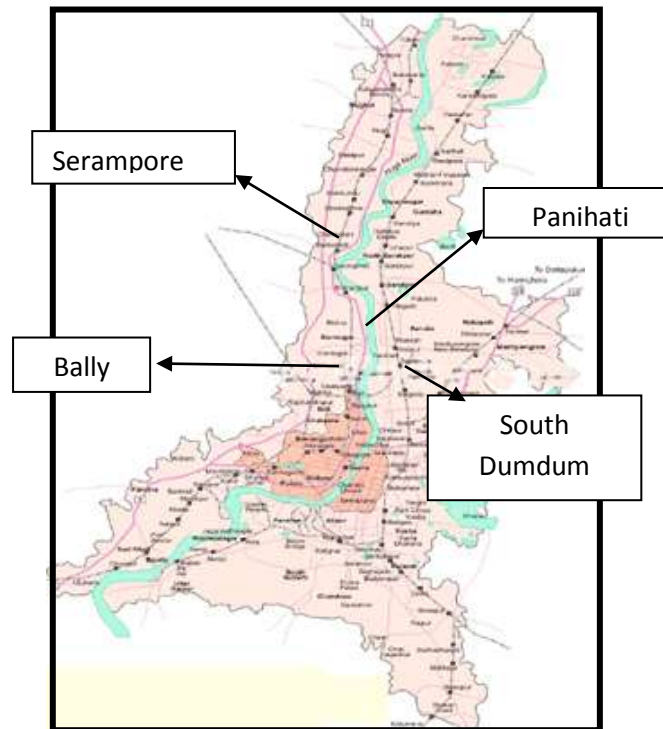
Panihati :

Panihati covers total area of 9.38 sq.km. and 380000 population (as per 2011 census). The locality which had been surveyed for this study are Panihati , Agartala , Krishnapur , Natagarh , Ghola and Ushumpur . Rate of water supply by municipality is 57.33 LPCD.

Serampur :

Serampur has a population of 210000 (as per cenus 2011) and covers an area of14.50sqkm . Rate of water supply by municipality is 59.01 LPCD

South Dumdum:

South Dumdum has total area of 15.3 sq. km. and the total population of 420000 (as per census 2011). Area surveyed are Dumdum park, Lake town, Pikepara , Nagerbazar, Private road. Rate of water supply by municipality is 44.98 LPCD.Total numbers buildings surveyed in the Study Area is given below.

		Residential	Educational	Medical	Institutional	Mixed Commercial
South Dumdum		55	13	9	12	20
Panihati		50	16	10	12	30
Serampur		40	11	8	11	20
Bally	36	12	8	10	14	

5.0 Analysis and finding

The analysis has been divided in the following sections

1. Analysis of rainfall pattern
2. Calculation of supply from runoff from the roof.(module roof area 1000sqm)
3. Type of RRWH from Demand supply ratio
4. Calculation of demand different end uses for various buildings (from survey)
5. AHP for Priority of different Socio-Economic Component for each type of Building
6. Correlation effect of other factor from regression analysis
7. DSS model

5.1 ANALYSIS OF RAINFALL

32 years (1982-2013) of daily rain-fall data pertaining to Kolkata Metropolitan Area rain-gauge station has been obtained from India Meteorological Department (IMD), Pune. The summary of the rainfall analysis is depicted in Table below. The region receives an average annual rainfall of 1662.2 mm occurring over average 44 rainy days. The highest observed rainfall over 32 years is 2303 mm during the year 1986 and minimum is 1215 mm during the year 1989. 95% of the annual rainfall occurs during the South West monsoon (June to September). From Table below it can be seen that the month of August receives highest rainfall in a year, 338 mm (avg) and with lowest rainfall during Dec. Over the past 32 years the area has seen a maximum of 56 rainy days in 1986 and minimum of 33 rainy days in the year 1994. Rainfall data has been used in estimating the volume of water to be stored in order to meet the daily water demand for the specific end use throughout the year.

32 years rainfall data were analysed for mean, range and variance of rainfall. Total wet days-dry days per month were also calculated. Total number of 1,2,3,4,and more than 7 days events were derived from the Analysis. Probability of each event has also been calculated. Calculation of reliabity requires consistent data of daliy and henceforth monthly rainfall data. The chance of rain rose sharply during the month of June, reached a peak in July and August and then started decreasing gradually during September.

a. The start of the season is not considered before June 1,
b. A date after June 1 indicates a potential start date, defined as the first occurrence of at least 70 mm of rain totaled over at least 2 consecutive days and,

c. The potential start could be a false start if a dry spell of 10 or more days occurs in the next 30 days.
d. The first occurrence of a long dry spell of atleast 15 days, after September 15.

The decade rainfall amounts for the period from June 1 to September 30 over the 32-year data base were statistically analyzed to estimate the amounts of rain that can be expected at given probability levels. Percentage points of decade rainfall amounts alongwith approximate 95% confidence limits have been estimated and these are given in Table below.

Table 5.1. Percentage Points and 95% Confidence Limits for Decade Rainfall Amounts

Year	Month	Decade	Percentage Point	Amount (mm)	Confidence Limits
1982-2013	June	I	25%	0.0	(0.0 ,3.0)
			50%	11.2	(5.3, 14.0)
			75%	29.8	(17.871.9)
		II	25%	19.0	(10.2, 29.1)
			50%	50.5	(32.0, 61.8)
			75%	77.4	(64.3, 120.9)
		III	25%	42.0	(21.1, 56.3)
			50%	92.6	(62.4,112.7)
			75%	135.1	(121.2,160.1)
	July	I	25%	53.4	(43.8, 71.1)
			50%	96.2	(84.3, 117.5)
			75%	143.2	(131.5, 169.4)
		II	25%	53.4	(43.8, 71.1)
			50%	96.2	(84.3, 117.5)
			75%	143.2	(131.5, 169.4)
		III	25%	66.6	(44.4, 75.8)
			50%	104.1	(85.1, 131.6)
			75%	173.2	(144.3, 210.8)
	Aug	I	25%	45.5	(29.5, 58.9)
			50%	99.4	(70.1, 114.5)
			75%	123.6	(117.2,157.5)
		II	25%	34.2	(20.6, 44.5)
			50%	65.9	(49.7, 96.8)
			75%	129.1	(107.9, 152.0)
		III	25%	28.9	(13.8, 50.6)
			50%	79.6	(54.8, 101.5)
			75%	130	(112.8, 164.3)
	Sept	I	25%	36.6	(23.1, 45.5)
			50%	71.8	(51.6,84.9)
			75%	111.8	(97.6, 143.6)
		II	25%	14.8	(7.6, 22.4)
			50%	39.5	(27.3, 54.2)
			75%	76.2	(58.2, 85.8)
		III	25%	7.1	(2.6, 10.5)
			50%	32.1	(15.7, 43.0)
			75%	84.8	(57.3, 94.8)

The analysis of dry spells is useful to design storage of rain water. Analysis has been done to determine the probability of dry days. It was found that probability of dry spell for more than 5 days is on june 1-6, and 11-16, Aug 11-16 and September 21-26. Dry spell of more than 7 days starts after October 13.
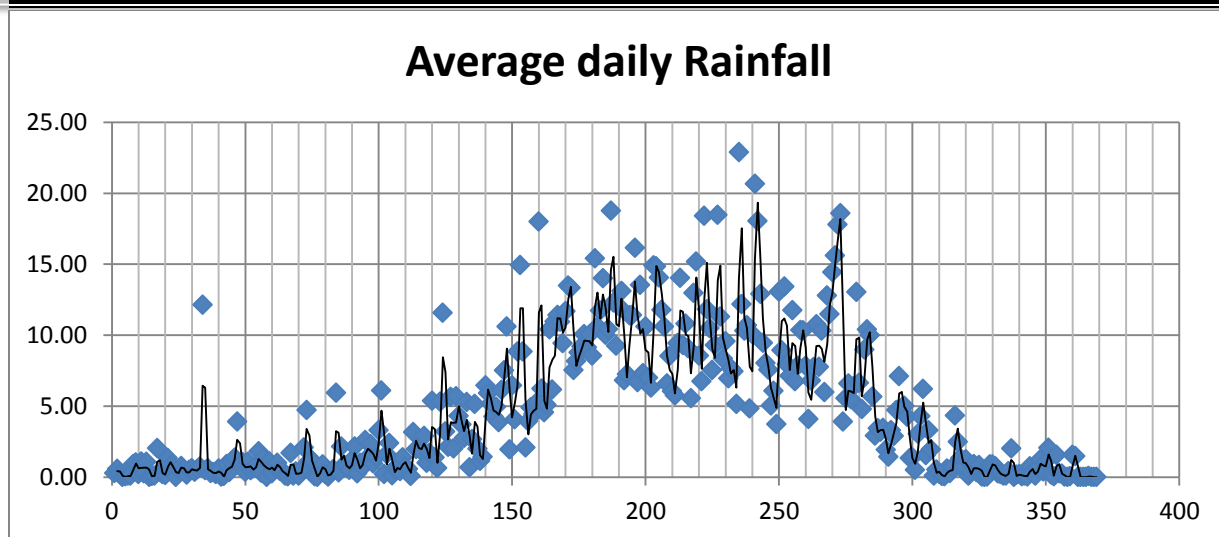
Average daily rainfall data was interpreted and plotted againt each day for the whole annual period.

5.2. Type and Size of the Roof area

The survey conducted for five types of building and the roof area was calculated from satelite imagery. Roof area greater than 1000 sqm was chosen. Then roof areas were grouped into five types namely *very small* 1000-1500 sqm , *small* 1501-3500 sqm , *medium* 3501-6000 sqm, *large* 6001-10000 sqm, and *very large* 10000-150000 sqm. From the graph it can be interpreted that only educational, institutional and mix commercial buildings has considerable number (>10%) of very large roof (10000-15000). Small roof area represents 23% in education, 43% in Medical building. Larger roof area ensures better reliability in terms of supply of rain water versus demand for particular end use.

5.3. Demand of water

Harvested Rainwater can be used in Landscape irrigation Per unit demand of water is extracted from survey given in the table below;

Sl No.	Type of end use	Water demand
1	Garden Landscpping	3-6 litres per square metre
2.	Health Centres	5 litres per Out-Patient
		40-60 litres per In-patient
2.1.	Hospital (with laundry facilities	220-300 litres per bed
	Schools	• 2 litres per student • 10-15 litres per student if water-flushed toilets
5.	Educational	
	a) Day schools	45 per user
	b) Boarding Schools	135 per user
6.	a) In Residential living units b) Hotels with lodging accommodation	135 per user 180 per user
7.	Assembly- Cinema theatres, auditoria, etc. (per seat accommodation)	15 per user
8.	Government or semi public business	45 per user
9.	Mercantile (Commercial)	
	a) Restaurants (per seat)	70 per user
	b) Other business building	45 per user

5.4. Couple supply- demand

The demand for specific enduse is derived from the survey. For outcome of the result total number of the consumer as input to DEPRaH model. The supply of rainwater can be derived from the roof area and max available rainfall.
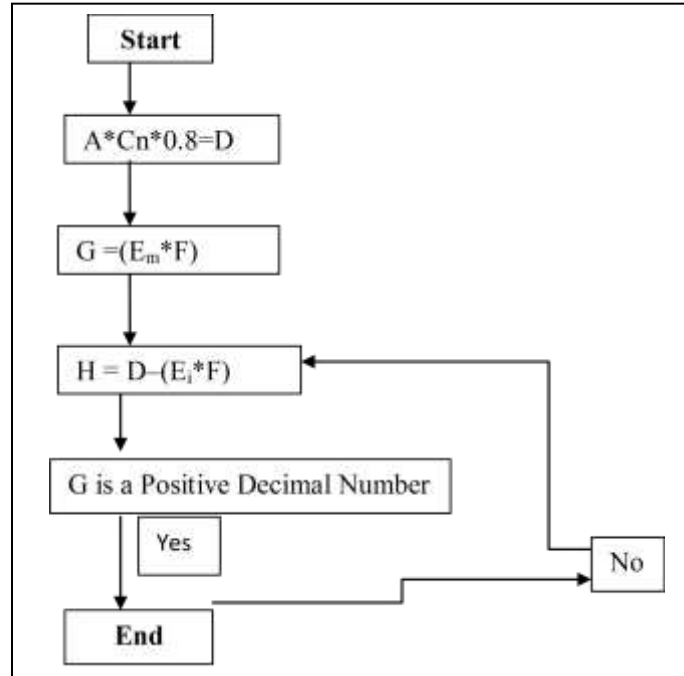
A = Roof area of the Building
C_{1-12} = Max available rainfall
D = Total Runoff to RW tank
E_{i-m} = Demand for each user for end use m
F = Total Number of User
G = Total Demand
H = Cumulative monthly supply
From the model it can be interpreted that choice of the type of end use is dependent on Supply of runoff and no of user.

Table Rainwater supply vs. feasible end use demand

| Sl No	Demand:Supply	Type of RWH proposed
1.	1	Full
2.	0.75	Occassional
3.	0.5	Partial
4.	0.3	Intermittent

5.5. AHP Analysis

AHP analysis has been adopted for determine the priority factor for each building use. Likert response survey questions have response choices such as; strongly disagree, disagree, agree, strongly agree. The response choices are typically considered ordinal; essentially, we will be using factor analysis to generate the composite scores. The Decoding of the responses into numbers which reflect the ordinality of the original responses is done for all five building. From the factor scores
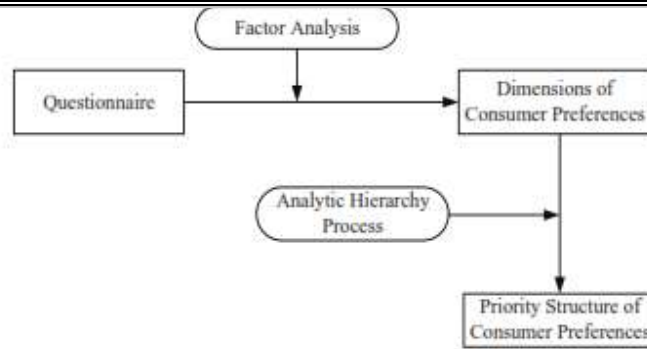
As the results suggest, Policy framework and legislation factor obtained the most important Coefficient for Institutional and mixed commercial buildings. So, this factor has the most effect on the **Acceptance of Rain Water Harvesting**. In fact the results correspond to the reality. The other factors; even though, regarded as one of the key and main effective factor on **Acceptance of Rain Water Harvesting**, but one has to keep in mind that their efficiency even directly or indirectly influenced by the factor of management. Thus, it is recommended to authorities of the branches, in order to increase the efficiency, attending to their role and management assignment as more as they can. Next, the most important coefficients have been obtained by the consumer, Performance factors for Medical Buildings and Judgment Strategies for educational buildings and Cost factors for Residential buildings; these factors have placed in their rank of importance and it's recommended that factors are to be addressed accordingly by Decision makers as for different building uses.
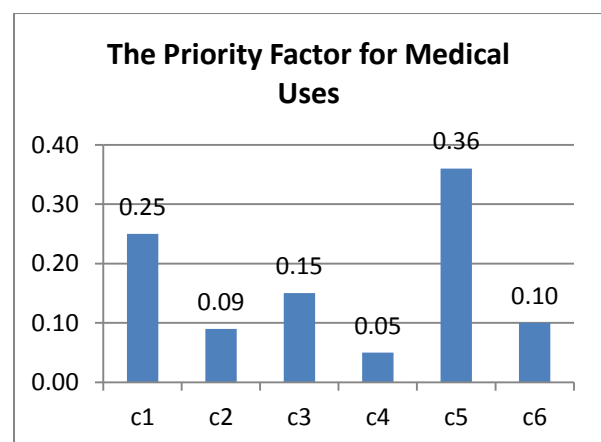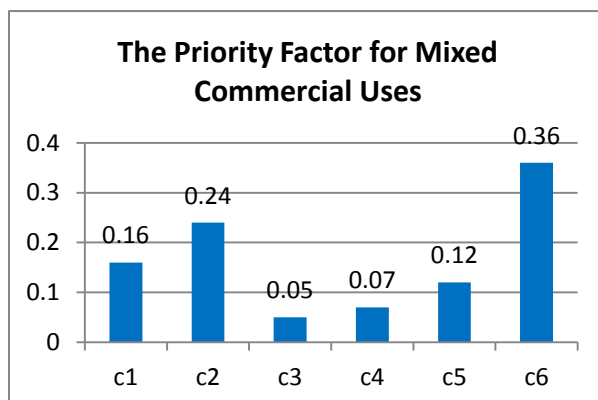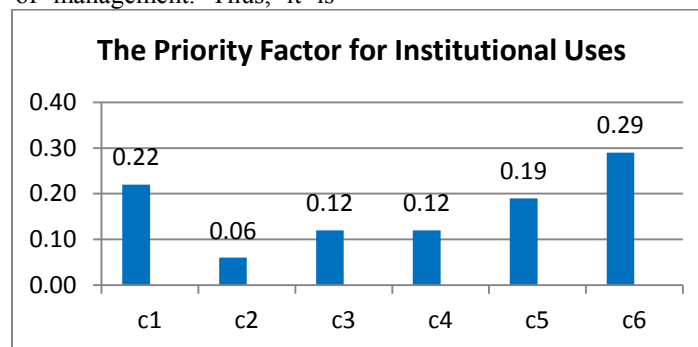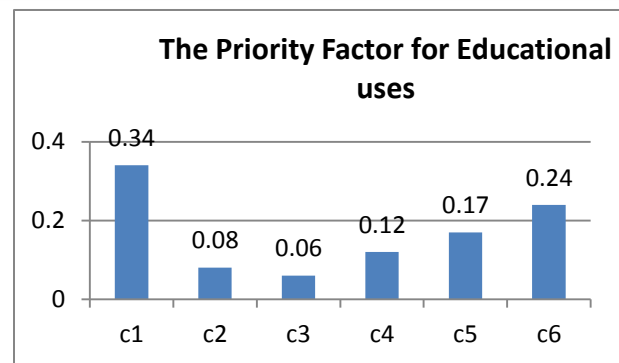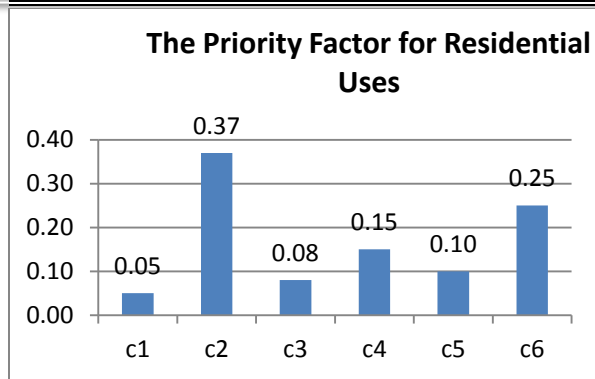
Weights of the Criteria for the Building use

Sl no	Residential	Educational	Medical	Institutional	Mix- Commercial
C1	0.26	0.20	0.26	0.18	0.10
C2	0.16	0.19	0.20	0.21	0.24
C3	0.24	0.17	0.18	0.21	0.20
C4	0.26	0.20	0.26	0.17	0.11
C5	0.24	0.20	0.28	0.16	0.10
C6	0.25	0.21	0.25	0.17	0.13

Normal Weights of the Criteria for the different building use

	Residential	Educational	Medical	Institutional	Mix- Commercial
C1	0.065	0.049	0.063	0.044	0.026
C2	0.036	0.037	0.041	0.041	0.049
C3	0.031	0.027	0.021	0.026	0.021
C4	0.027	0.035	0.045	0.035	0.013
C5	0.028	0.025	0.034	0.015	0.017
C6	0.046	0.026	0.032	0.030	0.015
Total	0.233	0.199	0.236	0.191	0.14
Rank	2	3	1	4	5

Level of acceptance of RRWH varies from different uses of building. From this study it was found medical uses building has highest acceptance of rrwh while mix-commercial has lowest acceptance. Further research suggest for end use options for different scale and type of activities in similar uses of building.

5.6. Regression analysis

1. The variables listed first in the problem statement are the independent variables(IV): "Space availability for storage tank", *"Options available locally"* "*Ground conditions"* "*Scale of development"* "*Stories of the building"* "*Water Scarcity"* "*Degree of Contact"* "*Number of WCs more than 1per 500sqft".* The variable used to define groups is the dependent variable (**DV**): "Opinion on type of end use on RWH"

2. The responses to The analysis will result in two comparisons:
   a. Survey respondents who thought RWH water enduse as toilet flushing versus survey respondents who thought to recharge it.
   b. Survey respondents who thought RWH water enduse as landscapping versus survey respondents who thought to to recharge it.
   c. Survey respondents who thought RWH water enduse as cleaning versus survey respondents who thought to recharge it.
3. Multinomial logistic regression requires that the dependent variable be non-metric and the independent variables be metric or dichotomous.

4. It contains four categories: TOILET FLUSHING, LANDSCAPPING, CLEANING, RECHARGE TO THE GROUND.
5. Multinomial logistic regression requires that the minimum ratio of valid cases to independent variables be at least 10 to 1. The ratio of valid cases (390) to number of independent variables (3) was 130 to 1, which was equal to or greater than the minimum ratio. The requirement for a minimum ratio of cases to independent variables was satisfied.
6. The preferred ratio of valid cases to independent variables is 20 to 1. The ratio of 195 to 1 was greater than the preferred ratio. The preferred ratio of cases to independent variables was satisfied.

	Estimated coefficients for different waste management options		
	Toilet Flushing	**Landscapping**	**Cleaning**
Space availability	0.160 (0.096**)	0.114 (0.175)	0.197 (0.013***)
Options available locally	0.250 (0.633)	0.394 (0.385)	0.069 (0.866)
Location of building	-0.057 (0.507)	-0.012 (0.857)	-0.100 (0.118)
Ground conditions	0.681 (0.254)	-0.698 (0.224)	-0.122 (0.806)
Scale of development	0.145 (0.804)	0.650 (0.204)	0.299 (0.521)
Stories of the building	-0.189 (0.738)	0.588 (0.193)	1.194 (0.023***)
Water Scarcity	4.312 (0.000***)	5.286 (0.000***)	2.688 (0.000***)
Degree of Contact	0.308 (0.019***)	0.048 (0.725)	-0.048 (0.714)
Number of WCs more than 1per 500sqft	2.295 (0.000***)	1.095 (0.064*)	2.222 (0.000***)

Notes: Figures in parenthesis are p-values. * 10 percent ** 5 percent *** 1 percent
Significance level, Number of observations 390 , Note: (*) Dy/Dx is for discrete change of dummy variable from 0 to 1, natural log of ground water level

Source: Survey Data 2010-2011

Independent variables	(Dy/Dx) Toilet Flushing	(Dy/Dx) Landscapping	(Dy/Dx) Cleaning
Space availability	0.006 (0.401)	0.004 (0.753)	0.025 (0.048**)
Options available locally	0.010 (0.806)	0.066 (0.381)	-0.021 (0.755)
Location of building	-0.002 (0.746)	0.006 (0.580)	-0.017 (0.119)
Ground conditions	0.200 (0.123)	-0.139 (0.276)	-0.002 (0.976)
Scale of development	0.028 (0.010***)	0.004 (0.853)	-0.021 (0.336)
Stories of the building	-0.067 (0.188)	0.189 (0.012***)	0.039 (0.583)
Water Scarcity	0.102 (0.019***)	0.623 (0.000***)	-0.057 (0.285)
Degree of Contact	-0.017 (0.798)	-0.078 (0.477)	0.043 (0.691)
Number of WCs more than 1per 500sqft	0.121 (0.058*)	-0.052 (0.513)	0.277 (0.002***)

Notes: Figures in parenthesis are p-values. * 10 percent ** 5 percent *** 1 percent
Significance level, Number of observations 390 , Note: (*) Dy/Dx is for discrete change of dummy variable from 0 to 1, natural log of ground water level

Results show that the key factors determining the choice of **Toilet Flushing** as a potential end use option are *Ground conditions, Scale of development, Degree of Contact, Number of WCs* more than 1per 500sqft. The determining factors for the choice of **Landscaping** is *Options available locally, Ground conditions, Scale of development, Degree of Contact, Water Scarcity*.

5.7. Development of final Decision Support System Model

Interpretation of the analysis from the previous section has generated outcomes

1. The priority factors for acceptance of rooftop rain water harvesting for different use of building has been derived from AHP analysis
2. Rain fall data has been analyzed for probability of occurrence, probability of dry spell and henceforth calculation of total runoff from the building roof area.
3. The demand for particular end use and rain water supply from building's roof area is given as input for Demand Supply ratio
4. The regression model calculates the weight of different factors having influence on type of end use.
5. Use maximum (80% Probability) rainfall as input for choice of the storage tank
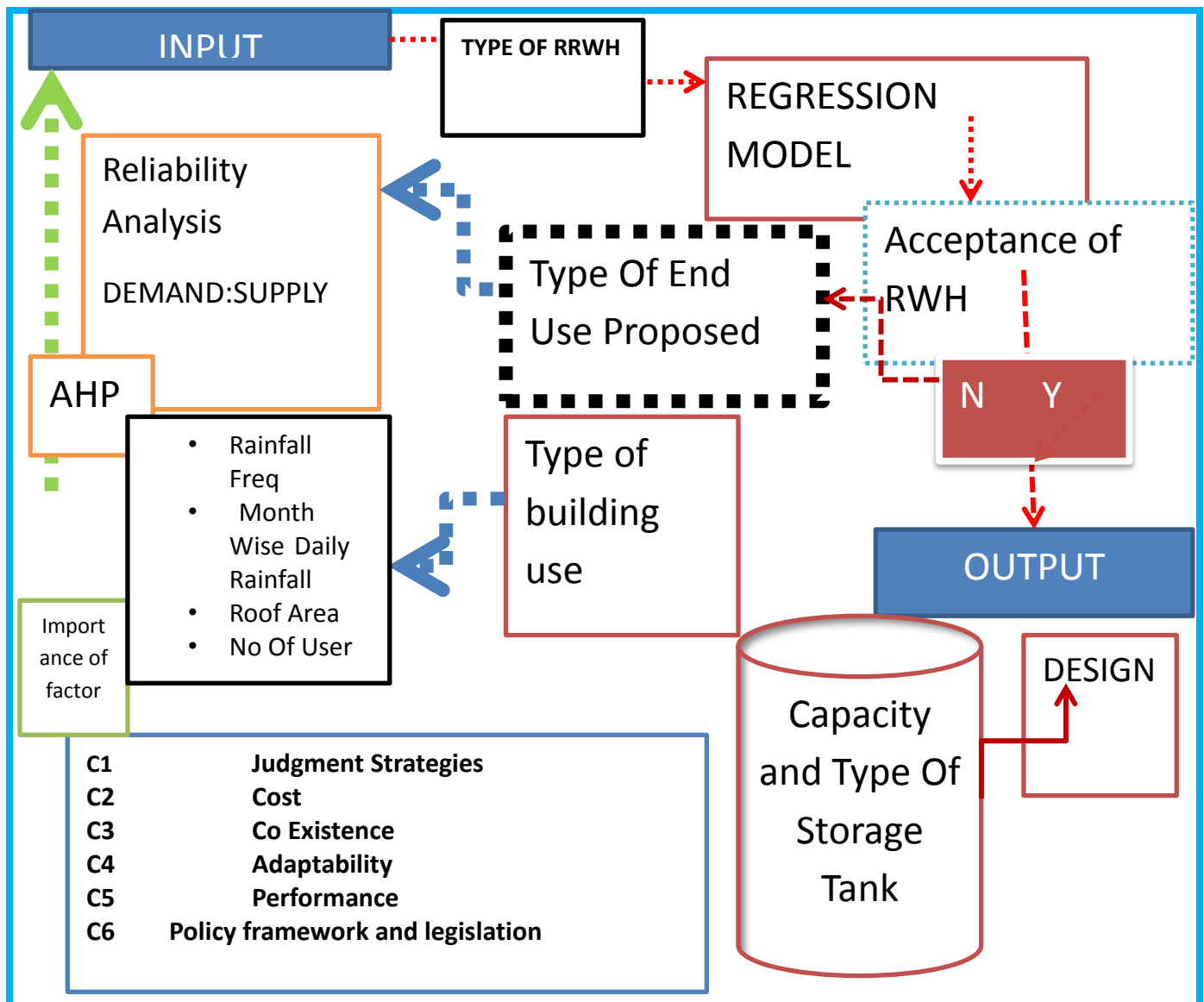
6.0. POLICY RECOMMENDATION

The barriers to find potential of Rooftop Rainwater Harvesting combine those of Water Recycling and WSUD and are compounded by the consultation required between different authorities. Knowledge gaps and research needs identified in the review include the following:

- Current guidelines, standards and regulations need to be more flexible to

allow innovation whilst conserving water and the environment.
- Few people have all the required skills and appropriate design tools and there are few decentralized maintenance services
- Local authorities avoid depending on central infrastructure and promote incentives for investment decisions of the stakeholders;

Installation of supplementary pipe for rain water harvesting and Post Project Appraisal is to be Conducted;
- Source control measures, particularly those that require behavioral change of individuals are poorly understood;
- There is a need for Decision frameworks for use along with potable use.
- Public Perceptions of Water Reuse

The importance of community acceptance of water reuse is fundamental but a review of research (Po, Kaercher & Nancarrow, 2004) found a conspicuous lack of social research in understanding the basis of public perceptions of water reuse and the psychological factors governing individual decision making processes. However they identified some basic principles for engaging the community in water reuse projects. Firstly offering early and genuine involvement so that the community has the opportunity to shape the project, and consider the full range of options. Where developers or utilities endeavor to convince a community of the value of a reuse project after these decisions has been will have a high probability that the issue will become political and the chances of acceptance are more random.

7.0. CONCLUDING REMARKS

As explained, policy-makers wanted to maintain the present centralized water supply in the ULBs of KMA, but not considering protecting rain water a valuable resource from wastage. In this thesis seeing the End use potentiality for acceptance of RRWH for different building and studying the AHP the policy can be devised in a right way. The Model had developed *Six Criteria* and *Eighteen Sub Criteria*, for Acceptance of RWH which define what, makes up an improved process for acceptance of RWH in different Buildings: *Association, People's Risk Perceptions, Awareness, Cost Recovery, Investment Level, Capacity to Pay, Flexibility, Skeptical About Durability, Adaptability, People Priorities, Disgust Emotion, Scope, Safety, Operation And Maintenance, Level Of Infrastructure, Service Delivery, Compensation, Water Availability.*

Further the type of end use had been a determining factor for acceptance of RRWH. The potential type of end use is to be dependent on *Space availability, Options available locally, Style of RWH, Ground conditions, Scale of development, Stories of the building, Water Scarcity, Degree of Contact, and Number of WCs more than 1per 500sqft.*

7.1. Recommendations for future research.

A number of areas where further research is necessary were recognised during this study. This thesis helps to identify certain socio-demographic variables which influence water consumption and their effects on water use

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