EVALUATION OF THE EFFECTIVENESS OF ORGANIZATIONAL OBJECTIVES AND IMPLEMENTATION FOR SUSTAINABLE DRINKING WATER SUPPLY SYSTEM USING A MULTI CRITERIA DECISION MODEL

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DECLARATION

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…………………………….. …………………….

Professor N.T.S. Wijesekera Date:

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Evaluation of the Effectiveness of Organizational Objectives and Implementation for Sustainable Drinking Water Supply System Using a Multi Criteria Decision Model

Abstract

The evaluation of the effectiveness of organizational objectives can be done by an analysis of the actual situation at the field level compared to the organizational objectives. Without proper management at the field level, the organization cannot be achieve objectives. Lack of guidelines at field level; reduces the effectiveness of water supply scheme. A system manager has to consider all major criteria to manage a water supply scheme. MCDA can be used to manage water supply schemes effectively.

This study identified the organizational objectives through a stakeholder survey and literature survey. Four parameters in the management of water supply schemes are income generation, system sustainability, system losses and system reliability. There are 12 sub parameters which were identified as new connection, bill collection, staff salaries, O&M expenditure, NRW, no water, water quality, leak main, leak connection, leak night time, low pressure, defective meter. The prioritization of all the sub and main parameters enabled the identification of management views corresponding to schemes. A MCDA model use for Ja Ela Water Supply Scheme. AHP method was selected as the type of MCDA model because it can determine preference among main and sub criteria by using pairwise comparison. Six zone office areas selected as an alternative for this study.

Model Identified the values 0.4, 0.44, 0.12 .0.04 respectively for main parameters for the income generation, system sustainability, system losses and system reliability. Identified sub parameters of main criteria are New connection, Bill collection, O&M expenditure ,Staff salaries, NRW, No water, Leak main, leak connection, Defective meters, Low pressure , Leak night time ,Water quality respective parameters for these are 0.49, 0.51, 0.56, 0.44, 1, 0.46, 0.23 ,0.12, 0.06, 0.05, 0.03, 0.05 respectively.

Model verification was completed by comparing the MCDA model priority order of alternatives and the prioritization alternatives at the field level. Only the area Engineer's priority order considered for field level prioritization. Priority order obtained from the MCDA model closely matched with the Area Engineer's Priority order and indicated satisfactory model verification. There is a lack of clear guidelines for various levels of management and field level management. Building up proper guidelines that reflect the organizational objectives will be easy for field level management and it will lead to increased effectiveness of achieving organizational objectives and sustainability of the water supply schemes.

Key Words:
Water Supply System, MCDA, Organizational Objectives, Stakeholder Survey,

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List of Abbreviations

AHP	Analytical Hierarchy Process
AWWA	American Water Works Association
BWTP	Biyagama Water Treatment Plant
CBO	Community Base Organization
CKD	Chloric Kidney Diseases
GND	Grama Niladhari Divisions
KDI	Korean Development Institute
LOS	Level of Service
MC	Main Criteria
MCDA	Multicriteria Decision Analysis
NRW	Non-Revenue Water
NWSDB	National Water Supply and Drainage Board
OIC	Office In Charge
PI	Performance Indicator
PIP	Project Investment Plan
SDG	Sustainable Development Goals
SC	Sub Criteria
W/N	Western North
WHO	World Health Organization

1 INTRODUCTION

1.1 General

More than 190 countries committed to achieve the Sustainable Development Goals (SDG) established by United Nations in 2019. These goals are developed to address the key global factors such as extreme poverty, inequality & injustice and fix climate change. We all have to play a role to achieve these sustainable development goals and it helps to create a prosperous, equitable and sustainable world. Goal number six deals with water and the very first target of goal number six is more than half of the households worldwide to have access to clean water in their home (United Nations, 2019).

Vilanova and Balestieri (2014) published the importance of accessibility of safe drinking water and mentioned that the diseases caused by contaminated water kill more people in each year than all forms of violence including war. By providing safe drinking water to all, it is possible to improve public health and living standards. It also increases the social and economic conditions. Water supply is closely related with economical, environmental and social spheres of sustainable development and improvement of this system is essential for providing safe water at an affordable cost.

1.2 Water Supply in Sri Lanka

Sri Lanka is located near the equator and it has approximately 1860 mm average annual rainfall mainly from monsoonal, conventional and depressional rainfall types. There are 103 rivers identified in Sri Lanka. Twenty rivers are classified as wet zone rivers and it carries about 50 percent of annual surface runoff. The average annual runoff is nearly 35 percent of annual rainfall. Unequal water distribution of dry zone and wet zone create a water scarcity in a dry zone. For this situation, proper management of the available water is required. In ancient times Sri Lanka has built reservoirs to collect the water and diverted water to the dry zone as a solution for this water scarcity. Currently, there are 80 dams in Sri Lanka which are classified as major dams according to the International commission of large dams. Compared to surface water, groundwater has less importance due to quantity and quality. However, groundwater is widely used for domestic, small scale irrigation, industrial and other uses in rural areas (Imbulana, Wljesekara, & Neupane, 2006).

The national water supply policy in Sri Lanka has presented major critical issues that are affecting the achievement of water supply targets in the water sector. Increasing water demand according to population growth, competing use of water in an expanding economy, increasing the cost of new developments, lack of policies and institutional constraints, water pollution due to urbanization are the identified major issues. Awareness about the value of the water has also been mentioned as a major issue in the water sector (NWSDB, 2006).

The government will ensure access to safe drinking water for all and it is the most important factor for health in the country. Then it will directly involve to the social and economic development of the country. National water policy presented the principle agency of water supply as National Water Supply and Drainage Board (NWSDB) which was established in 1975 under parliament act no 14. All the activities in drinking water supply such as development, provide water services to the public, regulate quality standards of design and operation and maintenance of water supply schemes is under the supervision of NWSDB. Community-based organizations and some other local authorities are also responsible for the water supply of safe water to the country (NWSDB, 2006).

NWSDB increased its coverage of 50 % pipe born water supply and mostly in urban section more than rural water supply schemes. The Sri Lankan population is expected to reach 23 million in 2025 and it is estimated that the demand for safe drinking water will be approximately 4.6 cubic meters per day. Approximately 3.3MCM per day out of this will for the requirements of the urban population (Imbulana et al., 2006).

The national water policy in Sri Lanka presents the guild line of government for the next five years. It mentions providing accessibility to safe drinking water for all Sri Lankans to achieve social and economic targets and then to improve the living standards. Commercial and industrial water demand is increasing day by day and it should consider managing water services. When design a new water supply scheme, it has limited coverage area according to the amount of water abstraction and available funds. Hence there are some gaps created in regions and future investments mainly consider bridging the gaps to reduce the regional disparities in the water supply. Providing good quality water to the victims of CKDu is considered as a high priority (NWSDB, 2006).

The department of community water supply focus to provide safe drinking water to the entire population of the country by 2020 and 60 percent of rural community would be with pipe born water (Public Investment Programme, 2020).

1.3 Management of water supply schemes

National Water Supply and Drainage Board (NWSDB) with a staff of more than 10,000 is the responsible organization to provide safe drinking water to the nation. Currently, it manages more than 300 water supply schemes and 11 sewerage schemes around the country. Community-based organizations and other local authorities are managing the rural water supply schemes. NWSDB provides necessary technical guidance to CBO and local authority to manage rural water supply schemes. Rural water supply schemes were introduced for small coverage and nearly 4000 schemes operated in the country. The Department of National Community Water Supply (DNCWS) was established for the sustainable operation and management of rural water supply schemes. Some CBO only involved with the distribution of drinking water while NWSDB supplies drinking water to CBOs as a bulk Supply.

The government will support to enhance the capacity of this DNCWS and help with formulating an institutional framework and operational strategy to sustain the rural water supply investments (Public Investment Programme, 2020).

Water supply utilities are required to supply adequately safe water for consumers at any time and anywhere. Consequently, they are required to satisfy management requirements. Lack of effective management or poor management is the single largest factor that causes the greatest negative impact on the performance of water supply systems. This is evident when there are no well-defined objectives, no long term planning, no short term programming or budgeting. Water supply managers have a vital role in the management of a water supply scheme and a lot of parameters are considered for effective management. Main responsibility of the WSS is to provide continuous supply of safe palatable water to all. Various water supply agencies defined their objectives in water supply. In Sri Lanka, the NWSDB also fixed their mission as " serve the nation by providing sustainable water & sanitation solutions ensuring total user satisfaction". As per the mission, user satisfaction & system sustainability are more important in management of water supply schemes. No water, leaks in pipe networks, low pressure, water quality issues, etc… are common customer complaints. Immediate actions must be taken for the complaints to achieve good user satisfaction service. Since water is very limited resources and hence management must reconsider about the losses of safe water in the water supply. System losses considered as non-revenue water which can occur through leakage of pipe network or illegal connection.

In the field level system managers concern to achieve their maximum target in water supply such as the user satisfied sustainable system with minimum losses. But the number of parameters has to considered with limited resources restrict their achievements. When the number of problems influences in the system in a time, managers have to prioritize the problems to most critical to lowest due to limited resources. This prioritization in the field varies from person to person. But with experience gain in the water supply field, their ability to prioritization has improved. It can deviate from the objectives of the organizations. It creates a gap between field-level management and organizational objectives.

However in according to the publications and the literature, a considerable gap is needed for the quantitative MCDA model with stakeholder concerns for system management in WSS.

1.4 Study Area

Ja Ela WSS which is managed by NWSDB was selected for this study. Ja Ela is a developing area in Gampaha district. The Government of Sri Lanka has invested funds for developing the area and also water supply projects. This area consists of urban, semi-urban and rural that can easily identify management concerns in each category. Proximity to the WSS was also considered to selection of study area.

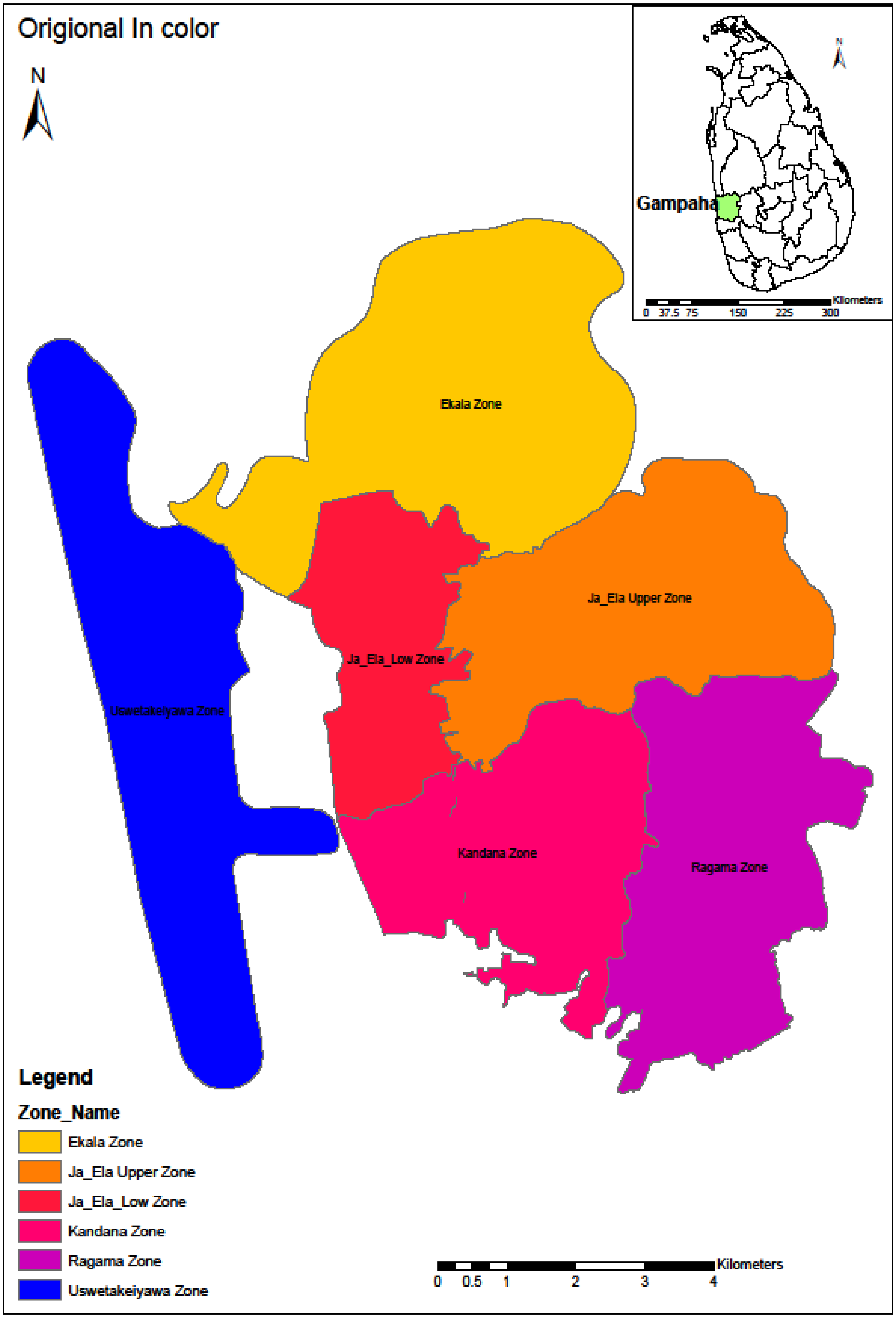

Figure 1.1: Study Area

1.5 Objectives

1.5.1 Overall Objectives

Identify priority organizational objectives, associated management parameters, and evaluate the effectiveness of field level implementation of drinking water supply institutions by using a multicriteria decision model, for sustainable water supply system management.

1.5.2 Specific Objectives

The specific objectives listed as follows for the present work

1. Identify the state of the art of water supply system management (objectives, criteria, parameters, methods, models, etc.,) to achieve organizational objectives.
2. Carry out a stakeholder-based identification of management criteria, parameters and practices (Stakeholders - Policy/Higher Management, Middle Management, and Field System Management).
3. Development of a MCDA model, calibration (of model weights), verification (with field data) and evaluation of present setting.
4. Make recommendations for sustainable management of drinking water supply systems.

2 LITERATURE REVIEW

2.1 Objectives of water supply and water supply institutions

Water is a basic need of human rights. Access to safe drinking water is an essential for humans and it leads to a healthy life. However currently considerable number of people are not able to access safe water and it causes water-borne diseases. To overcome this situation, the United Nations dedicated the water theme as goal number six of SDGs. There are seven targets under the theme of water and the first target deals with water supply and management. That aims to ensure availability and sustainable management of water and sanitation for all (United Nations, 2019).

Provide adequate water quantity to consumers is the main requirement of the water supply. In distribution network, demand is varying due to different types of consumers. Water supply managers are responsible for supply required water demand on adequate Pressure. When proving adequate water to the public it must be considered on environmental and financial aspects. Energy cost plays a vital role in pumping water supply scheme more than gravity-operated schemes. Proper management of WSS leads to increase the standard of service and it will cause to positive impact on consumer satisfaction.

Well defined objectives, long and short term planning of WSS & budget controlling are some main factors which should be considered on the management of water supply scheme. Poor management is directly involved to the performance and efficiency of the water supply scheme and it leads to negative impact on consumers. Hence it is required to observe and implement the management activities to increase efficiency and effectiveness of operation and maintenance works. Laser (2012) presented provide customer satisfactory services with affordable cost are the ultimate objectives of the water supply managers. And also mentioned the drinking water quality up to relative standards, required water demand with adequate pressure and cost of the water are main objectives of the efficient operation and maintenance of water supply schemes (Laser and GmbH, 2012).

According to the Namibia water supply and sanitation policy, (Ministry of Agriculture, 2008) overall long term policy is formulated include the essential water supply and sanitation services should become available to all Namibians and should be acceptable and accessible at a cost which is affordable to the country as a whole for the Water Supply in Namibia.

According to the global water strategy in united states, (USAID, 2017) they presented their vision as the importance of Water secure world and manage risk from floods and droughts. It is necessary to sustainable supply of water for required quantity and safe water to all people to meet human, economic activities.

Effective water services including the delivery of a sustainable and reliable clean water supply and safe disposal of wastewater are essential for a modern country. Irish water presents the water services strategic plan and establishes the vision as through responsible stewardship, efficient management and strong partnerships, Ireland has a world-class water infrastructure that ensures secure and sustainable water services, essential for our health, our communities, the economy and the environment. Meet customer expectations; ensure a safe and reliable water supply is the two strategic objectives according to the water services (No. 2) Act, 2013. (Irish Water, 2014)

The South African water service act presented the main objectives of water supply is every water services authority has a duty to all consumers or potential consumers within its area of jurisdiction to ensure efficient, affordable, economical and sustainable access to water services (Francisco, 2013).

The manual of operation of water supply systems published by WHO for India, presented the importance of operation and maintenance of water supply schemes. Provide safe drinking water in adequate quantity with pressure and quality of the water are ore the identified objectives of an efficient operation and maintenance of water supply schemes. Affordable cost for the consumers is also considerable fact in the management of WSS (The manual of operation of water supply systems, 1990).

According to the national water policy, (NWSDB, 2006) in Sri Lanka, access to drinking water is basic human rights and the government should be providing safe drinking water to all citizens. Ministry in charge of drinking water was nominated the NWSDB as the principal responsible organization for all activities on drinking water supply in the country such as development, operation and maintenance of drinking water supply schemes. The government should commit to the provision of an adequate quantity of safe water for all people an affordable cost and inequitable, efficient and sustainable manner. The objective is to serve the nation by providing sustainable water & sanitation solutions ensuring total user satisfaction.

2.2 Criteria used to measure the achievement of objective

The set of indicators used for performance measurement of WSSs in different countries and systems are usually quite similar, despite different nomenclatures and data availability (Nogueira Vilanova, Filho and Perrella Balestieri, 2014).

Lee and Kong (1996) presented from the research projects, 28 indicators were considered relevant to the water supply network. LOS assessment was selected by referring to performance indicators in the study on a standard plan for water supply network improvement BTL Project Performance Requirement Standard (2013) conducted by the Korea Development Institute (KDI) and the Water Supply Service Performance Indicator System (2007) suggested by the Ministry of Environment. 28 PIs selected were categorized based on the criteria suggested in the water supply service performance indicator system the types of customer’s satisfaction with tap water supplied through the water supply network were expressed as five assessment categories, consisting of water quality, water pressure, taste and odor, water rates and service.

Managers must listen to and act responsibly on stakeholders concern that impacts the planning process. Managers must marshal and allocate resources to those priorities that address both utility and stakeholder need. Every activity a manager engages in merit the time it takes to plan the activity. Several types of planning should be considered including operational, administrative, project planning, financial, organizational, communications and emergency (Water Utility Management, 2007).

Maintenance Management Plan for Drinking Water and Wastewater Systems in Canada presented seven criteria of water supply system. Reliability of system components /Life expectancy /Service interruptions and downtime system performance / Repairs /Detection and prevention of potential system failures (Affairs, Development and Aandc, 2014).

2.3 Field Level measurement Parameters to Evaluate the Criteria

Most utility maintains records on the amount of water treated and pumped, correlating that information to amount and billed or supplied for public health and safety requirements. This information assists managers in determining the need for special leak detection program or meter replacement programmers. Equally important, however, are records of the quantity and quality of work activities performed at pumping and treatment facilities, the level of customer satisfaction, number and type of customer complaint and such other system information as may enable managers to make informed decisions concerning the types and level of services offered (Water Utility Management,2007).

2.4 Mathematical Models Used

The AHP analysis is the decision-making technique that supports the systematic assessment of mutually exclusive alternatives when the objectives or evaluation criteria of decision making are complex (Lee and Kong, 1996).

Okeola and Sule (2012) presented AHP a technique used in Multicriteria Decision Analysis (MCDA) had made an important contribution to the practical decision-making process by recognizing the decision-makers (DMs) experience and in providing the possible best compromised solution in terms of multiple objectives and multiples DMs and stakeholder preferences. MCDA methods differ in the way the idea of multiple criteria is considered, the application and computation of weights, the mathematical algorithm utilized, the model to describe the system of preferences of the individual facing decision making, the level of uncertainty embedded in the data set and the ability for stakeholders to participate in the process (Pietersen, 2006). There are many different concepts and methods for MCDA. Some of the potentially useful techniques are goal programming, compromise programming, multi attribute utility theory (MAUT), analytical hierarchy process (AHP), ELECTRE I–III, PROMETRE, and co-operative game theory.

2.5 Summary of Management Criteria

Different types of main criteria and sub criteria are identified in the literature review. Summary of obtained criteria are present in Table 2-1.

Table 2-1: Main and Sub Criteria of Water Supply Management from Literature

#	Reference	Main Criteria	Sub Criteria
1	Water utility Management – AWWA	Operational, Administrative, Project Planning, Financing Planning, Organizational planning, Emergency Planning	
2	Hyundong Lee, and Myeongsik Kong	Water Quality/ Water Pressure/ Taste And Odor/ Water Rates/ Service	Sustainability/ Quality/ Affordability/ Accessibility/

#	Reference	Main Criteria	Sub Criteria
			Reliability/ Responsive/ Customer Service
3	Maintenance Management Plan for Drinking Water and Wastewater Systems in Canada	Reliability of system components / Life expectancy /Service interruptions and downtime / System performance /Repairs / Detection and prevention of potential system failures	
4	Water Service Strategic Plan: Irish Water	Sustainability/ quality / availability / reliability / An efficient and economic manner. /	
5	Namibia	reliable and accessible sources of safe water /sufficient capacity / sustainable basis / an affordable cost.	
6	India water Supply and sanitation by World bank	reliability, financial sustainability, environmental sustainability	Water Quality/Depletion of GW / O&M Cost/Capital cost Recovery/NRW/

#	Reference	Main Criteria	Sub Criteria
			Pressure/Quantity /Reliability/ Affordability
7	The performance indicator for water supply system IWA	Water resources /Personnel / Physical /Operational /Quality of service /Economic and financial	
8	Okeola and Sule (2012)	Environmental	Withdrawal, Quality/Reliability/Vulnerability
		Technical	Financial viability, Economic of sale, Securing of investment resources/ Minimization of Production cost
		Institutional	Access to advance technology/ Expertise employee/Operational efficiency
		Economic	Legal framework/ Policies/ Regulatory control/Participation
		Socio-cultural	Public health and safety/ Accessibility/Coverage ,/Intergenerational equity

2.6 Review of Current State of Art

According to the literature review Table 2-1 summarized the parameters and sub-parameters which are considered in the WSS management in different countries and different organizations. The factors are different by country by country and institutions by institutions. There is no specific method the identified the parameters affect to the WSS management. And also no method to prioritize the parameters selected in the table. Without a proper method to identify the parameters, it is difficult to evaluate the effectiveness of the organization/institution and the sustainability of the WSS. The best method is in practice is the different parameters are used in different countries and institutions for the management of WSS.

T.K.N.K Kumari (2015) has examined success of applying simple multicriteria models for WSS management. This type of modeling attempts and also points to the organizational gaps in guidance to employees through clear hierarchical objectives that start from the national level and then, moves through the organizational planning, monitoring and finally ends at recipient stakeholder level via field level operational management units.

It is required to identify the method to identify and prioritized parameters considered by the management of WSS and apply to the field level to verify the effectiveness of the organizational objectives and sustainability of WSS.

3 METHODOLOGY

3.1 General

In the introduction chapters, it briefly describes the current situation of the water supply scheme, management consent and the need for research on effective water supply system management and main objectives and specific objectives .Literature review presents detail water supply management, management models and management consideration on other countries describe under chapter three. The Arrangement of this research, display in chapter four as methodology. Chapter five, it is present the data collection and checking for this research. Data collection form designed according to the Sample investigation, literature review and tested with relative Engineers who are managing the Water Supply Systems. This survey carried to identify main parameters, Sub parameters which are used to manage the water supply systems. For the Obtain the area Engineer's prioritization in the study area as a field data to obtained According to Verification of the model. Chapter six presented the MCDM model develops to obtain relevant importance and model verification completed by comparing model output and Field data.

Different type of main parameters and sub parameters consider the management of water supply schemes. Identification of management parameters for water supply schemes carried out by literature review and stakeholder survey. Evaluation of multicriteria situation using conventional approaches is difficult and a structure decision making is necessary to visualize the decision making.

There are various tools for MCDA such as AHP, TOPSIS, NAIADE, MAUT, and MOP/GP. TOPSIS method gives both quantitative and qualitative study of the problem.

And it gives quick decision to our real life problems than AHP (Analytical Hierarchy Process .Considering the these tools APH was selected as Multicriteria Decision Analysis (MCDA) model because it provides criteria weights with measures of consistency, derives priorities among criteria and alternatives while simplifying the determination of preferences ratings among decision criteria with use of easy pairwise comparison.

Consistency check were carried out after obtaining the preferences of the main criteria, sub criteria and alternatives. Discussions, Conclusion and recommendations are presented as last three chapters. Methodology Flow Chart is shown in figure 3.1.

3.2 Methodology Flow Chart

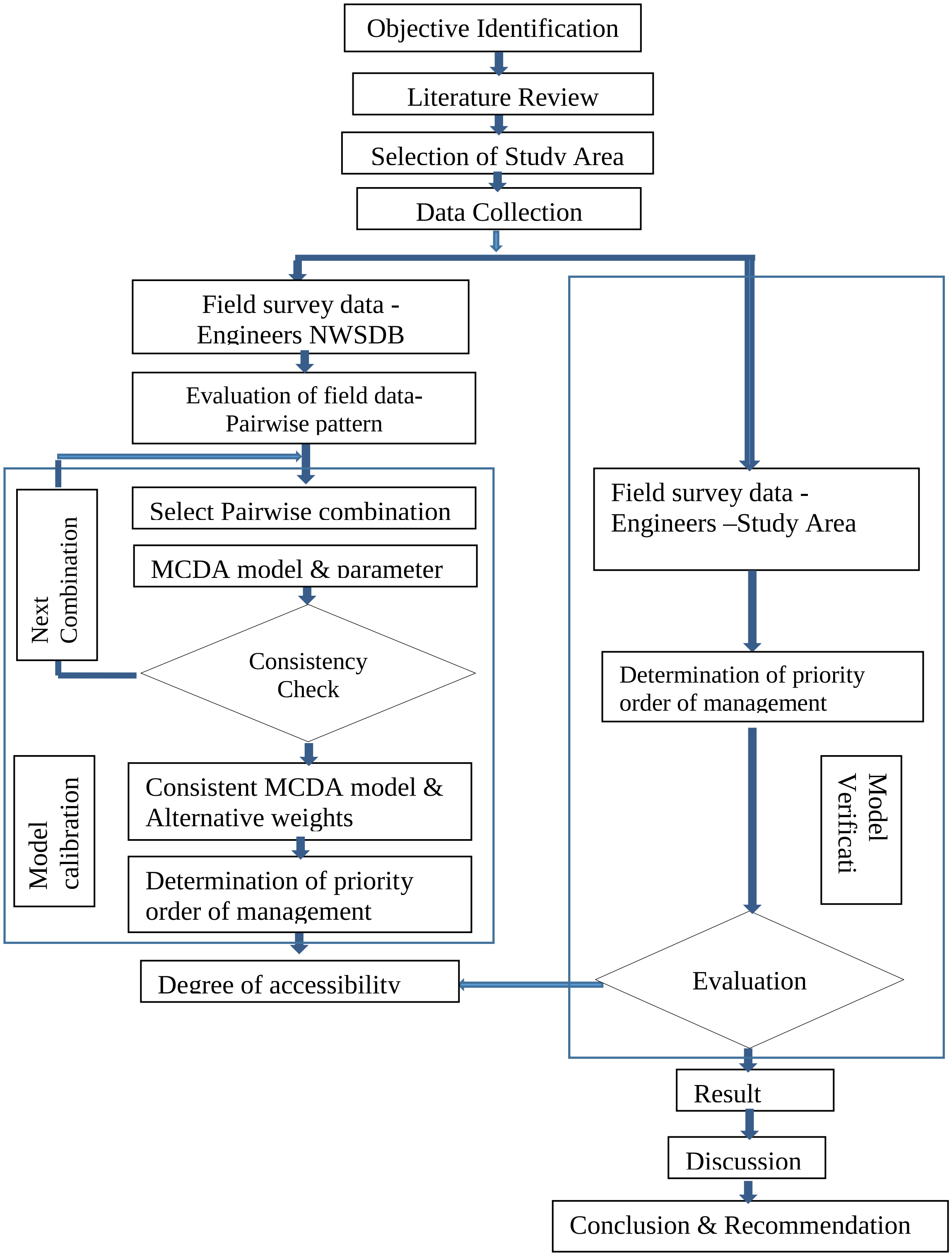

Figure 3.1: Methodology Flow Chart

4 DATA COLLECTION

4.1 Study Area

Regional Support Centre (North Western) of NWSDB is supplied pipe born water to the towns in the northern part of the western province. The water abstract from Kelani River about 15 km upstream from the sea and treated at Biyagama Water Treatment Plant (BWTP). This treated water is then pumped (185,000 m^3/day) to the church hill reservoir and distributed to Kelaniya region and Gampaha region by gravitational pressure through the transmission network and the distribution network. Kelaniya region consists of 03 distribution systems - Kelaniya, Biyagama and Jaela. Each distribution system is divided into OIC areas and each OIC area is consists of distribution zones.

Ja-Ela distribution system is situated in Gampaha district, Western province. It covers Ja Ela, Ragama, Kandana city areas and adjacent areas including about 85square kilometer. The distribution system covers 62 GND divisions. Ja ela water supply scheme is divided into two maintain offices as Ekala and Ragama. Distribution System is divided into 06 Sections named Ja-Ela - Upper, Ja-Ela - Lower, Ekala, Pamunugama, Ragama & Kandana. Study area is shown in Figure 4.1.

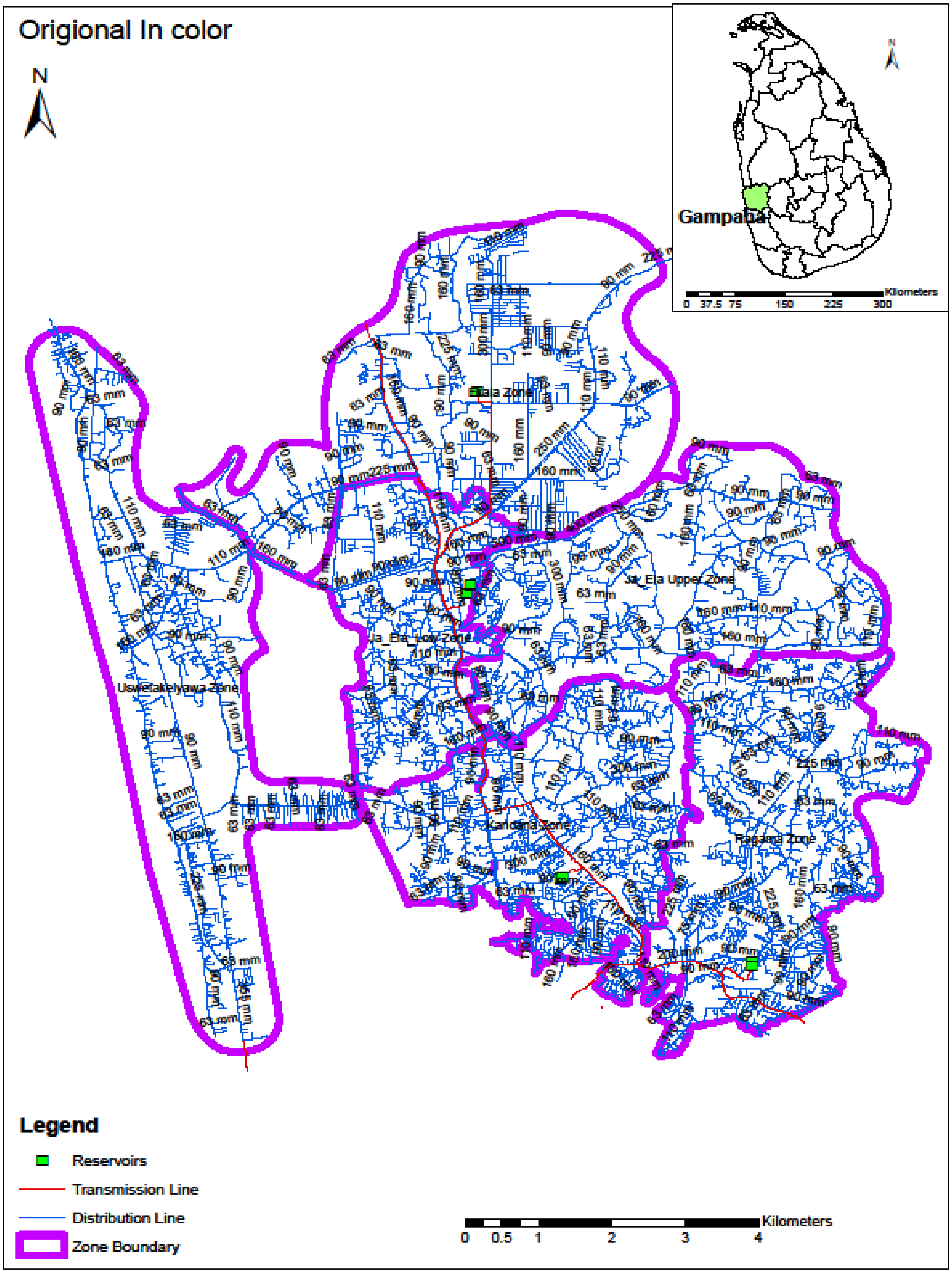

Figure 4.1: Ja Ela Distribution System

4.2 Data Collection

4.2.1 Data Collection on Study area

Data collection on study area completed from Area Engineer's office in Ja Ela and head office of the NWSDB. Collected data for Ja Ela area is list out in Table 4.1.

Table 4-1 : Data Collection for Ja Ela

	Data	Period	Resolution	Source
1	Inflow to Ja Ela Area	1 Years	Yearly	Manager Office (Kelaniya) (NWSDB)
2	Consumption data	6 Years	Monthly	Area Engineer Office Ja Ela (NWSDB)
3	Expenditure	5 years	Yearly	Manager office-Keleniya (NWSDB)
4	Billing Data	6 years	Yearly	Manager office-Keleniya (NWSDB)
5	Customer Complain	2 years	Daily	Head Office (NWSDB)-DataBase
6	Water Supply network –Ja Ela	2015		Regional Support Center(W/N)-NWSDB

There are six-zone officer's areas in Ja ela water supply schemes namely Ja ela Upper, Ja Ela Lower, Katana, Ragama, Uswetakeiyawa and Ekala. Consumption data for each zone office's area were obtained from the relevant dockets detail. Expenditure and billing data were abstract from the annual budget report which is published by regional office in Kelaniya. Refer to the online database of NWSDB for the Ja Ela area to identify the total number of customer complaints.

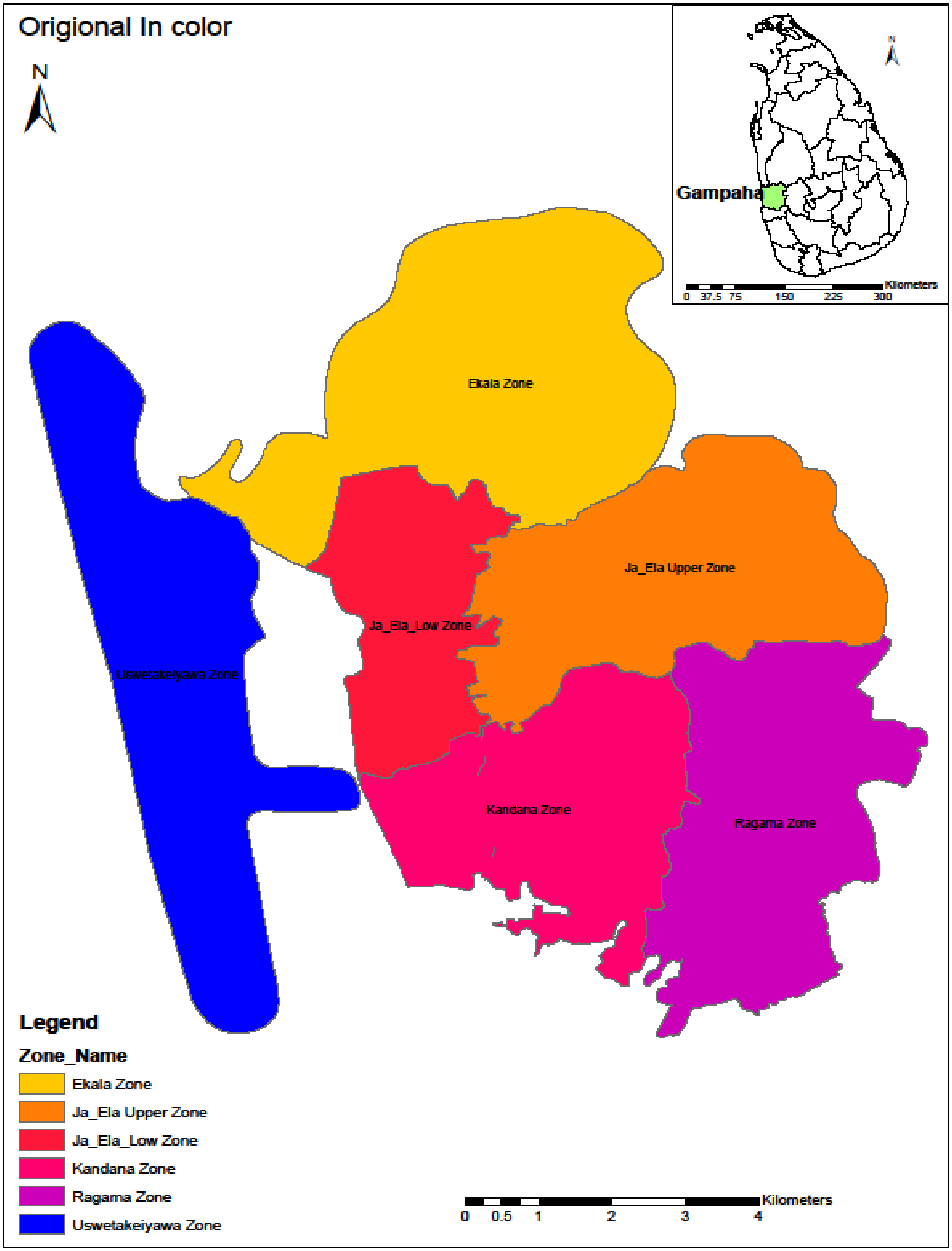

Figure 4.2 : Spatial Variation of OIC Boundaries

4.2.2 Stakeholder Survey

There are several stakeholders in water supply system such as consumers, management authorities, regulatory authorities, maintenance sections, etc. Management authorities are the most important stakeholder considering the managerial point of view of the water supply scheme. The principal agency responsible for development, operation and maintenance of drinking water supplies is the National Water Supply and Drainage Board (NWSDB), which functions under the ministry in charge of drinking water. (NWSDB, 2006) .Hence selected the NWSDB for the sample determination. In this study it is required to identify management view for the water supply schemes and select the sample from management position in NWSDB including technical and non-technical.

The estimation of the minimum sample size required for any study is not a single unique method, but the concepts underlying most methods are similar. Power analysis is the widely used method. If the sample size it too small, it will not yield valid results. An appropriate sample size can produce accuracy of results. Moreover, the results from the small sample size will be questionable. A sample size that is too large will result in wasting money and time. Sample size calculations must take into account all available data, funding, support facilities, and ethics of subjecting patients to research.

Most statisticians agree that the minimum sample size to get any kind of meaningful result is 100. There are 755 of management positions (Techinical-650 Engineers) and (non-technical -105 Chief accountants/HR managers) are available in NWSDB. Therefore consider 115 number of samples of higher & middle management persons of National Water Supply & Drainage Board working on technical & non-technical sections which is more 15% of the population.

4.2.2.1 Preparing Questionnaire

Data collection forms were designed under three stages to obtain data from stakeholders.

Stage 1: Identification main parameters & sub-parameters
Stage 2: Prioritization of sub-parameters
Stage 3: Prioritization of main parameter

Preliminary stage, literature survey, development of main and sub-parameter (Questionnaire), refine the main and sub-parameters (Pilot survey) are the main steps for preparing questionnaires.

Preliminary Stage - The principal agency responsible for development, operation and maintenance of drinking water supplies is the National Water Supply and Drainage Board. Hence preliminary discussion was held through senior management of NWSDB. The preliminary study observed the management criteria must be assessed considering situations where the water supply input, the pipe network, storage, staff and transport are in place and remain at near constant status.

Table 4-2 : Preliminary Discussion Group

#	Name	Designation	Division
1	Eng. W.N.Premasiri	Deputy General Manager	Production(Western)
2	Eng A.S.Kaluarachchi	Assistant General Manage	Planning & Design
3	Eng K.M.N.K. Kumari	Chief Engineer	Development
4	Eng M.R.Mathotarachchi	Area Engineer-Ratnapura	RSC(Sabaragamuwa)
5	Eng M.S.A.Karunarathne	Senior Engineer	RSC (N/C)

In the field level management of water supply schemes, officer in chargers for relevant water supply schemes have a vital role for management of the scheme. Considering the 14 number of OIC in Colombo district & obtain the management view of OIC and presented in Table B.1 & B.2 under the preliminary investigation.

Initial main and sub-parameters are followed by literature survey (Table 2-1) on parameters influencing water supply system management were identified.Identified initial main and sub parameters present on Table 4-3.

Table 4-3 : Initially Identified Main & Sub parameters

	Main Parameter		**Sub Parameter**
1	Income Generation	1	New Connection
		2	Bill Collection
		3.	Other (Please Specify) ……………..

2	Sustainability	1.	O&M Expenditure
		2.	Staff Salaries
		3.	Other (Please Specify) ……………..
3	System Losses	1.	NRW Reduction
		2.	Other (Please Specify) ……………..
4	User Satisfaction/Problem Solving (Reliability)	1.	No water
		2.	Main Leak
		3.	Leak – Connection
		4.	Defective meters
		5.	Low Pressure
		6.	Leak-Night time
		7.	Water Quality
		8.	Other (Please Specify) ……………..

Development of questionnaire – Main and sub-parameters are identify according to sample investigation and literature review and developed a questionnaire presented in Appendices B.1.1-B.1.3.

Pilot Survey – Developed questionnaire distribute to the 10 number of samples to refine the questionnaire. This sample also from NWSDB who having experience in water supply system management. Refined questionnaire is shown in Appendices B.2.1-B.2.3 and it is used for the stakeholder survey.

4.2.3 Collection of Respondent data

Corrected data collection forms were distributed to middle and higher management positions in various departments of NWSDB considering the experience in water supply system management. Consider the one hundred and fifteen numbers of samples and 88 forms were collected. The summary of data collection is as illustrated in Table 4-4.

Table 4-4 : Summary of data collection

Section	Distributed Form	Collected Forms
Planning & Design	35	29
Operation & Maintenance	20	16
Senior management	20	15
Middle level (Development /P&C)	15	10
Non-Technical (Finance/HR..)	25	18

Summary of data collection for main parameters illustrated as follows according to their working section.

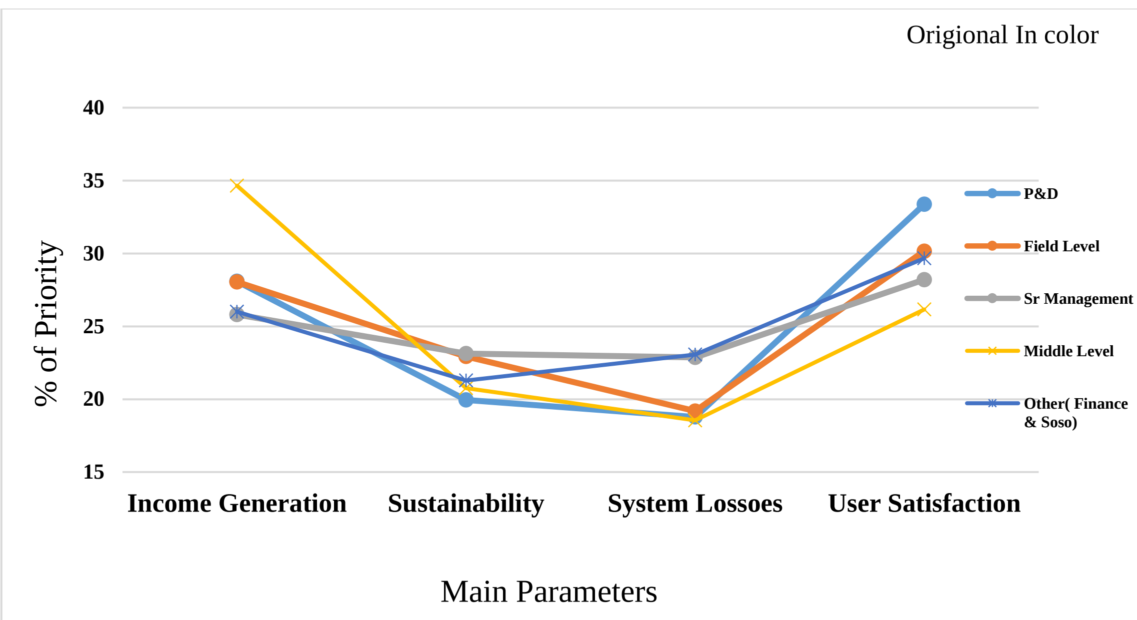

Figure 4.3 : Priority Scores vs. Main Parameters for Working Sections

88 data collection forms were considered for the analysis and summarized the data. There is no any additional comments for main parameters and identified all additional sub-parameters illustrated in Table 4.5. Additional sub-parameters according to main parameters are shown in Table B.4.1.

Table 4-5 : Summary of additional sub-parameters

Additional Sub Parameters	Additional Sub Parameters
Leak near meter	Illegal connection
Transport for staff	disconnection
Training for staff	meter shifting
Regular/preventive maintenance	Water Clearance
Laboratory testing	Replacement of pipes
GW management	Name Change
Estimated bills	Energy consumption
Attend complains effectively	defect in bulk meter
Pump/plant failure	Internal leak
category change	Improvement of IT
Plant loss	Complain management
Less demand	O&M activities
Catchment protection/WSP	Inventory losses
Air Releasing	Overhead
Number of break down	

According to the additional parameters which are obtained by data collection form were carefully reviewed in the analysis. Appendix B.3.1- B.3.3 presented the sample of data collections form which are collected from stakeholders.

4.3 Data Checking

4.3.1 Collected Field Data

Data checking was completed systematically and not observe any missing data or abnormal behavior of the data.

4.3.2 Stakeholder Response –Management View

Checking all data collected from stakeholders in management view in the same order. Check the summation of the scores given to main parameter and sub-parameters are equal to 100 and 1000. Few questionnaire forms of sub-parameters were corrected according to the weights given in those forms. Corrected priority scores from stakeholder's responses for main parameter and sub-parameters are giving in Table B.5.1- Table B.5.6 and Table B.6.1 –B.6.6 respectively.

4.3.3 Comparison of data

Obtain the total for sub parameters values for relative main parameters and plot the graph for difference between main and sub-parameters against the respondent as shown in figure 4.4 to figure 4.7.

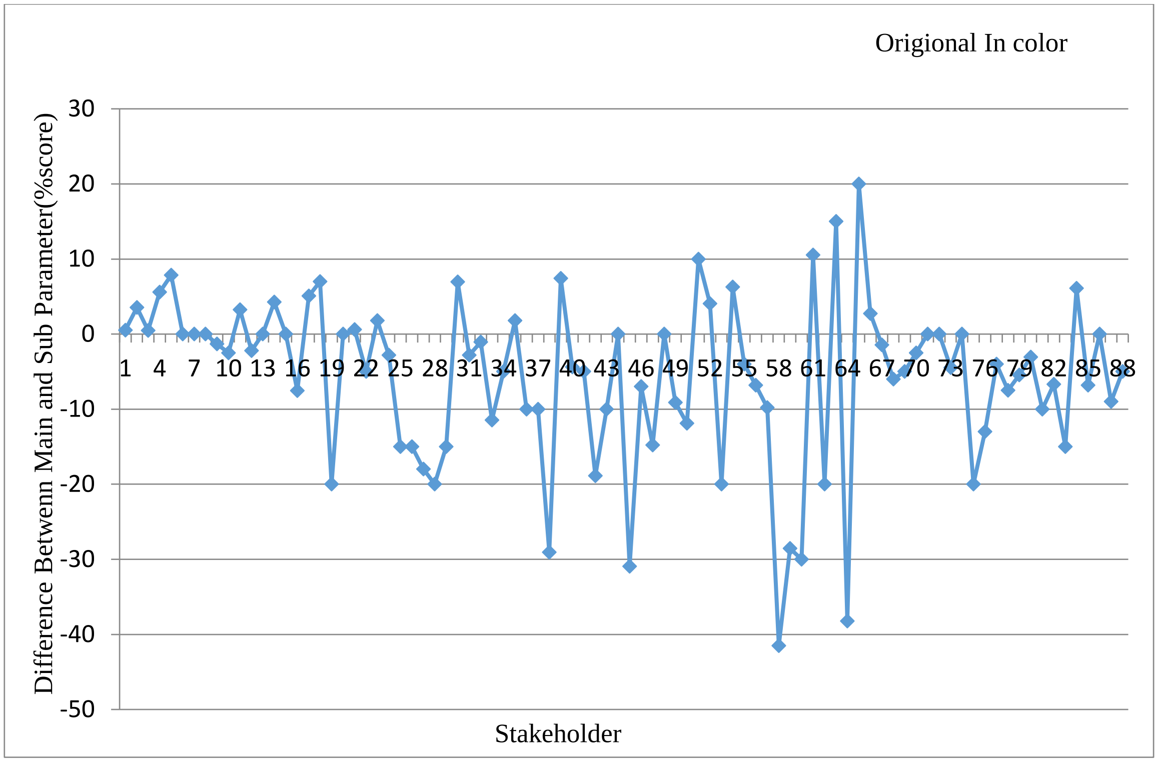

Figure 4.4 : Comparison of stakeholder data -Income Generation

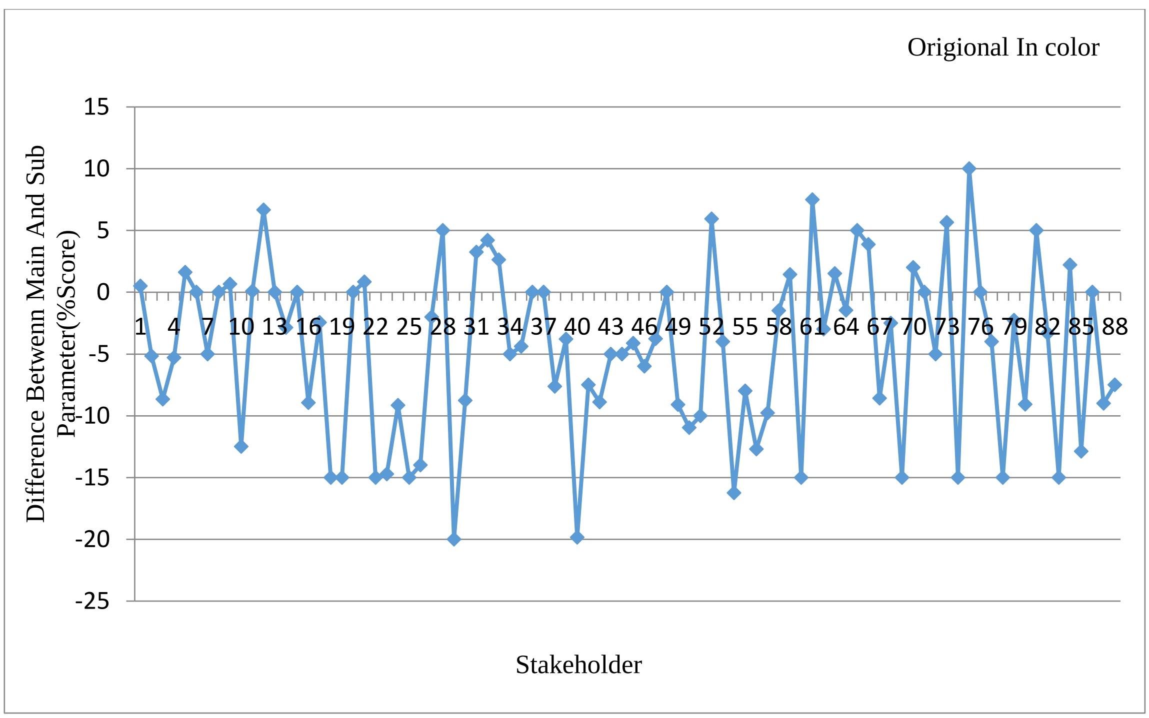

Figure 4.5 : Comparison of stakeholder data- System Sustainability

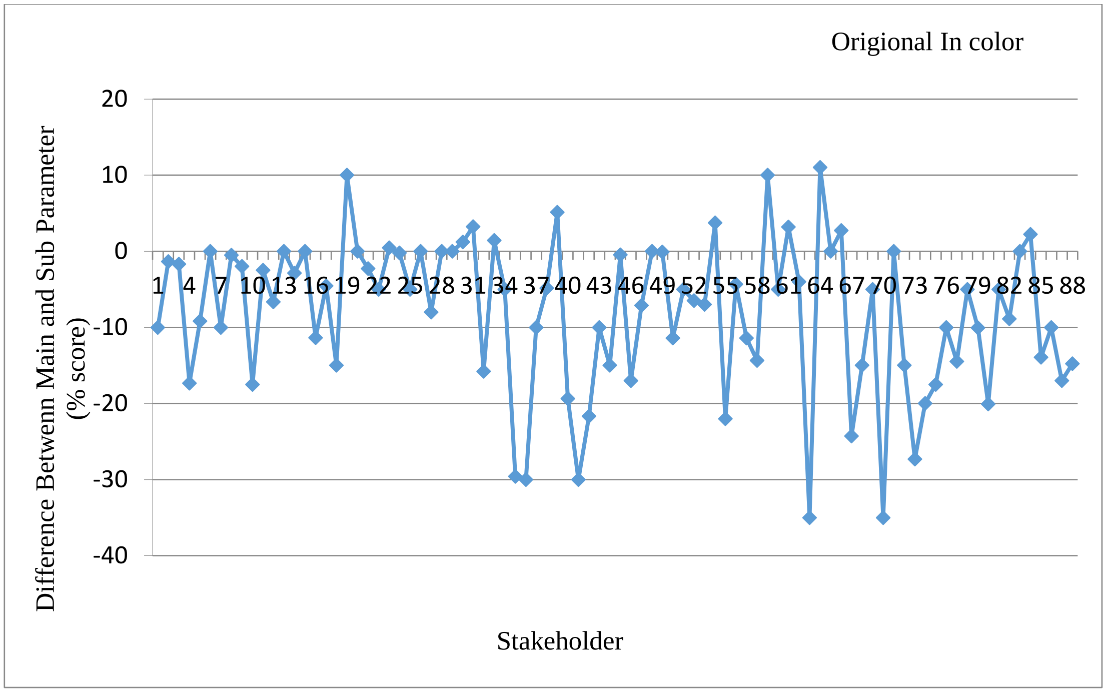

Figure 4.6 : Comparison of stakeholder data -System Losses

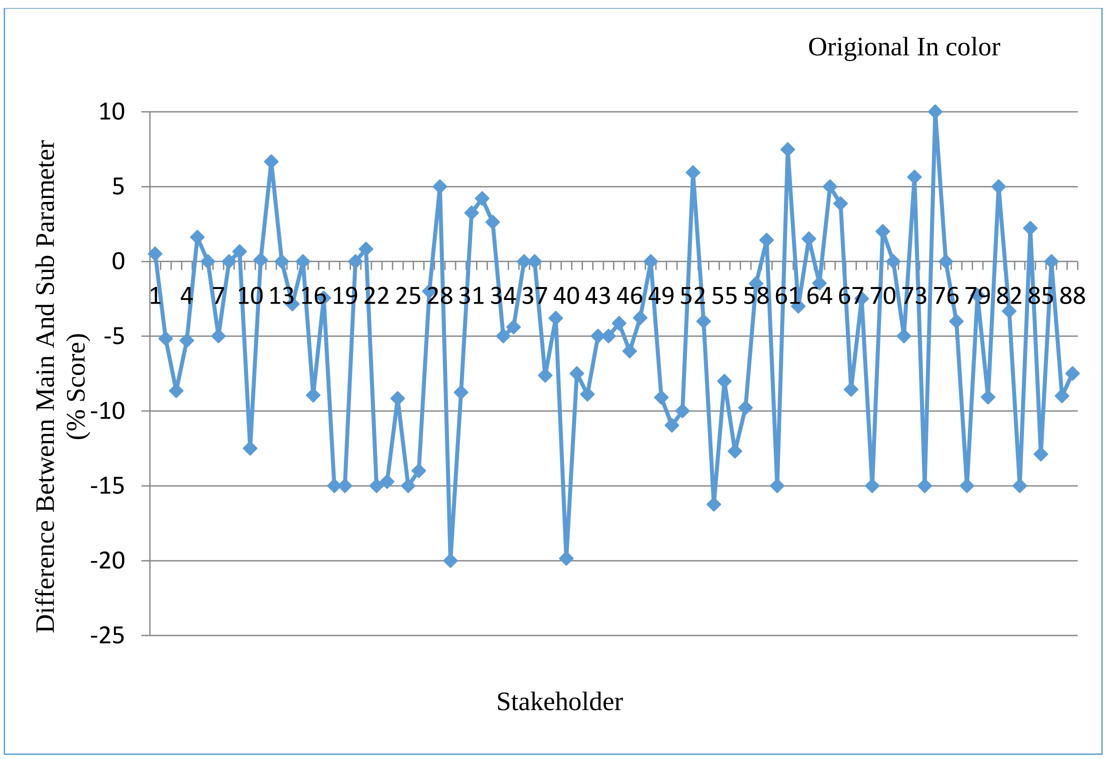

Figure 4.7 : Comparison of stakeholder data-System Reliability

Carefully observations of the graphs, % of respondent for each main parameter were presented in Table 4-6.

Table 4-6 : percentage of respondent and main criteria

	% of respondent (Difference more than 10)	% of respondent (Difference more than 20)
Income Generation	34	13
System Sustainability	22	2
System Losses	42	12
System Reliability	25	13

5 ANALYSIS AND RESULTS

5.1 MCDA model conceptualization

Multicriteria decision making models are characterized by the need to evaluate a finite set of alternatives with respect to multiple criteria. The criteria weights in different aggregation rules have different interpretations and implications which have been misunderstood and neglected by many decision makers and researchers. By analyzing the aggregation rules, identifying partial values, specifying explicit measurement units and explicating direct statements of pairwise comparisons of preferences, under the present study it is identified several plausible interpretations of criteria weights and their appropriate roles in different multicriteria decision making models.

Identified the main criteria and sub-parameters which are considering on the management of the water supply scheme according to the literature survey and stakeholder survey. Conceptual MCDA framework for this work shown in Figure 6.1. Six numbers of management zones of Ja Ela area considered as alternatives for this framework.

Obtained the priority order for main parameter, sub parameters and alternatives considering the MCDA framework. As per the literature, Analytical Hierarchy Process(AHP) is considered as the tool for the MCDA framework.

Criteria associated with the WSS project management are shown in Table 2-1. The Management zones associated with the project area are in Figure 4.2. Accordingly, the conceptual MCDA for the Stakeholder Survey was identified and is shown in Figure 5.1.

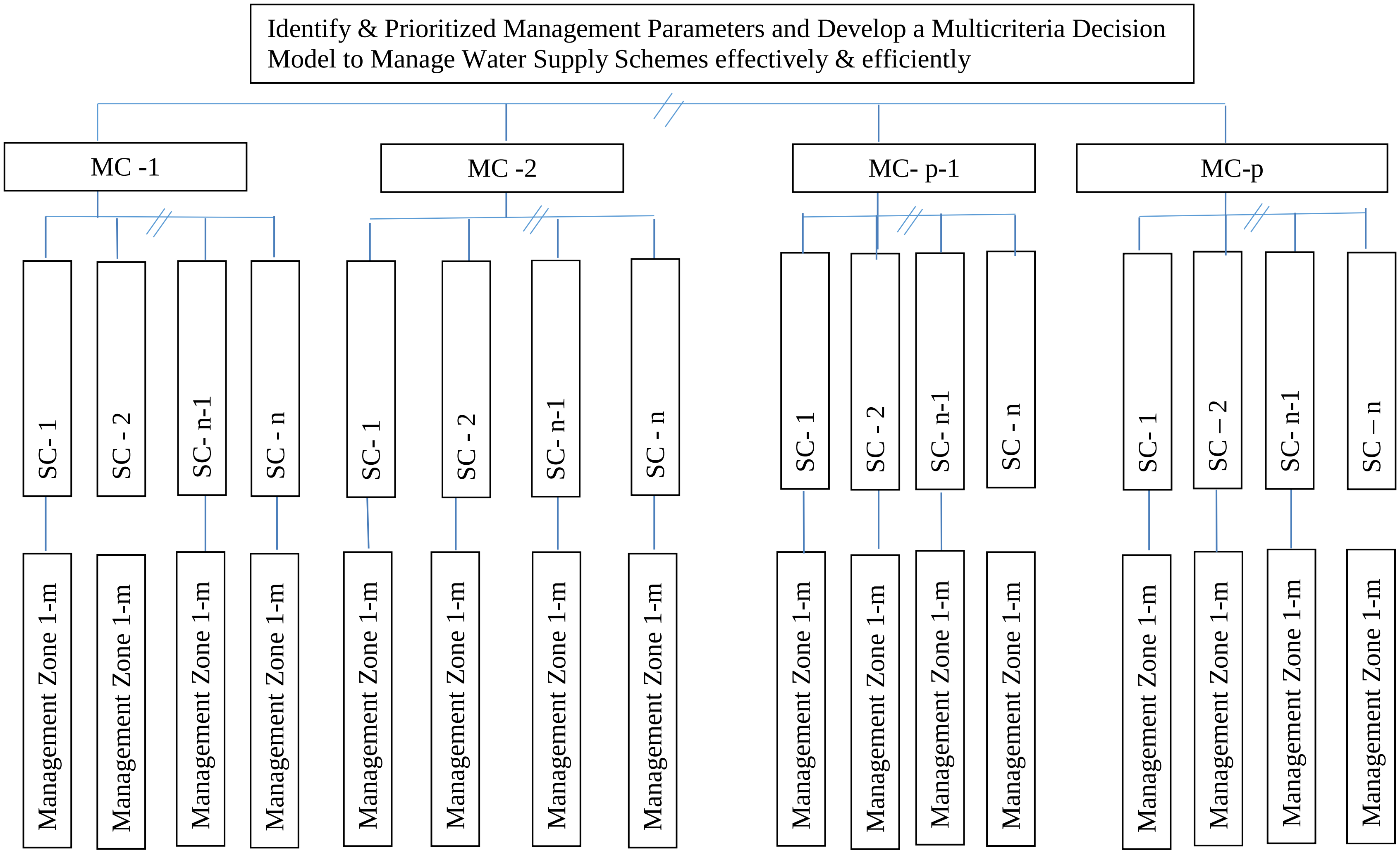

Figure 5.1 : MCDA Frame work

5.2 Criteria Identification

5.2.1 Survey Sample

115 numbers of Engineers in NWSDB were selected as stakeholders under management view. They have different types of designations and experience in the working station and shown in Table 5-1 & 5-2.

Table 5-1 : Designation of Stakeholders

Section	Distributed Form	Collected Forms
Chief Engineer	25	15
Senior Engineer	25	21
Engineer	40	34
Non-Technical	25	18

Table 5-2 Work Experience of Survey Sample

Section	Distributed Form	Collected Forms
Planning & Design	35	29
Operation & Maintenance	20	16
Senior management	20	15
Middle level (Development /P&C)	15	10
Non-Technical (Finance/HR.)	25	18
Total	115	88

5.2.2 Identification of Main criteria

Four main parameters were identified according to the literature survey and stakeholder survey response as income generation, system sustainability, system losses and system reliability. The collected preferences for main criteria from the stakeholder survey present in Annex B.

Percentage of score and exceedance of probability curves for each main criteria were prepared to get a better view of main criteria as shown in Figure 5.2. It shows all four curves in same graph and according to the graph the percentage scores vary with the preference of the various stakeholders. Officers from different type of working places lead this variation and it needs more attention to process the analysis of the main criteria. Also according to the working experience of relevant officers are heavily impacted by these variations.

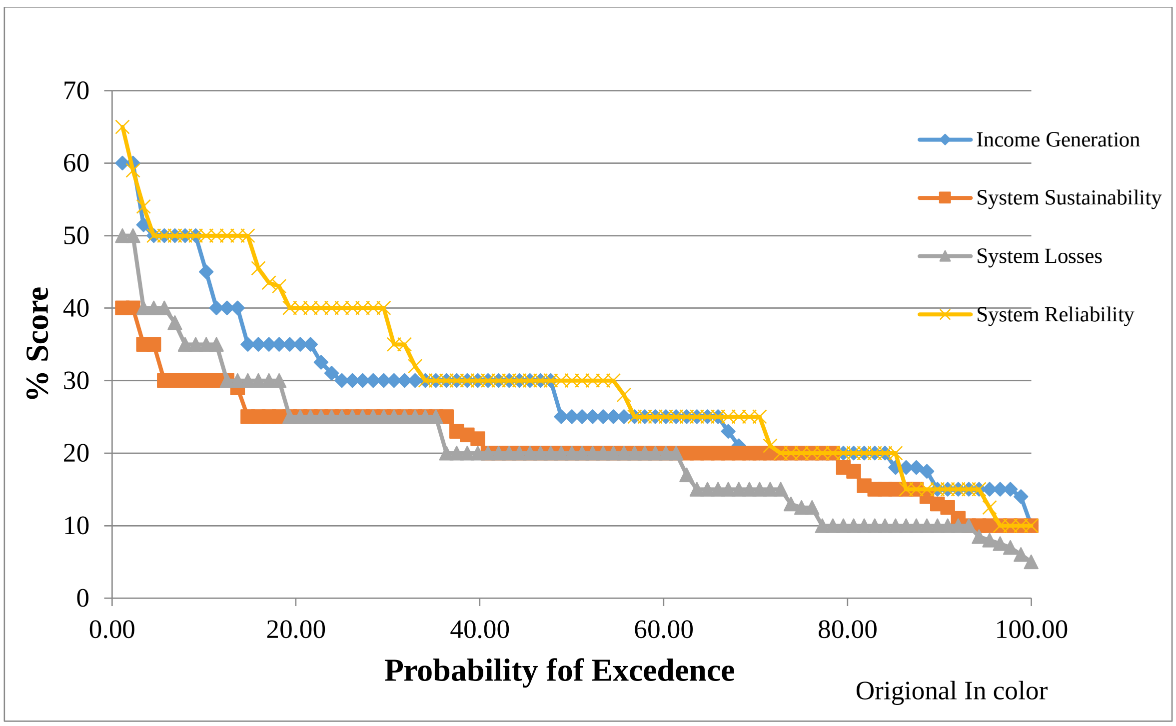

Figure 5.2 : Probability of Exceedance for main criteria

Identified breaks of each main criteria by visually observing the exceedance curves and breaks were classified as high, medium-high, medium-low and low. Summarized breaks values for each main criteria are given in Table 5-3.

Table 5-3 : Summarized the Main Criteria Values

	Income Generation	System Sustainability	System Losses	System Reliability
High	42.62	32.42	36.13	45.24
Medium –High	30.00	24.67	25.00	30.00
Medium – low	24.67	20.00	20.00	24.93
Low	17.70	12.97	11.24	16.50

Further evaluated the four major classes identified from the above graph and summation value for main criteria must be 100. According to the above combinations, selected most suitable 16 rational combinations considering the summation value which were close to the 100 and presented in Table 5-4.

Table 5-4 : Selected Combinations

Income Generation	System Sustainability	System losses	System Reliability	Total
17.70	12.97	25.00	45.24	100.92
42.62	20.00	20.00	16.50	99.12
30.00	32.42	20.00	16.50	98.92
30.00	24.67	20.00	24.93	99.61
30.00	20.00	36.13	16.50	102.63
30.00	20.00	25.00	24.93	99.93
30.00	20.00	20.00	30.00	100.00

Income Generation	System Sustainability	System losses	System Reliability	Total
30.00	12.97	11.24	45.24	99.45
24.67	24.67	36.13	16.50	101.97
24.67	24.67	25.00	24.93	99.27
24.67	20.00	25.00	30.00	99.67
24.67	20.00	11.24	45.24	101.14
17.70	32.42	25.00	24.93	100.05
17.70	32.42	20.00	30.00	100.12
17.70	12.97	25.00	45.24	100.92
24.67	24.67	20.00	30.00	99.34

Selected combinations were corrected considering the weight of each parameter and plot the probability of exceedance and % score for further analysis. Graphs are shown in Figure 5.4 to 5.7).

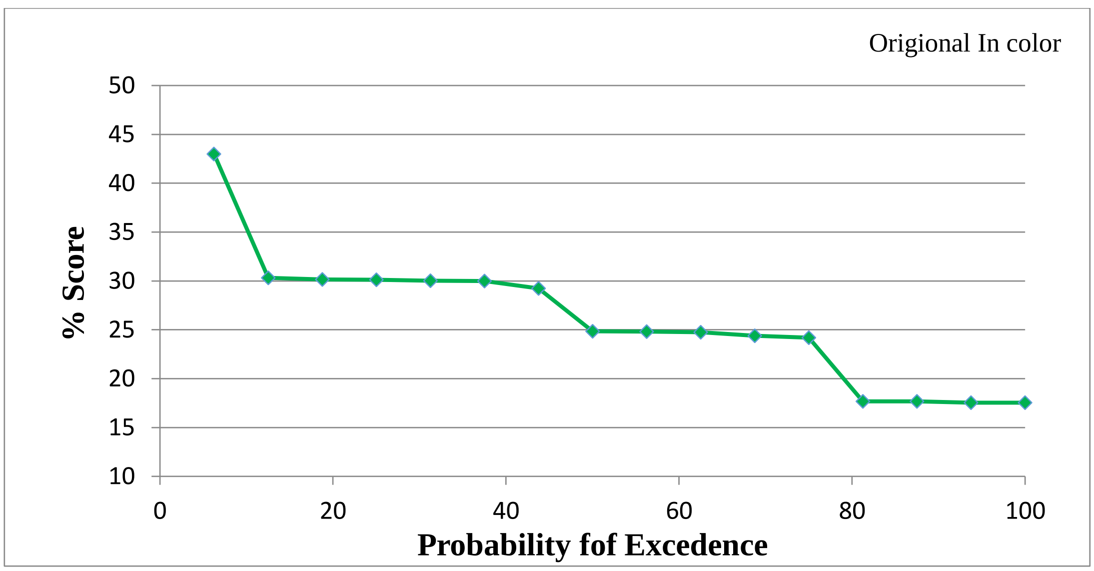

Figure 5.3 : probability of Exceedance curve-Income Generation - Selected Combi.

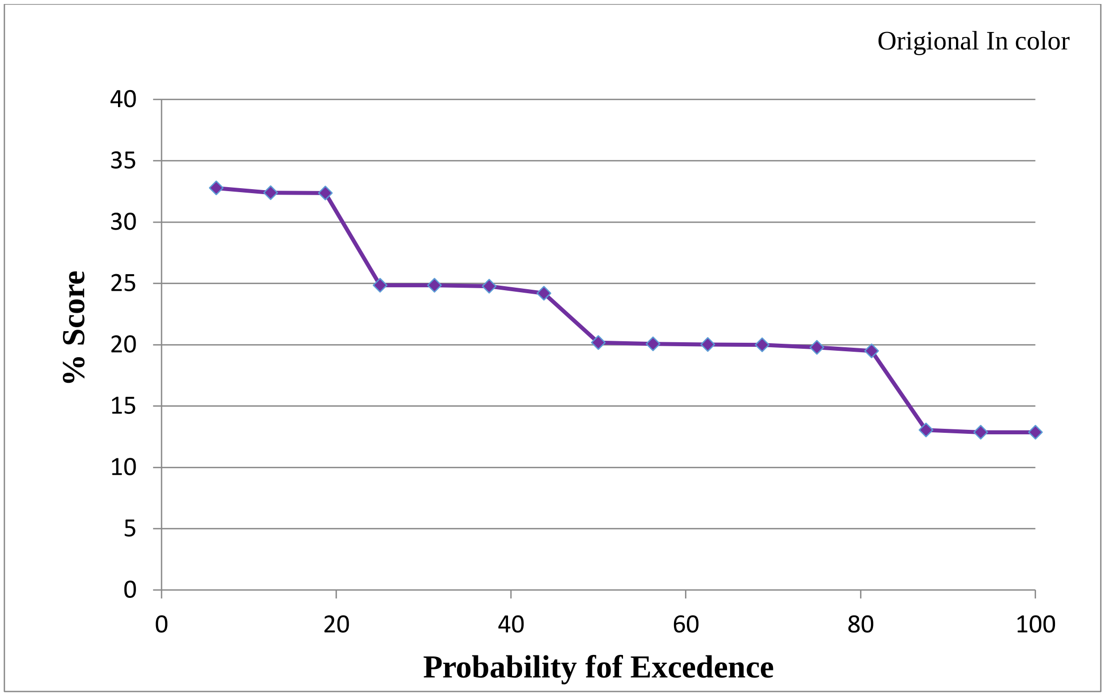

Figure 5.4 : probability of Exceedance curve-System Sustainability - Selected Combi

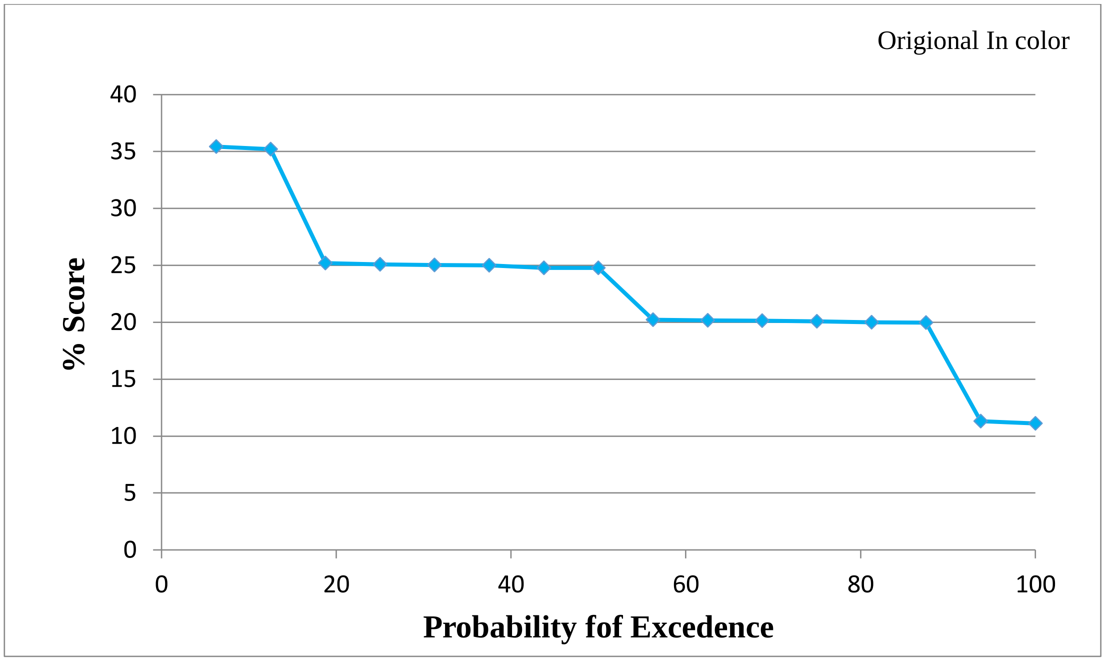

Figure 5.5 : probability of Exceedance curve-System Losses - Selected Combi

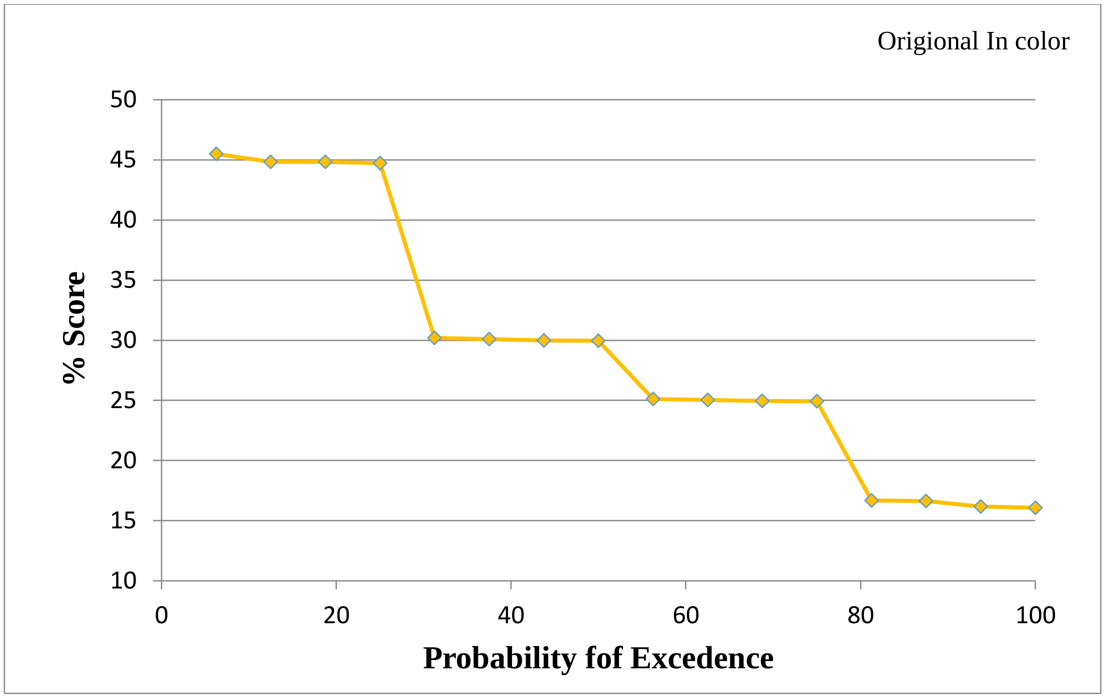

Figure 5.6: probability of Exceedance curve-System Reliability - Selected Combi

Each main criteria were classified as high medium and low according to the above graphs. Possible number of combination were created and select most suitable four combinations for the final analysis considering obtained value from above graphs and present in Table 5-5.

Table 5-5: Final Combinations

Main Criteria / Combination	Income Generation	System Sustainability	System losses	System Reliability	Total
C1	29.57	32.05	22.21	16.16	100
C2	29.44	21.41	22.12	27.03	100
C3	17.58	32.45	22.49	27.48	100
C4	17.97	13.18	22.98	45.87	100

5.2.3 Identification Sub Criteria

Preliminary studies and literature review were identified 12 numbers of sub-parameters which are considering the management of water supply scheme. 29 numbers of new sub-parameters were identified on the stakeholder survey in management view shown in table 5-5. Identified additional subcategories are list out with respect to the main criteria and present on Table B.4.1. All the identified sub-parameters in each main parameter were plotted against percent of respond as figure 5.7 to Figure 5.10. Twelve sub-parameters were selected for further analysis after carefully analysis of all the sub-parameters.

5.2.3.1 Income Generation

Income generation is one of the most important criteria of the WSS. Income is directly involving to maintain the Scheme, Staff salaries, new development/Improvement, etc. Nine Sub parameters were identified in the data collection from the stakeholders in management view and shown in Figure 5.7 according to the response percentages. Bill collection and new connections were the identified main income methods to WSS according to literature survey and the data collection from the stakeholders in management view. The other seven sub-parameters obtain less response percentages on the stakeholder survey. New connection and bill collection obtain 100% respond from the stake holder survey while other parameters obtain less than 12 %.

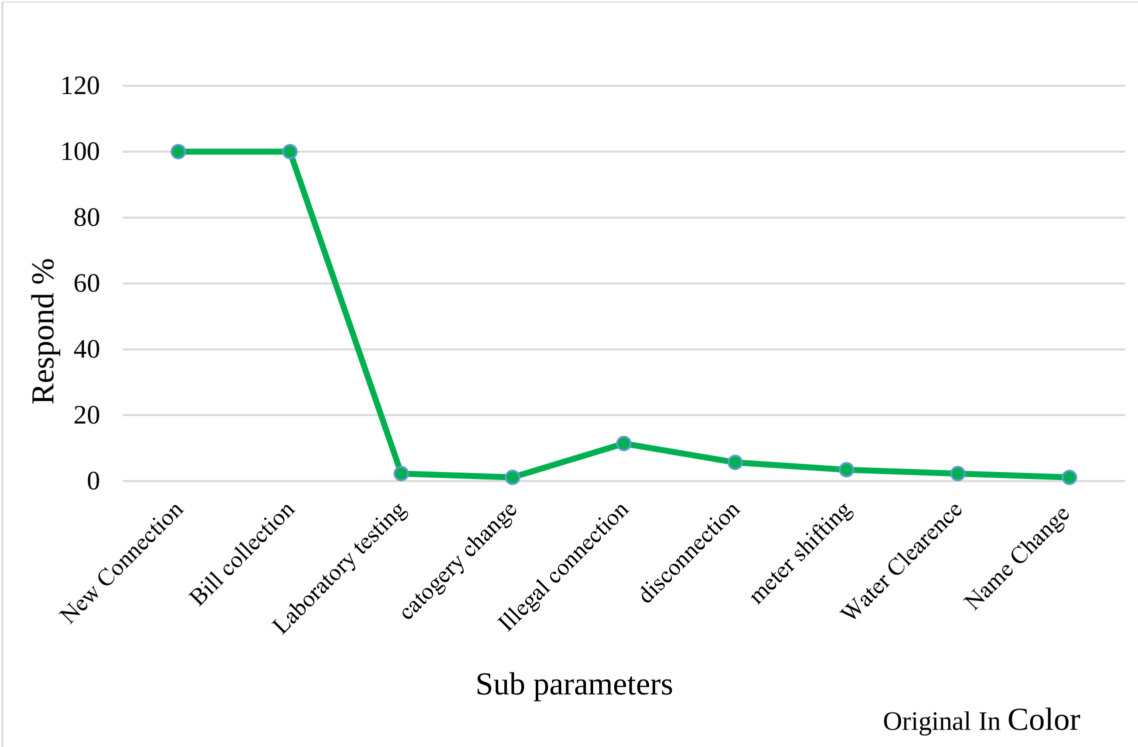

Figure 5.7 : Identified sub-parameters - Income Generation

5.2.3.2 System Sustainability

Ten sub parameters were identified according to the data collection from the stakeholders in management view under the main parameter of system sustainability. Identified sub-parameters and respond percent shown in Figure 5.8. Operation & Maintenance cost and staff salaries are obtained 100% of responding while other sub-parameters obtain less than 10% of responding. Operation & Maintenance cost and staff salaries consider for future analysis.

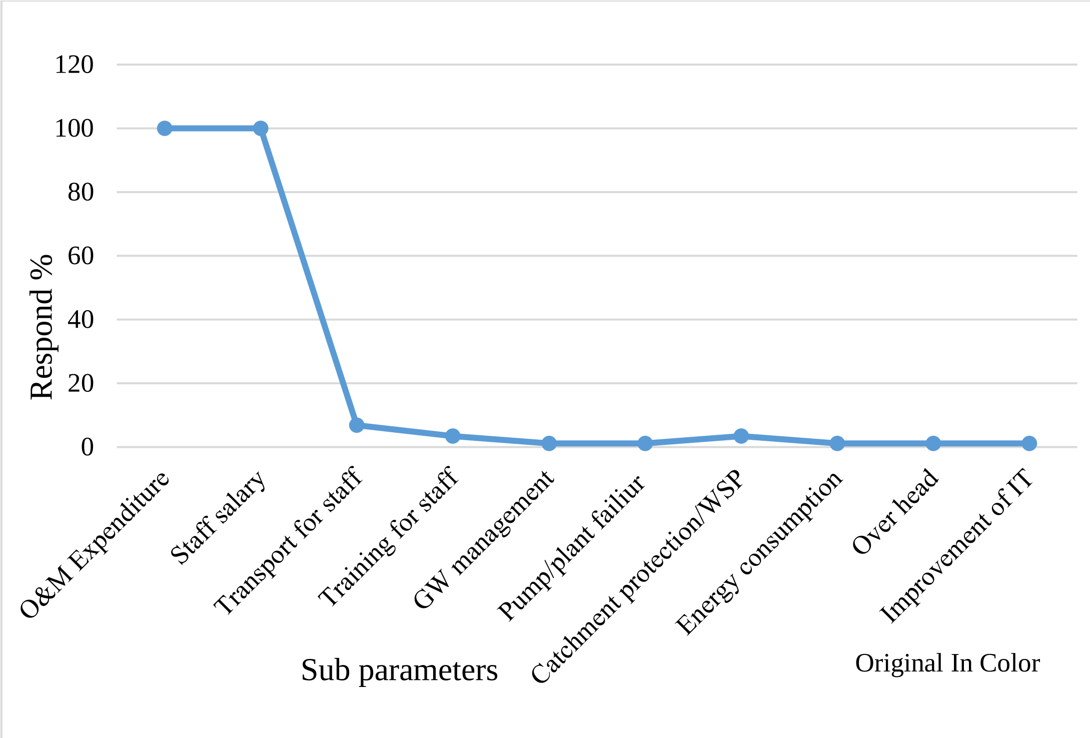

Figure 5.8 : Identified sub-parameters - System Sustainability

5.2.3.3 System losses

All the stakeholders of the management view were identified the non-revenue water is the most critical parameter with respect to the system losses. Nine other parameters were mentioned in the stakeholder questionnaire and number of respondents is very low for each parameter. All the sub-parameters and respond percentages plotted in Figure 5.9. Sub parameter NRW selected for further evaluation which having 100% respond for the stakeholder survey.

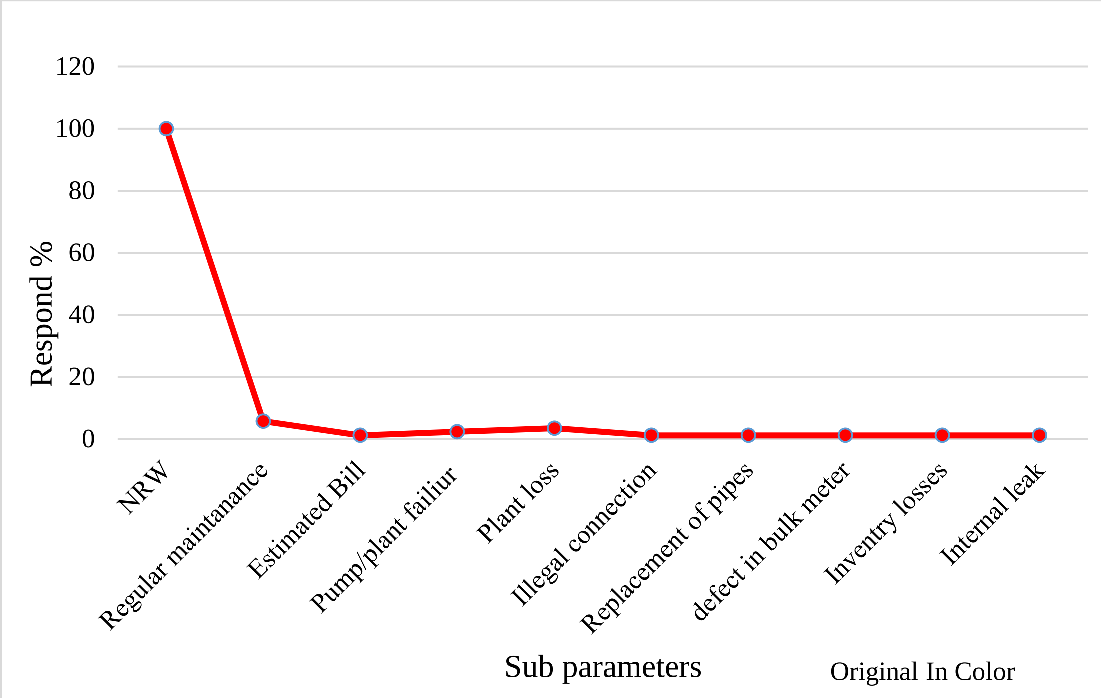

Figure 5.9 : Identified sub parameters - System Losses

5.2.3.4 System Reliability

According to the literature survey and preliminary discussions, seven parameters were identified under the main criteria of system reliability. Additional seven parameters of system reliability obtained from the stakeholder survey.100% response was obtained for the initially identified sub parameters while other parameters obtain less than 10% response. All identified sub parameters and % of respond was plotted in Figure 5.10.

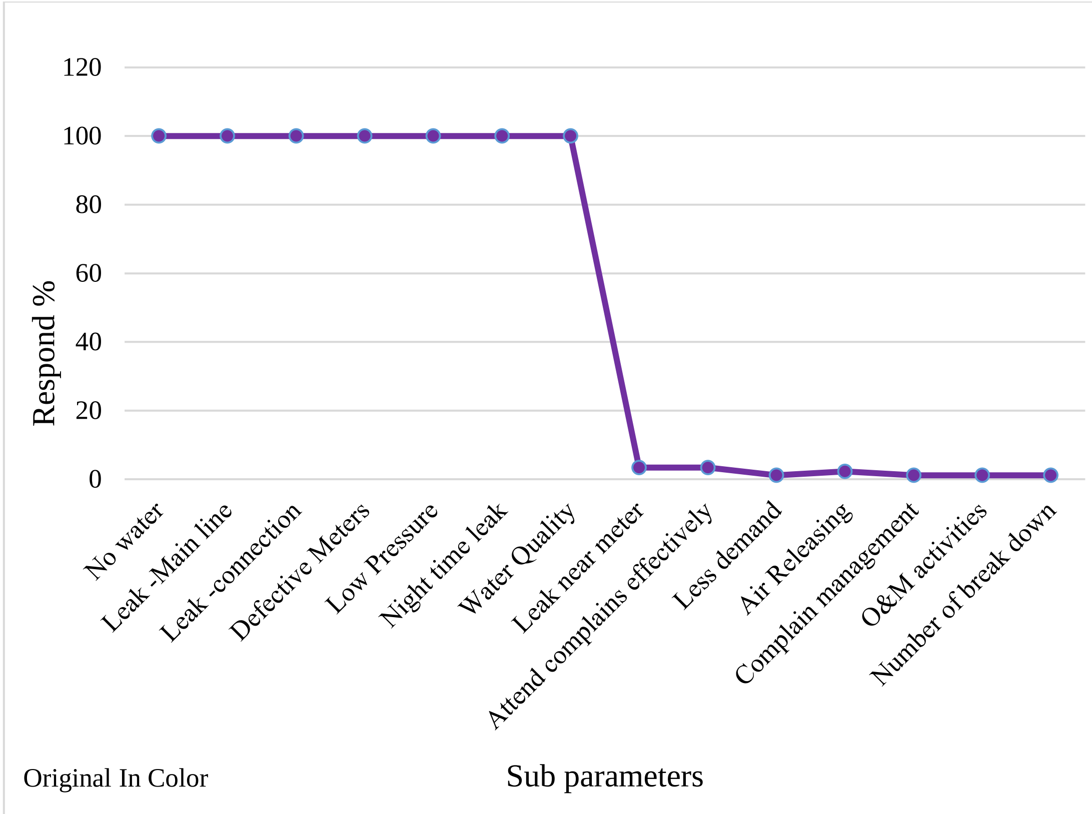

Figure 5.10: Identified sub parameters - System Reliability

Twelve numbers of sub parameters were selected for analysis according to the considering above four graphs. Select all sub parameters which are obtained 100% respond and other sub parameter not consider for this analysis due to less responded percentages.

Corrected response for each selected sub parameter is in Annex B Table B.6.1 to Table B.6.6. The correction was completed according to the equal distribution among the weight of the response. Graphs for probability of exceedance and percentage score were presented in Figure C-1 to Figure C- 4 for each sub parameter. All graphs classified as high, medium and low range by visual observations. Some graphs do not illustrate the clear separation values. In such a place consider the average value for further analysis. The summary of the classification values for each sub parameters are in Table 5-20.

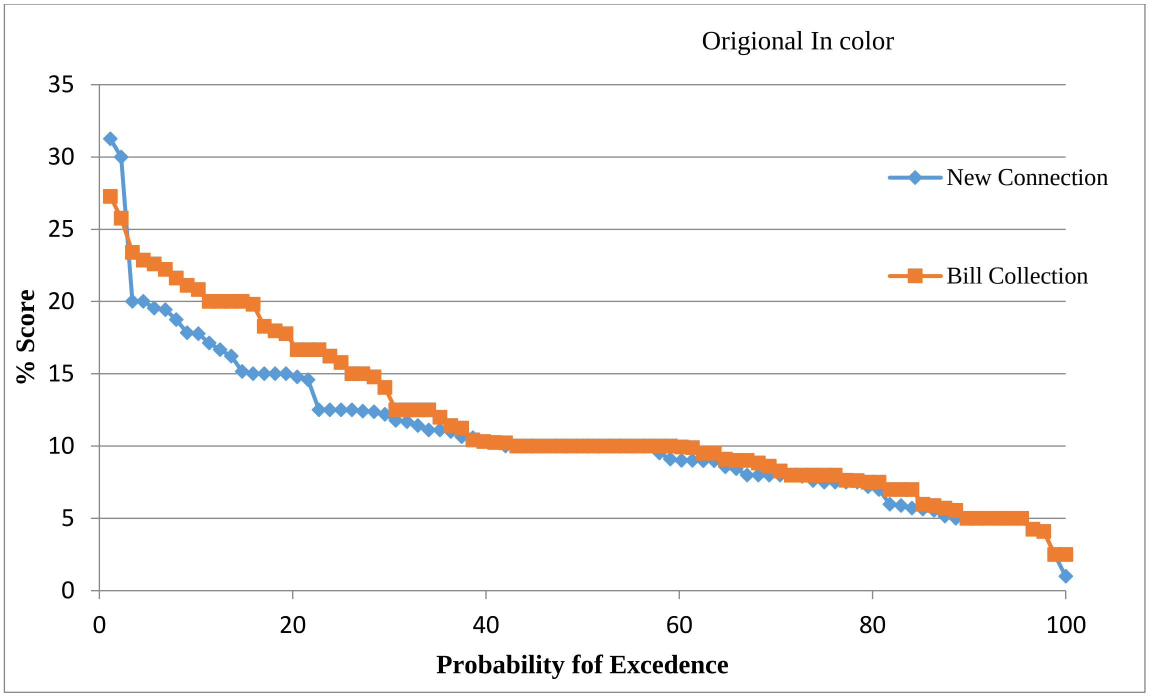

Figure 5.11: Probability of Exceedance - sub parameters- Income Generation

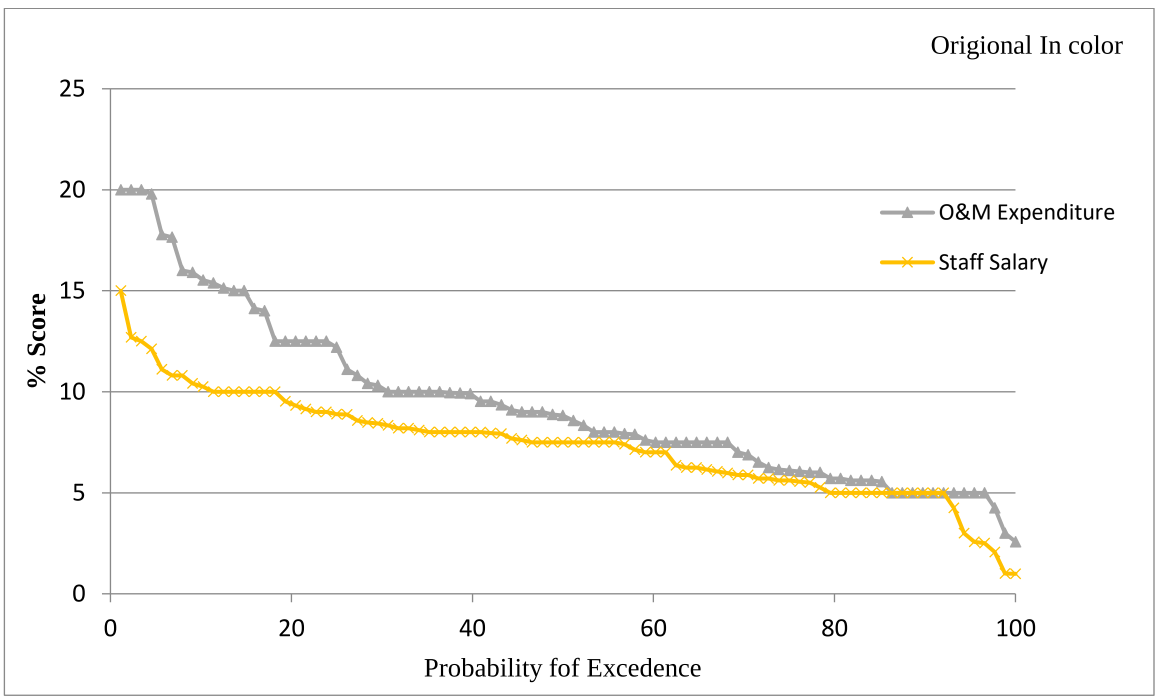

Figure 5.12: Probability of Exceedance -sub parameters – System Sustainability

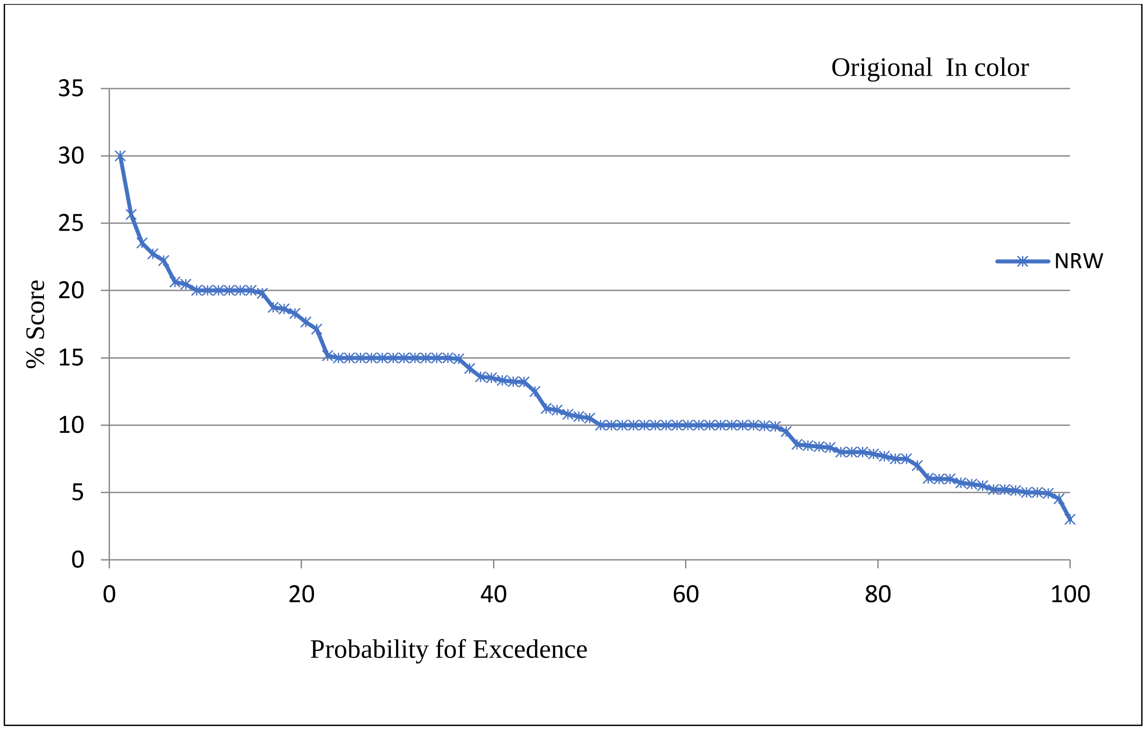

Figure 5.13: Probability of Exceedance - sub parameters -NRW

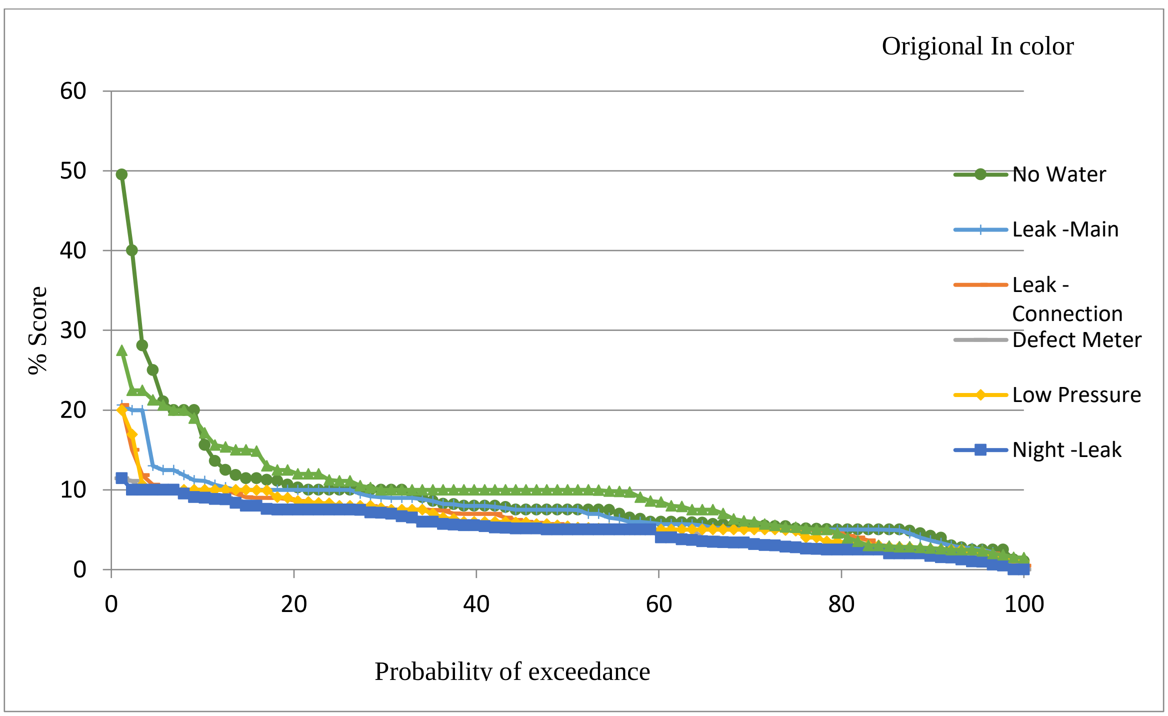

Figure 5.14: Probability of Exceedance - sub parameters – System Reliability

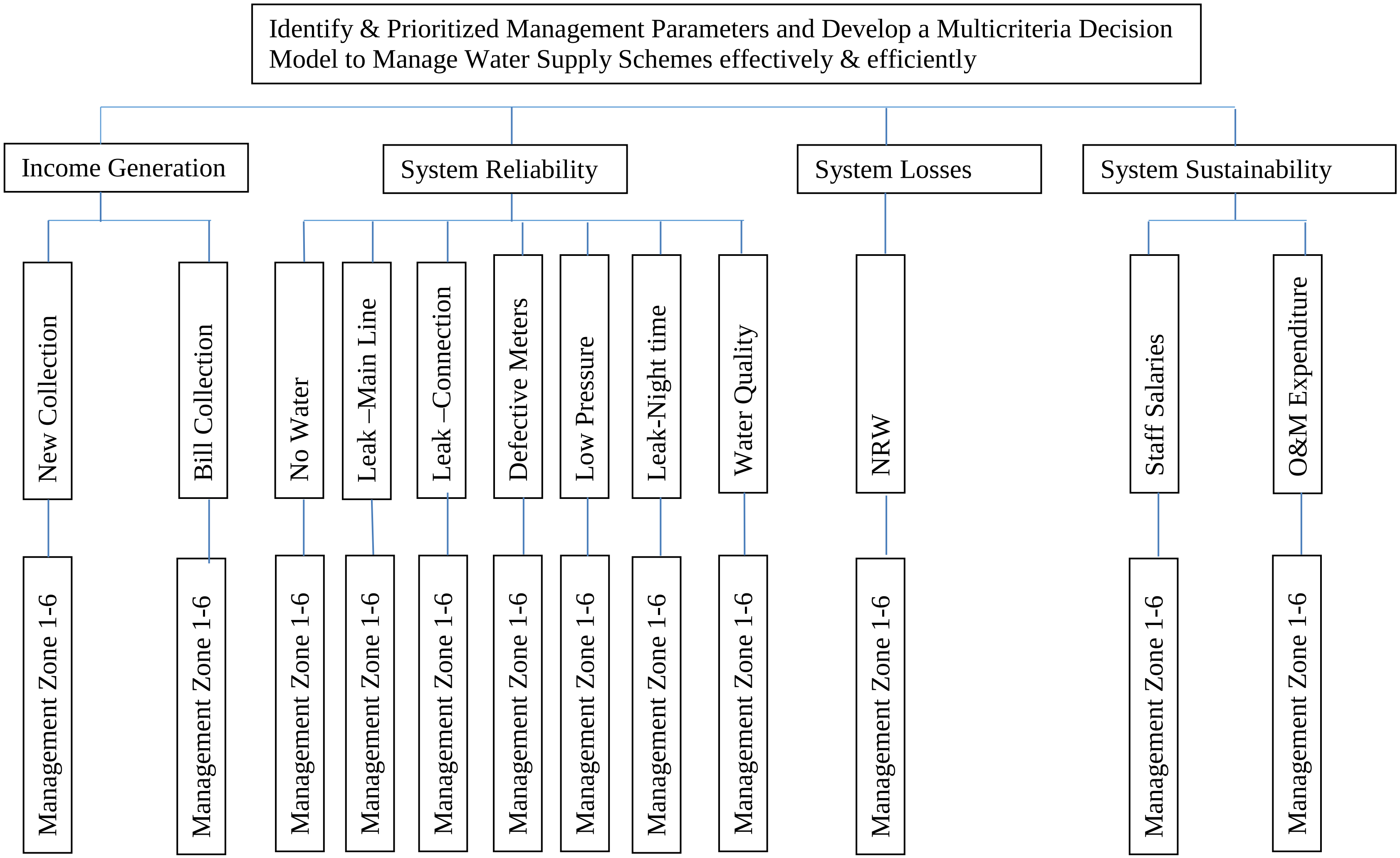

Figure 5.15 : MCDA Frame work

5.3 Alternatives

5.3.1 Management Zones

The map of Ja-Ela area Engineer boundaries for NWSDB shown in Figure 4.2 .Ragama & Ja Ela are the main two sections of the Ja-Ela area engineer's boundaries. Two Engineer assistants have appointed as officers in charge of relevant areas. Ease of operation and maintenance Ja Ela OIC area divide into four zone officer's areas and Ragama OIC area divide into two zone officer's area. Each zone officer area divides into meter reader zone and summery of the zone arrangement of the Ja Ela area shown Table 5-6.

Table 5-6: Summary of zone Arrangement in Ja Ela Area

Area- Engineer	Area-OIC	Area-Zone	Number ofMeter reader
Ja Ela	Ragama	Ragama	12
		Kandana	19
	Kandana	Ja Ela - Upper	10
		Ja Ela Lower	14
		Ekala	9
		Uswatekeiyawa	7

Identify the alternatives and pairwise comparison is required for the MCDA model development. Ja Ela area consist of six zone officer areas and considered as alternatives. For the each sub parameter it is required to identify pairwise comparison and related weights for all six zone officer area. But there is no literature or guild line to evaluate the pairwise comparison or relative importance of the zone officer areas. Hence it is required to rationalize the method used in the analysis. Area Engineers and managers of NWSDB are the most field experience persons in Sri Lanka regarding the management of water supply schemes. Hence it is decided to distribute a questionnaire to identify the link between pairwise comparison or relevant importance in zone officers area. Survey sample was selected in area Engineers and managers of the NWSDB.

5.3.2 Income Generation

New connection and bill collection are the identified two sub parameter of the income generation. Relative weights were calculated for this two sub parameters considering the alternatives.

5.3.2.1 New Connection

The total number of connections was increased in all six management zones in every year due to rapid developing in the study area and increasing the water production of the area. Summary of the connections in each alternatives shown in Table 5-7. End of the 2018, Kandana zone was the highest connection zone in the Ja Ela area.

Table 5-7 : Number of connection for each management Zone

Management Zone Name	2013	2014	2015	2016	2017	2018
Ekala	2,495	3,165	3,813	4,456	5,013	5,658
Ragama	5,010	5,638	6,143	6,909	7,593	7,962
JA Ela	5,365	6,088	6,555	7,058	7,407	7,794
Kadana	5,519	6,500	7,140	8,135	8,874	9,431
Uswetakeyawa	7,346	6,827	7,049	7,290	7,454	7,647
Ja Ela - upper	3,026	4,119	4,789	5,510	6,277	6,736

5.3.2.2 Bill Collection

Bill collection data for Ja Ela area is available for six years (2013-2018) on a monthly basis. Identify the related dockets numbers for each zone officer's area and summarized the bill collection amount for each zone for each month. Bill collection data include all the types of collections such as domestic connection, commercial connection, Bulk supply connection etc..Re- arranges the data in systematically according to the zone officer areas and it shows in table 5-8.

Table 5-8: Bill Collection for Study Area

Management Zone Name	2013	2014	2015	2016	2017	2018
Ekala	32.57	44.50	51.65	65.15	68.70	68.58
Ragama	39.21	44.81	44.57	57.31	61.01	66.69
JA Ela	34.62	43.98	47.20	61.13	55.44	65.21
Kadana	45.19	53.61	59.32	77.71	82.24	91.19
Uswetakeyawa	53.04	60.03	58.51	68.99	73.48	73.79
Ja Ela – upper	19.59	25.28	30.31	43.72	44.97	49.82

5.3.3 System Sustainability

Operation & Maintenance cost and staff salaries are two sub parameters identified according to the data collection from the stakeholders in the management view under the main parameter of system sustainability,

5.3.3.1 Operation & Maintenance Cost

Operation and maintained cost for the study area is available for 5 year period (2014-2018). But it is not distributed with the Zone office area or OIC office area. Operation & maintenance cost data available only for the Ja Ela Area. Assume the number of complaints is proportionate to the cost of operation & maintenance to obtain the operation and maintain the cost for each zone officer area. The summery of O&M Cost are in Table 5-9.

Table 5-9: O&M Cost for Study Area

Management Zone Name	O&M Cost (Rs. Million)			
	2015	2016	2017	2018
Ekala	54.30	51.61	53.66	48.19
Ragama	89.52	85.10	88.48	79.45
JA Ela	89.37	84.95	88.32	79.31
Kadana	103.05	97.96	101.85	91.45
Uswetakeyawa	102.52	97.46	101.33	90.98
Ja Ela - upper	66.93	63.63	66.15	59.40

5.3.3.2 Staff salaries

Staff salary available in the study area for 5 years (2014-2018).To convert the area staff salary to the zone officer area, assume the number of water supply connections in each zone proportionate to the staff salary in each zone officer area. Staff salary for the study area is shown in Table 5-10.

Table 5-10: Staff salary for Study Area

Management Zone Name	Staff Salaries (Rs. Million)			
	2015	2016	2017	2018
Ekala	40.87	41.91	43.32	49.81
Ragama	67.38	69.10	71.42	82.13
JA Ela	67.26	68.98	71.30	81.98
Kadana	77.56	79.54	82.22	94.54
Uswetakeyawa	77.17	79.13	81.80	94.05
Ja Ela - upper	50.38	51.66	53.40	61.41

5.3.4 System Losses

The Inflow data to each zone and consumption data available for one year. (2019). , Calculated the System losses considering the inflow and consumption flow for each zone and shown in Table 5.11.

Table 5-11: NRW for Study Area

Management Zone Name	NRW (%)
Ragama	21.00
Kandana	22.00
Ja Ela - Upper	23.00
Ja Ela Lower	22.50
Ekala	22.00
Uswatekeiyawa	21.00

5.3.5 System Reliability

System reliability was considered based on the complaints received in each zone. Data was collected through NWSDB online database and complaints categorized according to the identified sub parameters. Complaints were not recorded as zone officers area. Assume the number of complaints is proportionate to the number of connection in each zone. The total numbers of complaints are in Table 5-12 for the study Area.

Table 5-12: Total Number of Complaints for Study Area

Management Zone Name	Number Of Complaints -2018						
	No water	Main Leak	Connection Leak	Defective meter	Low Pressure	Leak-Night Time	Water Quality
Ekala	39	23	35	2	2	17	3
Ragama	148	120	228	36	1	83	14
JA Ela	58	33	52	3	3	25	5
Kadana	174	141	267	41	2	98	16
Uswetakeyawa	58	34	52	3	3	25	5
Ja Ela - upper	49	28	44	3	2	21	4

5.4 MDCA Model framework

5.4.1 Main Criteria

Four main parameters (Income Generation, System Sustainability, System Losses, System reliability) were identified based on the Stakeholder view which are most effective for the management of water supply system. Four major combinations are observed after a critical evaluation of the stakeholder's opinion. (Table 5.5).The initial values for combinations are used to build up pairwise comparisons in Table 5.13.

Table 5-13: Pairwise comparison of main criteria

	Combination 1	Combination 2	Combination 3	Combination 4
Income Generation/System Sustainability	0.92	1.37	0.54	1.36
Income Generation/System Losses	1.33	1.33	0.78	0.78
Income Generation/System Reliability	1.83	1.09	0.64	0.39
System Sustainability / System Losses	1.44	0.97	1.44	0.57
System Sustainability / System Reliability	1.98	0.79	1.18	0.29
System Losses / System Sustainability	1.37	0.82	0.82	0.50

5.4.1.1 Pairwise matrix- Main Criteria

Values obtained from the pairwise comparison were converted to saatys scale to develop the analytical hierarchy process. Saatys scale contains 1 to 9 and assumes that stakeholder opinions for selected combinations were varied linearly between maximum and minimum values. The converted pairwise combinations are in Table 5-14.

Table 5-14: Pairwise comparison for main criteria -Saaty scale

	Combination 1	Combination 2	Combination 3	Combination 4
Income Generation/System Sustainability	1	9	1	9
Income Generation/System Losses	4	8	3	5
Income Generation/System Reliability	8	5	2	2
System Sustainability / System Losses	5	3	9	3
System Sustainability / System Reliability	9	1	7	1
System Losses / System Reliability	4	1	3	3

Build up the pairwise matrix for each combination from the above values of saatys scale for development of the MCDA model. Matrix for each combination is in Table 5-15 to 5-18.

Table 5-15: Pairwise preferences -Combination 1

	Income Generation	System Sustainability	System Losses	System Reliability
Income Generation	1	1	4	8
System Sustainability	1	1	5	9
System Losses	1/4	1/5	1	4
System Reliability	1/8	1/9	1/4	1

Table 5-16: Pairwise preferences -Combination 2

	Income Generation	System Sustainability	System Losses	System Reliability
Income Generation	1	9	8	5
System Sustainability	1/9	1	3	1
System Losses	1/8	1/3	1	1
System Reliability	1/5	1	1	1

Table 5-17: Pairwise preferences -Combination 3

	Income Generation	System Sustainability	System Losses	System Reliability
Income Generation	1	1	3	2
System Sustainability	1	1	9	7
System Losses	1/3	1/9	1	3
System Reliability	1/2	1/7	1/3	1

Table 5-18: Pairwise preferences -Combination 4

	Income Generation	System Sustainability	System Losses	System Reliability
Income Generation	1	9	5	2
System Sustainability	1/9	1	3	1
System Losses	1/5	1/3	1	3
System Reliability	1/2	1	1/3	1

5.4.1.2 Ranking Main Criteria

To obtain ranking order of the main parameter of each combination was carried out by calculation of Eigen vector. (Saaty,1990). Consider the selected matrix and squared. Then obtained the summation of the row and normalized by row total. Obtain the eigen vectors to relate main criteria. Continue the same procedure or verification of eigen vector up to eigen vector difference reach to forth decimal places. Relative importance of main criteria presented in Table 5-19.

Table 5-19: Relative importance of main criteria

	Combination 1	Combination 2	Combination3	Combination4
Income Generation	0.402	0.697	0.291	0.586
System Sustainability	0.441	0.125	0.524	0.153
System Losses	0.116	0.073	0.110	0.137
System Reliability	0.042	0.105	0.075	0.124

5.4.2 Sub Parameter

Graphs for probability of exceedance and percentage score were presented in Figure C.1 to Figure C.4 in Appendix C for each sub parameter. Sub parameter values were divided into the categories by visual observation of considering the probability of exceedance and % of priority score graphs. Some graphs do not illustrate the clear separation values. In such a place consider the average value for further analysis. The summary of the classification values for each sub parameters are in Table 5-20.

Table 5-20: Summary of classification values for sub parameter

	Sub parameter	Value 1	Value 2
1	New Connection	15.46	7.64
2	Bill Collection	17.79	8.01
3	O&M Expenditure	9.41	
4	Staff Salaries	7.32	
5	NRW Reduction	16.78	4.51
6	No water	9.01	
7	Leak-Main Line	7.45	
8	Leak – Connection	6.27	
9	Defective meters	5.29	
10	Low Pressure	6.16	
11	Leak Night time	5.07	
12	Water Quality	9.35	

5.4.2.1 Pairwise Comparison

According to the MCDA model framework, Income generation and system sustainability are having two sub parameters and does not require any pairwise. System losses have only one sub-parameter and do not require any comparison. A pairwise comparison is needed for system reliability only. System reliability has seven sub parameters and obtain the pairwise comparison for the sub parameters related to their main criteria in Table 5-21. Pairwise comparison of system reliability required to convert saaty scale assuming that stakeholder opinions for selected combinations were varied linearly between maximum and minimum values.

Table 5-21: pairwise comparison for the sub parameters

Main Criteria	Pairwise Criteria	Stakeholder value	Saaty value
Income Generation	New Connection/Bill Collection	0.95	
System Sustainability	O&M Expenditure/Staff Salaries	1.29	
System Losses	NRW	1	
System Reliability	No water/Leak-Main Line	1.21	5
	No water/Leak – Connection	1.44	7
	No water/Defective meters	1.70	9
	No water/Low Pressure	1.46	7
	No water/Leak Night time	1.78	9
	No water/Water Quality	0.96	4
	Leak-Main Line/Leak – Connection	1.19	5
	Leak-Main Line/Defective meters	1.41	7
	Leak-Main Line/Low Pressure	1.21	5
	Leak-Main Line/Leak Night time	1.47	7
	Leak-Main Line/Water Quality	0.80	3
	Leak – Connection/Defective meters	1.19	5
	Leak – Connection/Low Pressure	1.02	4
	Leak – Connection/Leak Night time	1.24	5
	Leak – Connection/Water Quality	0.67	2
	Defective meters/Low Pressure	0.86	3
	Defective meters/Leak Night time	1.04	4
	Defective meters/Water Quality	0.57	1
	Low Pressure/Leak Night time	1.21	5
	Low Pressure/Water Quality	0.66	2
	Leak Night time/Water Quality	0.54	1

5.4.2.2 Pairwise matrix- Sub criteria

Pairwise matrix was developed same as per the main criteria. Developed matrixes are in Table 5-22 to 5-24.

Table 5-22: pairwise matrix of sub parameter - Income Generation

	New Connection	Bill Collection
New Connection	1.00	0.95
Bill Collection	1.05	1.00

Table 5-23: pairwise matrix of sub parameter -System Sustainability

	O&M Expenditure	Staff Salaries
O&M Expenditure	1.00	1.29
Staff Salaries	0.78	1.00

Table 5-24: pairwise matrix of sub parameter -System Reliability

	No water	Leak-Main Line	Leak – Connection	Defective meters	Low Pressure	Leak Night time	Water Quality
No water	1	5	7	9	7	9	4
Leak-Main Line	1/5	1	5	7	5	7	3
Leak – Connection	1/7	1/5	1	5	4	5	2
Defective meters	1/9	1/7	1/5	1	3	4	1
Low Pressure	1/7	1/5	1/4	1/4	1	5	2
Leak Night time	1/9	1/7	1/5	1/4	1/5	1	1
Water Quality	1/4	1/3	1/2	1	1/2	1	1

5.4.2.3 Ranking sub criteria

Obtain the relative importance of calculating eigen vectors as similar to main criteria. Relative importance of sub criteria were obtained and shown in Table 6-25 to table 6-27.

Table 5-25: Relative Importance -Income Generation

New Connection	0.488
Bill Collection	0.512

Table 5-26: Relative Importance - System Sustainability

O&M Expenditure	0.562
Staff Salaries	0.437

Table 5-27: Relative Importance -System Reliability

No water	0.461
Leak-Main Line	0.234
Leak – Connection	0.117
Defective meters	0.058
Low Pressure	0.053
Leak Night time	0.025
Water Quality	0.050

5.4.3 Alternative Priority

Obtain the pairwise comparison for each alternative for each sub criteria according to the collected field data.

5.4.3.1 New Connection

Connections per unit area for the each zones consider to the determination of the pairwise comparison on a new connection. Obtained relative weights for new connections are in Table 5-28 and Table 5-29 presented pairwise preferences converted to saaty scale by assuming that alternative opinions for new connections were varied linearly between maximum and minimum values.

Table 5-28: Relative weights for New Connections

	Population Per Year (AVG 5 year)	(Population/ Connection)* 1000	Relative weights
Ekala	3,807	4.97	0.32
Ragama	6,276	2.24	0.14
JA Ela	6,265	1.27	0.08
Kadana	7,225	1.67	0.11
Uswetakeyawa	7,188	2.41	0.15
Ja Ela - upper	4,693	3.09	0.20

Table 5-29: Pairwise preferences converted to saaty scale- New Connection

	Zone 1	Zone 2	Zone 3	Zone-4	Zone-5	Zone-6
Zone 1	1	5	9	7	5	4
Zone 2	1/5	1	4	3	2	2
Zone 3	1/9	1/4	1	2	1	1
Zone 4	1/7	1/3	1/2	1	2	1
Zone **5**	1/5	1/2	1/1	1/2	1	2
Zone 6	1/4	1/2	1/1	1/1	1/2	1

5.4.3.2 Bill Collection

Summarized the bill collection revenue for each zone with related dockets details and obtain relative weights for pairwise comparison are in Table 5-30. Pairwise preferences converted to saaty scale shown in Table 5-31 by assumes that alternative opinions for bill collections were varied linearly between maximum and minimum values.

Table 5-30: Relative weights for Bill Collections

Zone	Average Revenue- Rs. Mn (Six Years)	Relative Weights
Zone 1	55.19	0.17
Zone 2	52.27	0.16
Zone 3	51.26	0.16
Zone 4	68.21	0.21
Zone 5	64.64	0.20
Zone 6	35.62	0.11

Table 5-31: Pairwise preferences converted to saaaty scale-Bill Collection

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	3	3	1	2	6
Zone 2	1/3	1	3	1	1	6
Zone 3	1/3	1/3	1	1	1	6
Zone 4	1/1	1 /1	1	1	3	9
Zone **5**	1/2	1/1	1/1	1/3	1	8
Zone 6	1/6	1/6	1/9	1/9	1/8	1

5.4.3.3 O&M Expenditure

Field data collection of the O&M expenditure for the Ja Ela area Engineer region and assume O&M expenditure cost is proportionate to the total complaints of each zone. Relative weights for O & M Expenditure and Pairwise preferences converted to saaaty scale are in Table 5-32 & 5-33 respectively.

Table 5-32: Relative weights for O & M Expenditure

Zone	Average Expenditure (Six Years)Rs.Mn	Relative Weights
Ekala	29.16	0.06
Ragama	152.91	0.32
JA Ela	43.09	0.09
Kadana	178.71	0.37
Uswetakeyawa	43.36	0.09
Ja Ela - upper	36.51	0.08

Table 5-33: Pairwise preferences converted to saaaty scale- O & M Expenditure

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	2	1	2	2
Zone 2	1	1	7	2	7	8
Zone 3	1/2	1/7	1	1	2	3
Zone 4	1	1/2	1/1	1	8	9
Zone **5**	1/2	1/7	1/2	1/8	1	3
Zone 6	1/2	1/8	1/3	1/9	1/3	1

5.4.3.4 Staff Salaries

Obtain the relative weights for staff salaries on each zone according to the annual report data of Keleniya AE office's expenditure. Assume staff salaries propitiate to the Number of connection of each Zones. Relative weights for staff salary and Pairwise preferences were converted to saaty scale are in Table 5-34 & 5-35 respectively.

Table 5-34: Relative weights for Staff Salaries

Zone	Average Expenditure (Six Years)Rs.Mn	Relative Weights
Ekala	24.69	0.060
Ragama	129.47	0.32
JA Ela	36.48	0.09
Kadana	151.31	0.37
Uswetakeyawa	36.71	0.09
Ja Ela - upper	30.92	0.07

Table 5-35: Pairwise preferences converted to saaty scale- Staff Salaries

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	2	1	2	2
Zone 2	1	1	7	2	7	8
Zone 3	1/2	1/7	1	1	2	3
Zone 4	1	1/2	1/1	1	8	9
Zone **5**	1/2	1/7	1/2	1/8	1	3
Zone 6	1/2	1/8	1/3	1/9	1/3	1

5.4.3.5 Non-Revenue Water

NRW for each zones was calculated by the data to obtain from Kelaniya manager office. Relative weights for NRW and pairwise preferences were converted to saaty scale are in Table 5-36 & 5-37 respectively.

Table 5-36: Relative weights for NRW

Zone	Average NRW (9 months)	Relative Weights
Ekala	21.00	0.160
Ragama	22.00	0.167
JA Ela	23.00	0.175
Kadana	22.50	0.171
Uswetakeyawa	22.00	0.167
Ja Ela - upper	21.00	0.160

Table 5-37: Pairwise preferences converted to saaty scale- NRW

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	3	1	2	3	5
Zone 2	1/3	1	3	4	5	7
Zone 3	1	1/3	1	5	6	9
Zone 4	1/2	1/4	1/5	1	3	4
Zone 5	1/3	1/5	1/6	1/3	1	4
Zone 6	1/5	1/7	1/9	1/4	1/4	1

5.4.3.6 System Reliability

There are seven sub criteria were identified under the main criteria of system reliability. The online data base of NWSDB recorded different types of complaints. Mainly it divides to night time complaints and day time complaints. Summarized the customer complaints from each OIC area and assume those complaints are proportionate to the number of connections in each relevant zones. Obtain pairwise comparison and convert to the saaty scale by assuming stakeholder opinions for selected combinations were varied linearly between the maximum and minimum value. Table 5-38 presents the relative weights for customer complaints and pairwise preferences of matrix in Table 5-38 to 5-45.

Table 5-38: Relative weights for Customer Complaints

	No water	Main Leak	Connection Leak	Defective meter	Low Pressure	Leak-Night Time	Water Quality
Ekala	0.07	0.06	0.05	0.02	0.14	0.06	0.07
Ragama	0.28	0.32	0.34	0.40	0.12	0.31	0.29
JA Ela	0.11	0.09	0.08	0.04	0.21	0.09	0.10
Kadana	0.33	0.37	0.39	0.47	0.13	0.36	0.34
Uswetakeyawa	0.11	0.09	0.08	0.04	0.21	0.09	0.10
Ja Ela - upper	0.09	0.07	0.06	0.03	0.18	0.08	0.09

5.4.3.7 No water

Table 5-39 : Pairwise preferences converted to saaty scale- No water

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	2	1	2	2
Zone 2	1	1	7	3	7	8
Zone 3	1/2	1/7	1	1	3	3
Zone 4	1	1/3	1/1	1	8	9
Zone **5**	1/2	1/7	1/3	1/8	1	3
Zone 6	1/2	1/8	1/3	1/9	1/3	1

5.4.3.8 Main Leak

Table 5-40: Pairwise preferences converted to saaty scale- Main Leak

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	2	1	2	2
Zone 2	1	1	7	2	7	8
Zone 3	1/2	1/7	1	1	2	3
Zone 4	1	1/2	1/1	1	8	9
Zone **5**	1/2	1/7	1/2	1/8	1	3
Zone 6	1/2	1/8	1/3	1/9	1/3	1

5.4.3.9 Connection Leak

Table 5-41: Pairwise preferences converted to saaty scale- Connection Leak

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	2	1	2	2
Zone 2	1	1	7	2	7	8
Zone 3	1/2	1/7	1	1	2	2
Zone 4	1	1/2	1	1	8	9
Zone **5**	1/2	1/7	1/2	1/8	1	2
Zone 6	1/2	1/8	1/2	1/9	1/2	1

5.4.3.10 Defective meter

Table 5-42: Pairwise preferences converted to saaty scale- Defective Meters

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	1	1	1	1
Zone 2	1	1	7	1	7	8
Zone 3	1	1/7	1	1	1	2
Zone 4	1	1	1	1	8	9
Zone 5	1	1/7	1	1/8	1	2
Zone 6	1	1/8	1/2	1/9	1/2	1

5.4.3.11 Low Pressure

Table 5-43: Pairwise preferences converted to saaty scale- Low Pressure

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	6	2	5	2	3
Zone 2	1/6	1	1	3	1	2
Zone 3	1/2	1	1	9	5	6
Zone 4	1/5	1/3	1/9	1	2	3
Zone 5	1/2	1	1/5	1/2	1	6
Zone 6	1/3	1/2	1/6	1/3	1/6	1

5.4.3.12 Night Time Leak

Table 5-44: Pairwise preferences converted to saaty scale- Night Time Leak

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	2	1	2	2
Zone 2	1	1	7	2	7	8
Zone 3	1/2	1/7	1	1	2	3
Zone 4	1	1/2	1	1	8	9
Zone 5	1/2	1/7	1/2	1/8	1	3
Zone 6	1/2	1/8	1/3	1/9	1/3	1

5.4.3.13 Water Quality

Table 5-45: Pairwise preferences converted to saaty scale- Water Quality

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1	1	2	1	2	2
Zone 2	1	1	7	2	7	8
Zone 3	1/2	1/7	1	1	3	3
Zone 4	1	2/7	1	1	8	9
Zone 5	1/2	1/7	1/3	1/8	1	3
Zone 6	1/2	1/8	1/3	1/9	1/3	1

5.4.4.1 Ranking Alternatives

Calculated the eigen vectors as similar of main criteria to obtain the relative importance for income generation, system sustainability, system losses and system reliability.

Income Generation

New Connection	
Ekala	0.514
Ragama	0.176
JA Ela	0.077
Kadana	0.075
Uswetakeyawa	0.081
Ja Ela - upper	0.077

Bill Collection	
Ekala	0.312
Ragama	0.191
JA Ela	0.128
Kadana	0.214
Uswetakeyawa	0.130
Ja Ela - upper	0.026

System Sustainability

O&M Expenditure	
Ekala	0.181
Ragama	0.379
JA Ela	0.116
Kadana	0.224
Uswetakeyawa	0.060
Ja Ela - upper	0.040

Staff Salaries	
Ekala	0.181
Ragama	0.379
JA Ela	0.116
Kadana	0.225
Uswetakeyawa	0.060
Ja Ela - upper	0.040

System Losses

NRW	
Ekala	0.28
Ragama	0.29
JA Ela	0.25
Kadana	0.09
Uswetakeyawa	0.06
Ja Ela - upper	0.03

System Reliability

No water	
Z1	0.190
Z2	0.381
Z3	0.122
Z4	0.211
Z5	0.059
Z6	0.036

Main Leal	
Z1	0.181
Z2	0.378
Z3	0.116
Z4	0.225
Z5	0.060
Z6	0.040

Leak Connection	
Z1	0.176
Z2	0.376
Z3	0.113
Z4	0.232
Z5	0.060
Z6	0.042

Defective Meter	
Z1	0.160
Z2	0.362
Z3	0.106
Z4	0.257
Z5	0.063
Z6	0.052

Low Pressure	
Z1	0.353
Z2	0.130
Z3	0.284
Z4	0.073
Z5	0.112
Z6	0.046

Night Time Leak	
Z1	0.183
Z2	0.379
Z3	0.117
Z4	0.223
Z5	0.060
Z6	0.039

Water Quality	
Z1	0.187
Z 2	0.381
Z3	0.120
Z4	0.216
z5	0.059
Z6	0.037

5.5 Consistency check

The consistency ratio was checked for all the main parameters, sub parameter and alternatives.

$$\text{Consistency Ratio} = \frac{\text{Consistency Index (CI)}}{\text{Random Index (RI)}}$$

$$\text{Consistency Index (CI)} = \frac{\lambda max - 1}{N-1}$$ N= number of alternatives

According to AHP, consistency ration must be less than 0.1 to consist of the alternatives/parameters. If the CR of the matrix is high, it means that the input judgments are not consistent and hence are not reliable. If the value is higher than 0.10, the judgments are not reliable and have to be elicited again. If the maximum Eigen value, CI and CR are satisfactory, then a decision is taken on the basis of the normalized values; otherwise, the procedure is repeated until these values lie in a desired range.

5.5.1 Main Criteria

Consistency ratio for all four combinations were calculated and shown in Table 5-46.

Table 5-46 : Consistency Ratios – Main Criteria

Combination	Number of Alternatives (N)	Lambda(ƛmax)	Consistency Ratio	Status
Combination 1	4	4.076	0.028	Consistent
Combination 2	4	4.477	0.177	Inconsistent
Combination 3	4	4.160	0.059	Consistent
Combination 4	4	5.020	0.378	Inconsistent

5.5.2 Sub Criteria

Income Generation

Table 5-47 : Consistency Ratio for sub parameter

Number of Alternatives	Lambda	Consistency Ratio	Status
2	2	0	Consistent

System Sustainability

Table 5-48 : Consistency Ratio for sub parameters

Number of Alternatives	Lambda	Consistency Ratio	Status
2	2	0	Consistent

System Reliability

Table 5-49 : Consistency Ratios for sub parameters

Number of Alternatives	Lambda	Consistency Ratio	Status
7	7.7913683	0.099	Consistent

5.5.3 Alternatives

Table 5-50 : Consistency Ratios for Alternatives

Combination	Number of Alternatives	Lambda	Consistency ratio	Consistency
New Connection	6	6.452	0.071754	Consistent
Bill Collection	6	6.410	0.06	Consistent
O&M Expenditure	6	6.602	0.095591	Consistent
Staff Salaries	6	6.602	0.095591	Consistent

NRW Reduction	6	6.518	0.082354	Consistent
No water	6	6.606	0.096202	Consistent
Leak-Main Line	6	6.622	0.098781	Consistent
Leak – Connection	6	6.603	0.09437	Consistent
Defective meters	6	6.622	0.098749	Consistent
Low Pressure	6	6.615	0.097699	Consistent
Leak Night time	6	6.609	0.0967	Consistent
Water Quality	6	6.572	0.090851	Consistent

Model frame work was completed and show in figure according to the obtained relative importance for the main parameter, sub parameter and alternatives.

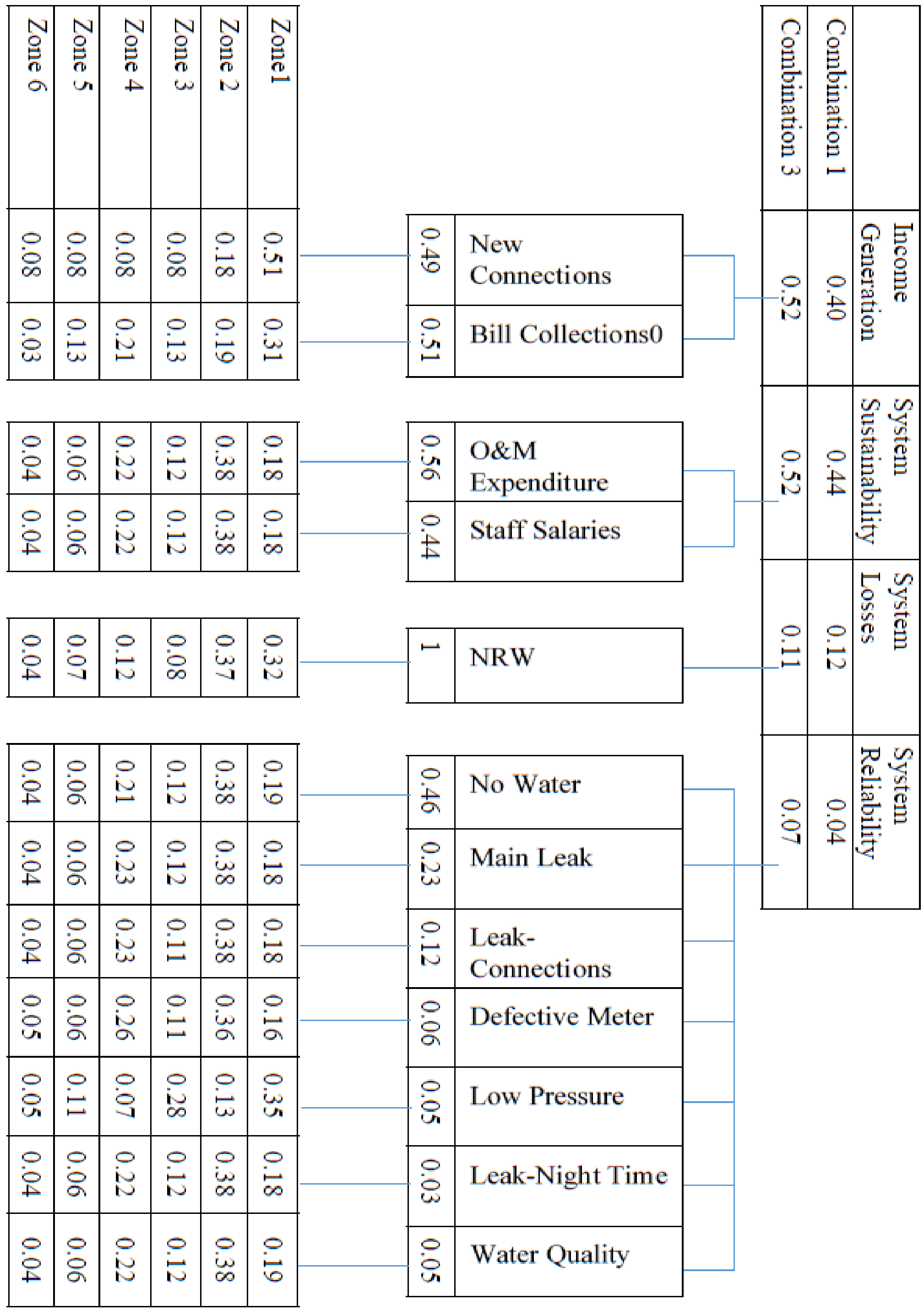

Figure 5.16 : Results for MCDA Model

Prioritized management zone was identified according to the MCDA model framework for both consisting combinations as follows. In this study consider combinations only for the main parameters due to the differences of input values obtain from stakeholder. Both combination illustrated the same ranking for the each zone and it shows the consistency of two combinations.

Table 5-51 : Prioritized zones for combination 1 and combination 3

	Combination 1	Combination 3	Rank
Zone 1	0.260	0.286	2
Zone 2	0.311	0.289	1
Zone 3	0.127	0.126	4
Zone 4	0.186	0.177	3
Zone 5	0.073	0.078	5
Zone 6	0.042	0.043	6

5.6 Model Calibration Results

Computation of weights corresponding to each management zone required the evaluation of combination of main criteria identified as consistent. The alternative weights for the two consistent combinations are in Table 5-52.Maximum difference between two combinations is 0.0255 and minimum is 0.0011.

Table 5-52: Difference between combination 1 and combination 3

	Combination 1	Combination 3	Difference	Rank
Zone 1	0.2600	0.2855	-0.0255	2
Zone 2	0.3110	0.2894	0.0216	1
Zone 3	0.1274	0.1263	0.0011	4
Zone 4	0.1864	0.1774	0.0090	3
Zone 5	0.0732	0.0782	-0.0050	5
Zone 6	0.0417	0.0429	-0.0012	6

5.7 Model Verification

The Prioritization obtained from combination 1 and combination 3 were same.But the weightage obtained for zone 1 and zone 2 in combination 3 was leading to same values. Difference between obtained values for zone 1 and zone 2 in combination 3 was 0.0049 and very low values lead to wrong interpretation in ranking. Hence Combination 1 is the most suitable for this study to evaluation.

The priority order of each zone was obtained according to the MCDA model. Field level priority order obtained from the Area Engineer (Ja Ela). Both priority orders value were presented in Table 5-53. Field preferences obtained only from the Area Engineer opinion.

Table 5-53: Model Prioritization vs Field Prioritization

Zone Name	MCDA Model	Field Level
Zone 1 - Ekala	2	2
Zone 2- Ragama	1	1
Zone 3 - JA Ela	4	3
Zone 4- Kadana	3	4
Zone 5- Uswetakeyawa	5	5
Zone 6 - Ja Ela -upper	6	6

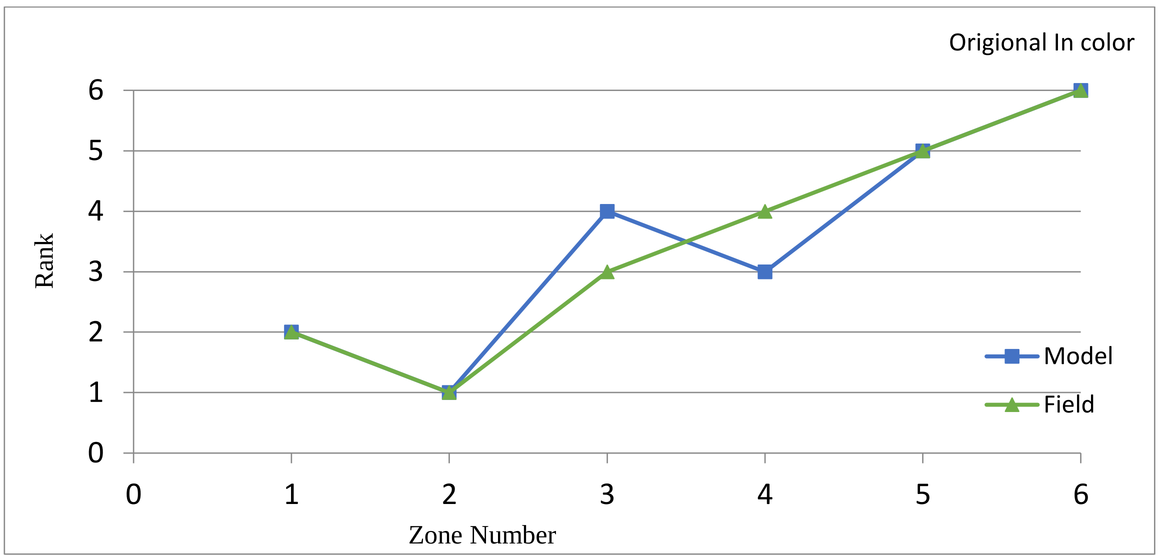

Figure 5.17 : Results –Model Prioritization vs Field Prioritization

6 DISCUSSION

6.1 MCDA model framework

When developing a Multicriteria model for the management of the water supply scheme, it has to identify the related criteria, sub criteria and alternatives. The organizations which manage water supply schemes must have a proper guideline of water supply management. It is much easier to identify the criteria/parameters, which are consider to achieve organizational objectives. Lack of guidelines is a critical factor to achieve the effectiveness of organizational objectives. Hence for the development of the MCDA model it was carried out discussion with expertise & literature survey to identify the criteria. Three combinations were selected and check for the consistency. A model was technically accepted model.

6.2 Stakeholder survey

This work only done in the NWSDB frame work considering higher and middle management people. And it required to obtain the view of other water supply scheme management expertise as stakeholder survey. In this study it is observed the disparity of summation of sub parameter values for each main parameter and main parameter values. Less experience in management of WSS may lead to this situation. It is better to provide implement programs of capacity building of stakeholders.

6.3 Data Checking

Two type of data were collected in this study as field data and stakeholder survey data.

Checking of all data was carried out in a systematic manner. Checks included investigated missing data, observed the patterns, screen for inequalities and incompatibilities. Also cumulative behaviors were observed to capture any unexpected or unacceptable data.

Graphical plots of base data showed there are no missing values inflow, consumption and billing data.

Checking the all data collected from stakeholders in management view in same order. Check the summation of the scores given to main parameter and sub parameters are equal to 100 and 1000. Few questionnaire forms of Sub parameters are corrected according the weights given in those forms.

6.4 Main Criteria

In this study, very low attention given for the system reliability in stakeholder data and it is deviate from the organizational objectives. Improve their management view on water supply scheme by the time with gain more experience in field and provide capacity building training for stakeholders. Model identify the values 0.4, 0.44, 0.12 .0.04 for main parameters respectively for the income generation system sustainability, system losses and system reliability.

6.5 Sub Criteria

In this study it is consider 12 parameters as sub parameter which was selected by majority of the sample. There were additional 29 sub parameters identified as sub parameters, but not included to the analysis. Compare the results with more identified sub parameters. But increasing of sub parameters leads more difficulties in the analysis.

Comparing the scores given for the sub parameters by stakeholders, it was identified break values for the each sub criteria. Stakeholder's experience & working section lead to this variation. .Identified sub parameters of main criteria are New connection, Bill collection, O&M Expenditure ,Staff salaries, NRW, No water, Leak main, Leak Connection, Defective meters, Low pressure , Leak night time ,Water Quality obtain respective parameters as 0.49, 0.51, 0.56, 0.44, 1, 0.46, 0.23 ,0.12, 0.06, 0.05, 0.03, 0.05 respectively.

6.6 Alternatives

Several assumptions were made in this study for obtaining details for each alternative in the field. If there any proper guidelines available for the management of water supply scheme, the managers easily go through the guideline and collect the specific data from the field. Then it can develop the model with corrected data without assumptions.

6.7 Verification of model

The consistency of the judgment can be determined by calculating the consistency ratio. Consistency check carried out for main criteria, sub criteria and alternatives. If the consistency ratio of the matrix is high, it means that the input judgments are not consistent and hence are not reliable.

Two combinations of main criteria obtained more than 0.1 for the consistency ratio. Combination 1 & combination 3 not considered for further evaluation because the input judgments are not consistent. Table 6-1 also clearly demonstrates that all consistent combinations were leading to almost the same result.

Table 6-1 Comparison of Consistent Weight Combination1 & 3

	Combination 1	Combination 3	Difference
Zone 1	0.2600	0.2855	-0.0255
Zone 2	0.3110	0.2894	0.0216
Zone 3	0.1274	0.1263	0.0011
Zone 4	0.1864	0.1777	0.0090
Zone 5	0.0732	0.0782	-0.0050
Zone 6	0.0417	0.0429	-0.0012
Maximum Error			0.0255
Minimum Error			0.0011

Alternatives and sub criteria obtained less than 0.1 for the consisting ratio and consider the input values are reliable. MCDA model output calculates according to the consistent value and model should be consistent.

For the verification of the model considered only Area Engineer's priority condition of Alternatives. There is no guideline for the management of water supply scheme and hence management of WSS is depend on the Area Engineer. The accuracy of the model will be changed according to Area Engineer‘s opinion. To overcome this situation, obtain the zone officers view of the system and verify the Area Engineer's priority order. Zone 1, Zone 2, Zone 5 and Zone 6 results were same for MCDA model and field level. Zone 3 and Zone 4 prioritization results are slightly different from the model and field level analysis.

Table 6-2 Model Prioritization and Field Prioritization

Zone Name	MCDA Model	Field Level
Zone 1	2	2
Zone 2	1	1
Zone 3	4	3
Zone 4	3	4
Zone 5	5	5
Zone 6	6	6

In this study a linear behavioral approximation was considered as sufficient. It must be noted that this may require strengthening. Hence it is important to develop system management guidelines and then conduct direct pairwise comparison assessments by using employees conversant with multi criteria modeling.

The non-uniformity in weight conversions, the gaps in criteria determination, field level constraints for obtaining verification data would have led to the mismatch of MCDA model output and the actual situation.

6.8 MCDA models for Water Supply

This study shows the success of applying a MCDA model for the management of the water supply scheme. It shows improvements needed to the organizations and employers. It is necessary to provide a clear path to transform organizational objectives to the field level and achieve objectives.

It is necessary to carry out similar types of studies and compare the identification of criteria, sub criteria and quantifications. Considering the weightage for stakeholder data according to their experience will be lead to more accurate results. For whole analysis, it is assumed the conversion of pairwise comparison to saaty scales is linear behavior between the maximum and minimum values.

6.9 Results

Different types of organizational objectives in water supply institutions were identified in the literature review considering the different countries in the world. Most of the organizational objectives are usually quite similar. All the water supply institutions are mainly focus to accessibility safe water to all. Most of the countries indicated the affordability is a main consideration of organizational objectives due to water supply system managed by private sector. In country like Sri Lanka it is not considering the affordability because of water supply institutions are controlled by the government.

Identification of management parameters of WSS is very important to sustainability of the water supply scheme. Four main parameters identified according to the literature survey, preliminary investigation and stakeholder survey which is not mutually exclusive. And also obtained associated twelve sub parameters for identified main parameters.

MCDA frame work developed and converts it in to the study area according to the identified main parameters, sub parameters and alternatives. Model weights and consistency ratio of model obtained to check the consistency of the model. Preferences obtained from the model which represent the management of the institution and evaluate with the field results (Table 6.2). Identified management prioritization and field prioritization for Ja Ela area were slightly varied.

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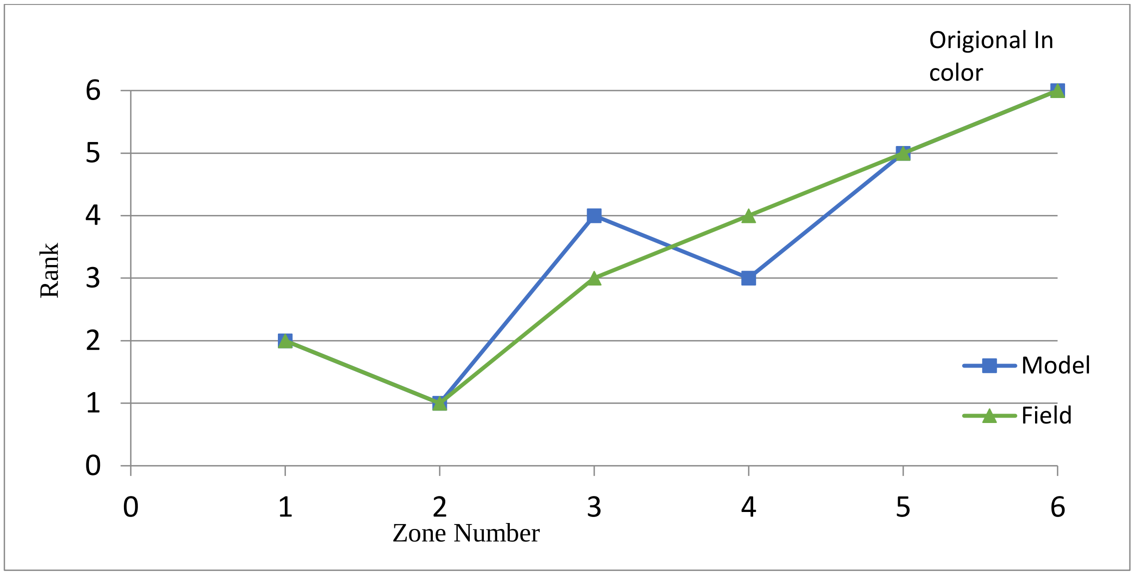

Figure 6-1: Model Prioritization and Field Prioritization

The non-uniformity in weight conversions, the gaps in criteria determination, field level constraints for obtaining verification data would have led to the mismatch of MCDA model output and the actual situation.

According to this model frame work it can be evaluate the effectiveness of the water supply scheme incorporating the alternative values for the model for each water supply scheme. Hence it is important to develop system management guidelines and then conduct direct pairwise comparison assessments by using employees conversant with multi criteria modeling.

7 CONCLUSION

1. A multicriteria decision model with AHP can be used to identify the management parameters, priorities of the parameters in water supply schemes and evaluate the effectiveness of the schemes.

2. Four main parameters for the management of water supply schemes were identified as income generation, system sustainability, system losses, system reliability and obtained model values 0.4, 0.44, 0.12 .0.04 respectively.

3. Twelve sub parameters for the management of water supply schemes were identified according to the main parameters. Obtained higher prioritization value as 0.51, 0.56, and 0.46 for income generation, staff salaries and no water in each main parameter.

4. Model values for sub parameters of system reliability were varied from 0.46 to 0.03. Relatively high attention given for the no water while given the lowest for water quality.

5. The priority of the MCDA model closely matched the area engineer's prioritization exhibiting the satisfactory level of model verification. According to the variation of these two prioritizations, evaluate the effectiveness of the organizational objectives.

8 RECOMMENDATIONS

1. Recommend to do the same work after time and check the variation of the stakeholder survey data.
2. Carryout for another water supply scheme in a similar manner by considering current issues.
3. Considering the weight for each stakeholder's marks for Main and sub parameters and redo a similar study for Ja Ela.

4. Build up a proper guideline/ link to the management of field level and management of the organization.

9 REFERENCES

Affairs, A., Development, N., & Aandc, C. (2014). *Maintenance Management Plan for Drinking Water and Wastewater Systems in First Nations Communities*.

Alegre, H., Baptista, J. M., Cabrera, E., Cubillo, F., Duarte, P., Hirner, W., … Parena, R. (2016). Performance Indicators for Water Supply Services: Third Edition. In *Water Intelligence Online* (Vol. 15). https://doi.org/10.2166/9781780406336

American Water Works Association. (2007). *Water Utility Management*.USA

Department of National Planning. (2017), *Public Investment Programme*, Ministry of National Policies and Economic Affairs.

Imbulana, K. A. U. S., Wljesekara, N. T. S., & Neupane, B. R. (2006), Case study : Sri Lanka Sri Lanka National Water Development Report. *UN-Water,* 1–221.

Kumari, T.K.N.K.(2014).*multicriteria decision modeling for management of water supply system in the piliyandala-kesbewa water supply scheme,Colombo district* (master'sthesis). Available from UOM

Laser, R. D., & GmbH, A. (2012), Operation and Maintenance Manual, NarrowDiode. (May), 2006.

Lee, H., & Kong, M. (2017), Analysis on level of service for asset management in water supply network, International Journal of Applied Engineering Research, 12(20), 9890–9895.

National Water Supply & Drainage Board, (2006), *National Drinking Water Policy*, Part A 1. 1–11.

Nogueira Vilanova, M. R., Filho, P. M., & Perrella Balestieri, J. A. (2014), Performance measurement and indicators for water supply management: Review and international cases. Renewable and Sustainable Energy Reviews, 43, 1–12. https://doi.org/10.1016/j.rser.2014.11.043.

NWSDB-3 (2013). *Annual Report.* National Water Supply & Drainage Board, Sri Lanka.

NWSDB-2 (2014). *Management Information Report.* National Water Supply & Drainage Board, Sri Lanka

Okeola, O. G., & Sule, B. F. (2012). Evaluation of management alternatives for urban water supply system using Multicriteria Decision Analysis. *Journal of King Saud University - Engineering Sciences*, *24*(1), 19–24. https://doi.org/10.1016/j.jksues.2011.07.004

Saaty,T.L. (1994), How to make a decision: the analytical hierarchy process. *Interfaces,* Vol. 24(6), 19-43.

USAID. (2017). *U.S. Government Global Water Strategy*. 70. Retrieved from https://www.usaid.gov/sites/default/files/documents/1865/Global_Water_Strategy_2017_final_508v2.pdf.

World Health Organization. (1999) .*The manual of operation of water supply system*.India

APPENDIX B- STAKEHOLDER SURVEY

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Table B.2 –Preliminary Investigation –OIC View
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Appendix B.1.2 - Questionnaire – To refine
Appendix B.1.3 - Questionnaire – To refine
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Appendix B.2.3 - Questionnaire – To Distribute
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Table B.8.5 - Comparison of Main Criteria and Relative Summation of Sub Criteria
Table B.8.6 - Comparison of Main Criteria and Relative Summation of Sub Criteria

Table B.1 –Preliminary Investigation –OIC View

OIC Office	Horana	Panadura	Gampaha	kotte	homagama	Wattala
No of Connection	13304	42000	4630	51000	21000	34000
Meter Readers	05	10	02	20	Maharagama	12
Zone Officers	02	05	01	06	3	5
Supportive Team	01	05	01	06	3	5
Avg. Complain per day	04	20	8(depends)	17	25	20
Complain methods	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit
Average NRW %	20	15-20	20-22	17	23	17
Water Quality	3	8	8	7	4	8
Main Leak	1	1	1	2	1	1
New Connection	4	5	5	5	6	5
Bill Connection	4	5	5	6	AE Office	9
No water	7	1	1	1	3	1
Reduction NRW	6	7	7	9	7	7
Leak – Connection	2	3	1	3	2	1
Defective meters	9	8	9	8	AE office	6
O&M Expenditure	10	10	10	10	8	11
Low Pressure	7	3	1	4	5	1
Staff Salaries	10	10	10	11	9	10
Others Priority Areas	Night Leak Hospital	Forces/ Police	Hospital	Depend On the Situation	Meter Shifting	

Table B.2 –Preliminary Investigation –OIC View

	Kaluthara	beruwala	Mattakkuliya	Thibirigasyaya	Negambo	mahara
No of Connection	18210	12500	26000	14790	36500	42000
Meter Readers	7	5	9	8	15	15
Zone Officers	2	2	3	3	5	5
Supportive Team	2	2	3	3	5	5
Avg. Complain per day	15	20	20	30	15	30
Complain methods	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit	1919/Direct Col Office visit
Avg.NRW %	15	45* Leak -sump	50	40-42	-	17
Water Quality	3	9	7	8	10	5
Main Leak	1	1	1	1	1	1
New Connection	Contract	Contract	5	5	Contract	Contract
Bill Connection	6	6	6	5	5	6
No water	4	3	3	1	1	1
Reduction NRW	10	7	11	11	9	8
Leak – Connection	1	1	1	1	1	1
Defective meters	7	5	8	7	6	7
O&M Expenditure	9	8	9	9	8	10
Low Pressure	4	4	4	1	1	1
Staff Salaries	8	10	10	9	7	9
Other …	Meter Shifting		Night Leak			
Priority Areas	School /Hospital	Forces/Police/	School /Hospital	School /Hospital	School /Hospital	School /Hospital

Appendix B.1.2 Questionnaire – To refine

Master Degree Research 2018/2019 - University of Moratuwa Sri Lanka

T.A.A.I.Jayaranga, Senior Engineer, Planning & Design Section,
NWSDB Head Office, Ratmalana, Sri Lanka

Dear Sir/Madam,

I am currently reading for a master degree research on Evaluation of the Effectiveness of Organizational Objectives and Implementation for sustainable drinking water supply system using a multicriteria decision model. In this Questionnaire I am expect main parameters which are considering the management of water supply scheme

………………….

T.A.A.I.Jayaranga

Identification Main parameters

A preliminary study revealed that in a situation where the water supply input, the pipe network, storage, staff and transport are in place and they remain at a near constant stage, Please observe the main parameter which consider management of water supply scheme and **comment on any other additional consideration** that requires to be included in the list as the view of system manager.

	Main Parameter		**Sub Parameter**
1	Income Generation	1	New Connection
		2	Bill Collection
		3.	Other (Please Specify) ……………..
2	Sustainability	1.	O&M Expenditure
		2.	Staff Salaries
		3.	Other (Please Specify) ……………..
3	System Losses	1.	NRW Reduction
		2.	Other (Please Specify) ……………..
4	User Satisfaction/Problem Solving (Reliability)	1.	No water
		2.	Leak-Main Line
		3.	Leak – Connection
		4.	Low Pressure
		5.	Water Quality
		6.	Other (Please Specify) ……………..

Stage 2. Prioritization of sub parameters

Stage two is prioritized the sub parameters to ease of capturing relative importance and it is completed by Without considering main parameters as view of system manager. Any comment on any other additional consideration that requires to be included in the list. Sub parameters are to be ranked in a scale of 1000 in total.

Score for Each sub parameter without considering main parameter.

	Sub Parameter	**Score /1000**	**Remarks**
1	New Connection		
2	Bill Collection		
3	O&M Expenditure		
4	Staff Salaries		
5	NRW Reduction		
6	Low Pressure		
7	No water		
8	Water Quality		
9	Leak- Main line		
10	Leak – Connection		
11.	Other (Please Specify) ……………..		
12.	Other (Please Specify) ……………..		
13	Other (Please Specify) ……………..		
14.	Other (Please Specify) ……………..		
15.	Other (Please Specify) ……………..		
16.	Other (Please Specify) ……………..		
17.	Other (Please Specify) ……………..		
Total		**1000**	

Stage 3. Prioritization of Main parameters

Stage three is prioritized the main parameters as view of system manager. Any comment on any other additional consideration that requires to be included in the list. The main parameter weights are expected as a percentage.

	Main Parameter	Weight (%)
1.	Income Generation	
2.	Sustainability	
3.	System Losses	
4.	User Satisfaction/Problem Solving (Reliability)	
Total		**100**

Comment (If any)
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Name Of respondent: ……………………………………………
Designation : ………………………………………………………..
Division:……………………………………………………………….
Date:………………………………………………………

Appendix B.2.1 Questionnaire – To Disribute

Master Degree Research 2018/2019 - University of Moratuwa Sri Lanka

T.A.A.I.Jayaranga, Senior Engineer, Planning & Design Section,
NWSDB Head Office, Ratmalana, Sri Lanka

Dear Sir/Madam,

I am currently reading for a master degree research on Evaluation of the Effectiveness of Organizational Objectives and Implementation for sustainable drinking water supply system using a multicriteria decision model. In this Questionnaire I am expect main parameters which are considering the management of water supply scheme

………………….
T.A.A.I.Jayaranga

Identification Main parameters

A preliminary study revealed that in a situation where the water supply input, the pipe network, storage, staff and transport are in place and they remain at a near constant stage, Please observe the main parameter which consider management of water supply scheme and **comment on any other additional consideration** that requires to be included in the list as the view of system manager.

	Main Parameter		**Sub Parameter**
1	Income Generation	1	New Connection
		2	Bill Collection
		3.	Other (Please Specify) ……………..
2	Sustainability	1.	O&M Expenditure
		2.	Staff Salaries
		3.	Other (Please Specify) ……………..
3	System Losses	1.	NRW Reduction
		2.	Other (Please Specify) ……………..
4	User Satisfaction/Problem Solving (Reliability)	1.	No water
		2.	Leak-Main Line
		3.	Leak – Connection
		4.	Defective meters
		5.	Low Pressure
		6.	Leak Night time
		7.	Water Quality
		8.	Other (Please Specify) ……………..

Stage 2. Prioritization of sub parameters

Stage two is prioritized the sub parameters to ease of capturing relative importance and it is completed by Without considering main parameters as view of system manager. Any comment on any other additional consideration that requires to be included in the list. Sub parameters are to be ranked in a scale of 1000 in total.

Score for Each sub parameter without considering main parameter.

	Sub Parameter	**Score /1000**	**Remarks**
1	New Connection		
2	Bill Collection		
3	O&M Expenditure		
4	Staff Salaries		
5	NRW Reduction		
6	Low Pressure		
7	No water		
8	Water Quality		
9	Defective meters		
10	Leak- Main line		
11	Leak – Connection		
12	Leak Night time		
13.	Other (Please Specify) ……………..		
14.	Other (Please Specify) ……………..		
15.	Other (Please Specify) ……………..		
16.	Other (Please Specify) ……………..		
17.	Other (Please Specify) ……………..		
18.	Other (Please Specify) ……………..		
19.	Other (Please Specify) ……………..		
Total		**1000**	

Stage 3. Prioritization of Main parameters

Stage three is prioritized the main parameters as view of system manager. Any comment on any other additional consideration that requires to be included in the list. The main parameter weights are expected as a percentage.

	Main Parameter	Weight (%)
1.	Income Generation	
2.	Sustainability	
3.	System Losses	
4.	User Satisfaction/Problem Solving (Reliability)	
	Total	**100**

Comment (If any)
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Name Of respondent: ……………………………………………
Designation : …………………………………………………………..
Division:……………………………………………………………….
Date:…………………………………………

Table **B.**8.5- Additional Sub parameters from Survey

Income Generation	**System Sustainability**	**System Losses**	**System Reliability**
Illegal connection	Transport for staff	Plant loss	Complain management
disconnection	Training for staff	O&M activities	Replacement of pipes
meter shifting	Laboratory testing	Pump/plant failure	Leak near meter
Water Clearance	Energy consumption	Internal leak	Regular/preventive maintenance
Name Change	Catchment protection/WSP	Number of break down	Attend complains effectively
GW management	Improvement of IT	Air Releasing	Less demand
Estimated bills	Inventory losses		
category change	Over head		
defect in bulk meter			

Table B.5.1- Stakeholder Responses- Main Parameter

Main Parameter	Form (1 – 15)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Income Generation	17.5	30	30	15	30	20	35	25	25	15	25	30	18	30	30
Sustainability	17.5	30	30	20	20	15	20	20	12.5	20	22.5	20	18	20	15
System Lassoes	25	20	20	35	20	15	20	13	12.5	25	7	20	10	20	5
User Satisfaction	40	20	20	30	30	50	25	43	50	40	45.5	30	54	30	50

Table B.5.2-Stakeholder Responses- Main Parameter

Main Parameter	Form (16 – 30)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Income Generation	51.5	25	31	35	35	40	30	60	20	20	51.5	25	31	35	35
Sustainability	20	25	29	25	30	20	25	10	40	20	20	25	29	25	30
System Lassoes	7.5	25	8	20	20	10	15	10	20	10	7.5	25	8	20	20
User Satisfaction	21	25	32	20	15	30	30	20	20	50	21	25	32	20	15

Table B.5.3 - Stakeholder Responses- Main Parameter

Main Parameter	Form (31 – 45)														
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Income Generation	30	20	32.5	25	14	20	30	60	35	25	20	30	30	20	50
Sustainability	10	10	15.5	20	20	15	20	20	25	25	30	20	20	20	20
System Lassoes	10	30	8.5	15	38	40	20	10	10	40	40	30	25	30	10
User Satisfaction	50	40	43.5	40	28	25	30	10	30	10	10	20	25	30	20

Table B.5.4 - Stakeholder Responses- Main Parameter

Main Parameter	Form (46 – 60)														
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Income Generation	23	35	18	20	30	25	30	30	25	20	15	25	50	40	50
Sustainability	22	15	11	20	30	30	20	10	35	25	25	25	10	10	25
System Lassoes	25	15	6	10	20	20	20	10	15	30	30	25	25	10	15
User Satisfaction	30	35	65	50	20	25	30	50	25	25	30	25	15	40	15

Table B.5.5 - Stakeholder Responses- Main Parameter

Main Parameter	Form (61 – 75)														
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Income Generation	25	50	15	50	20	20	30	20	30	15	18	20	25	15	45
Sustainability	25	30	20	25	20	20	20	25	40	20	13	20	20	35	10
System Lassoes	10	10	50	12.5	10	20	30	25	15	50	10	20	35	35	25
User Satisfaction	40	10	15	12.5	50	40	20	30	15	15	59	40	20	15	20

Table B.5.6- Stakeholder Responses- Main Parameter

Main Parameter	Form (76 – 88)														
	76	77	78	79	80	81	82	83	84	85	86	87	88	81	82
Income Generation	35	20	25	35	15	25	40	25	30	25	15	25	30	25	40
Sustainability	25	20	25	20	25	20	20	25	20	25	15	25	20	20	20
System Lassoes	25	20	25	15	35	25	20	20	20	20	20	25	20	25	20
User Satisfaction	15	40	25	30	25	30	20	30	30	30	50	25	30	30	20

Table B.6.1 - Corrected Stakeholder Responses - Sub Parameters

Form Number (1-15)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	New Connection	90	124	122	118	162	100	150	125	79	100	56	111	90	114	100
2	Bill Collection	90	211	183	88	216	100	200	125	158	25	226	167	90	229	200
3	O&M Expenditure	90	155	122	88	108	75	75	100	79	50	141	178	90	86	50
4	Staff Salaries	90	93	91	59	108	75	75	100	53	25	85	89	90	86	100
5	NRW Reduction	150	186	183	176	108	150	100	125	105	75	45	133	100	171	50
6	No water	50	25	49	59	54	75	50	25	211	250	56	56	55	57	75
7	Leak-Main Line	50	50	37	88	27	75	50	125	53	100	56	33	90	57	50
8	Leak – Connection	50	62	37	88	54	50	50	25	26	50	45	22	80	57	75
9	Defective meters	50	25	37	59	27	75	50	80	26	100	85	22	90	29	75
10	Low Pressure	50	25	49	59	54	50	50	25	53	75	85	22	50	57	50
11	Leak Night time	50	25	30	88	54	75	50	20	53	75	34	56	75	29	75
12	Water Quality	190	19	61	29	27	100	100	125	105	75	85	111	100	29	100
		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table B.6.1 - Corrected Stakeholder Responses - Sub Parameters

		Form Number (16-30)														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	New Connection	84	117	100	50	110	313	100	106	124	100	150	50	300	25	90
2	Bill Collection	140	234	70	50	100	208	100	222	198	100	100	70	100	25	180
3	O&M Expenditure	56	94	50	50	70	104	50	69	79	75	30	150	100	50	56
4	Staff Salaries	84	82	50	50	70	104	50	74	79	75	30	80	50	150	56
5	NRW Reduction	56	205	100	300	150	52	200	85	198	150	100	70	100	200	112
6	No water	281	58	100	75	65	78	50	42	40	75	100	100	50	200	56
7	Leak-Main Line	17	58	100	75	70	10	50	63	50	75	200	60	40	90	79
8	Leak – Connection	6	58	50	75	55	26	50	42	25	50	20	50	40	50	22
9	Defective meters	6	29	100	50	55	26	100	37	35	75	20	50	40	10	56
10	Low Pressure	28	35	100	75	60	26	100	169	99	50	40	200	40	100	34
11	Leak Night time	17	6	100	50	75	26	50	37	35	75	10	20	40		34
12	Water Quality	225	23	80	100	120	26	100	53	40	100	200	100	100	100	225
		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table B.6.3 - Corrected Stakeholder Responses - Sub Parameters

		Form Number (31-45)														
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	New Connection	196	107	111	100	72	50	150	52	152	103	50	56	100	100	95
2	Bill Collection	76	83	99	100	86	50	50	258	273	103	100	56	100	100	95
3	O&M Expenditure	61	65	99	75	75	100	125	103	91	26	125	56	75	75	95
4	Staff Salaries	71	77	82	75	81	50	75	21	121	26	100	56	75	75	63
5	NRW Reduction	132	142	99	100	84	100	100	52	152	206	100	83	150	150	95
6	No water	51	59	82	25	95	200	100	52	30	10	75	111	75	75	63
7	Leak-Main Line	112	130	82	75	92	100	50	103	30	206	50	111	50	50	95
8	Leak – Connection	102	118	70	100	90	50	50	52	30	206	50	83	50	50	95
9	Defective meters	31	36	58	75	75	50	50	0	30	10	75	111	100	100	79
10	Low Pressure	51	59	70	75	83	50	100	52	30	26	100	83	50	50	63
11	Leak Night time	71	71	76	100	88	100	50	52	30	26	100	83	75	75	95
12	Water Quality	46	53	70	100	79	100	100	206	30	52	75	111	100	100	63
		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table B.6.4 - Corrected Stakeholder Responses - Sub Parameters

		Form Number (46-60)														
		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	New Connection	80	90	80	10	86	200	178	50	188	80	41	76	43	57	100
2	Bill Collection	80	112	100	99	95	150	162	50	125	80	41	76	43	57	100
3	O&M Expenditure	80	56	60	99	95	100	151	50	125	90	62	76	43	57	50
4	Staff Salaries	80	56	50	10	95	100	108	10	63	80	62	76	43	57	50
5	NRW Reduction	80	79	60	99	86	150	135	30	188	80	256	136	106	200	100
6	No water	80	112	200	495	86	50	54	400	13	100	103	136	106	114	125
7	Leak-Main Line	100	90	100	10	86	50	22	200	125	80	77	65	106	57	50
8	Leak – Connection	70	90	70	5	48	25	22	50	13	70	77	65	106	57	50
9	Defective meters	80	56	50	10	86	50	11	50	13	80	51	65	53	57	25
10	Low Pressure	60	90	100	10	86	50	22	30	13	80	77	65	106	57	50
11	Leak Night time	80	56	70	5	67	25	38	50	13	60	51	65	32	57	25
12	Water Quality	130	112	60	149	86	50	97	30	125	120	103	98	213	171	275
		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table B.6.5 - Corrected Stakeholder Responses - Sub Parameters

		Form Number (61-75)														
		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
1	New Connection	178	150	100	59	200	125	171	70	125	75	100	100	103	50	125
2	Bill Collection	178	150	200	59	200	102	114	70	125	50	80	100	103	100	125
3	O&M Expenditure	198	200	160	176	200	159	57	125	200	140	60	100	154	100	125
4	Staff Salaries	127	70	55	59	50	80	57	100	50	80	70	50	103	100	75
5	NRW Reduction	132	60	150	235	100	227	57	100	100	150	100	50	77	150	75
6	No water	51	60	60	82	25	45	114	100	50	80	70	100	51	100	75
7	Leak-Main Line	51	70	100	82	25	45	57	100	50	100	100	100	51	50	75
8	Leak – Connection	25	80	100	82	100	80	86	90	100	150	70	50	51	50	75
9	Defective meters	15	60	30	59	25	11	114	100	50	50	80	100	51	50	75
10	Low Pressure	15	60	15	35	25	34	29	60	50	50	80	50	51	100	75
11	Leak Night time	15	20	15	35	25	34	114	60	50	50	90	100	51	0	25
12	Water Quality	15	20	15	35	25	57	29	25	50	25	100	100	154	150	75
		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table B.6.6 - Corrected Stakeholder Responses - Sub Parameters

	Form Number (75-88)													
		76	77	78	79	80	81	82	83	84	85	86	87	88
1	New Connection	100	80	75	148	60	75	167	50	194	91	75	80	146
2	Bill Collection	120	80	100	148	60	75	167	50	167	91	75	80	104
3	O&M Expenditure	150	80	50	89	100	125	83	50	111	61	75	80	63
4	Staff Salaries	100	80	50	89	60	125	83	50	111	61	75	80	63
5	NRW Reduction	150	55	200	49	149	200	111	200	222	61	100	80	52
6	No water	60	100	75	118	75	50	56	100	28	91	80	80	156
7	Leak-Main Line	60	100	75	118	75	50	56	100	28	91	80	80	52
8	Leak – Connection	60	100	75	74	75	50	56	100	28	91	80	80	52
9	Defective meters	20	75	50	10	75	50	56	25	28	91	40	80	52
10	Low Pressure	60	100	100	49	100	50	56	100	28	91	80	80	52
11	Leak Night time	20	50	50	10	75	50	56	25	28	91	40	80	52
12	Water Quality	100	100	100	99	100	100	56	150	28	91	200	120	156
		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table B.7.1 - Aggregated Sub Criteria Responses Corresponding to each Main Criteria

	Form Number (1-15)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Income Generation															
New Connection	90	124	122	118	162	100	150	125	79	100	56	111	90	114	100
Bill Collection	90	211	183	88	216	100	200	125	158	25	226	167	90	229	200
Sub Total	**180**	**335**	**305**	**206**	**378**	**200**	**350**	**250**	**237**	**125**	**282**	**278**	**180**	**343**	**300**
Sub Total %	**18**	**34**	**30**	**21**	**38**	**20**	**35**	**25**	**24**	**13**	**28**	**28**	**18**	**34**	**30**
Sustainability															
O&M Expenditure	90	155	122	88	108	75	75	100	79	50	141	178	90	86	50
Staff Salaries	90	93	91	59	108	75	75	100	53	25	85	89	90	86	100
Sub Total	**180**	**248**	**213**	**147**	**216**	**150**	**150**	**200**	**132**	**75**	**226**	**267**	**180**	**171**	**150**
Sub Total %	**18**	**25**	**21**	**15**	**22**	**15**	**15**	**20**	**13**	**8**	**23**	**27**	**18**	**17**	**15**
System Losses															
NRW Reduction	150	186	183	176	108	150	100	125	105	75	45	133	100	171	50
Sub Total	150	186	183	176	108	150	100	125	105	75	45	133	100	171	50
Sub Total %	**15**	**19**	**18**	**18**	**11**	**15**	**10**	**13**	**11**	**8**	**5**	**13**	**10**	**17**	**5**
System Reliability															
No water	50	25	49	59	54	75	50	25	211	250	56	56	55	57	75
Leak-Main Line	50	50	37	88	27	75	50	125	53	100	56	33	90	57	50
Leak – Connection	50	62	37	88	54	50	50	25	26	50	45	22	80	57	75
Defective meters	50	25	37	59	27	75	50	80	26	100	85	22	90	29	75
Low Pressure	50	25	49	59	54	50	50	25	53	75	85	22	50	57	50
Leak Night time	50	25	30	88	54	75	50	20	53	75	34	56	75	29	75
Water Quality	190	19	61	29	27	100	100	125	105	75	85	111	100	29	100
Sub Total	**490**	**230**	**299**	**471**	**297**	**500**	**400**	**425**	**526**	**725**	**446**	**322**	**540**	**314**	**500**
Sub Total %	**49**	**23**	**30**	**47**	**30**	**50**	**40**	**43**	**53**	**73**	**45**	**32**	**54**	**31**	**50**

Table B.7..2 - Aggregated Sub Criteria Responses Corresponding to each Main Criteria

	Form Number (15-30)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Income Generation															
New Connection	84	117	100	50	110	313	100	106	124	100	150	50	300	25	90
Bill Collection	140	234	70	50	100	208	100	222	198	100	100	70	100	25	180
Sub Total	**225**	**351**	**170**	**100**	**210**	**521**	**200**	**328**	**322**	**200**	**250**	**120**	**400**	**50**	**270**
Sub Total %	**22**	**35**	**17**	**10**	**21**	**52**	**20**	**33**	**32**	**20**	**25**	**12**	**40**	**5**	**27**
Sustainability															
O&M Expenditure	56	94	50	50	70	104	50	69	79	75	30	150	100	50	56
Staff Salaries	84	82	50	50	70	104	50	74	79	75	30	80	50	150	56
Sub Total	**140**	**175**	**100**	**100**	**140**	**208**	**100**	**143**	**158**	**150**	**60**	**230**	**150**	**200**	**112**
Sub Total %	**14**	**18**	**10**	**10**	**14**	**21**	**10**	**14**	**16**	**15**	**6**	**23**	**15**	**20**	**11**
System Losses															
NRW Reduction	56	205	100	300	150	52	200	85	198	150	100	70	100	200	112
Sub Total	**56**	**205**	**100**	**300**	**150**	**52**	**200**	**85**	**198**	**150**	**100**	**70**	**100**	**200**	**112**
Sub Total %	**6**	**20**	**10**	**30**	**15**	**5**	**20**	**8**	**20**	**15**	**10**	**7**	**10**	**20**	**11**
System Reliability															
No water	281	58	100	75	65	78	50	42	40	75	100	100	50	200	56
Leak-Main Line	17	58	100	75	70	10	50	63	50	75	200	60	40	90	79
Leak – Connection	6	58	50	75	55	26	50	42	25	50	20	50	40	50	22
Defective meters	6	29	100	50	55	26	100	37	35	75	20	50	40	10	56
Low Pressure	28	35	100	75	60	26	100	169	99	50	40	200	40	100	34
Leak Night time	17	6	100	50	75	26	50	37	35	75	10	20	40	0	34
Water Quality	225	23	80	100	120	26	100	53	40	100	200	100	100	100	225
Sub Total	**579**	**269**	**630**	**500**	**500**	**219**	**500**	**444**	**322**	**500**	**590**	**580**	**350**	**550**	**506**
Sub Total %	**58**	**27**	**63**	**50**	**50**	**22**	**50**	**44**	**32**	**50**	**59**	**58**	**35**	**55**	**51**

Table B.7.3 - Aggregated Sub Criteria Responses Corresponding to each Main Criteria

	Form Number (31-45)														
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Income Generation															
New Connection	196	107	111	100	72	50	150	52	152	103	50	56	100	100	95
Bill Collection	76	83	99	100	86	50	50	258	273	103	100	56	100	100	95
Sub Total	**272**	**189**	**211**	**200**	**158**	**100**	**200**	**309**	**424**	**206**	**150**	**111**	**200**	**200**	**190**
Sub Total %	**27**	**19**	**21**	**20**	**16**	**10**	**20**	**31**	**42**	**21**	**15**	**11**	**20**	**20**	**19**
Sustainability															
O&M Expenditure	61	65	99	75	75	100	125	103	91	26	125	56	75	75	95
Staff Salaries	71	77	82	75	81	50	75	21	121	26	100	56	75	75	63
Sub Total	**132**	**142**	**181**	**150**	**156**	**150**	**200**	**124**	**212**	**52**	**225**	**111**	**150**	**150**	**159**
Sub Total %	**13**	**14**	**18**	**15**	**16**	**15**	**20**	**12**	**21**	**5**	**23**	**11**	**15**	**15**	**16**
System Losses															
NRW Reduction	132	142	99	100	84	100	100	52	152	206	100	83	150	150	95
Sub Total	**132**	**142**	**99**	**100**	**84**	**100**	**100**	**52**	**152**	**206**	**100**	**83**	**150**	**150**	**95**
Sub Total %	**13**	**14**	**10**	**10**	**8**	**10**	**10**	**5**	**15**	**21**	**10**	**8**	**15**	**15**	**10**
System Relaibility															
No water	51	59	82	25	95	200	100	52	30	10	75	111	75	75	63
Leak-Main Line	112	130	82	75	92	100	50	103	30	206	50	111	50	50	95
Leak – Connection	102	118	70	100	90	50	50	52	30	206	50	83	50	50	95
Defective meters	31	36	58	75	75	50	50	0	30	10	75	111	100	100	79
Low Pressure	51	59	70	75	83	50	100	52	30	26	100	83	50	50	63
Leak Night time	71	71	76	100	88	100	50	52	30	26	100	83	75	75	95
Water Quality	46	53	70	100	79	100	100	206	30	52	75	111	100	100	63
Sub Total	**463**	**527**	**509**	**550**	**602**	**650**	**500**	**515**	**212**	**536**	**525**	**694**	**500**	**500**	**556**
Sub Total %	**46**	**53**	**51**	**55**	**60**	**65**	**50**	**52**	**21**	**54**	**53**	**69**	**50**	**50**	**56**

Table B.7.4 - Aggregated Sub Criteria Responses Corresponding to each Main Criteria

	Form Number (46-60)														
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Income Generation															
New Connection	80	90	80	10	86	200	178	50	188	80	41	76	43	57	100
Bill Collection	80	112	100	99	95	150	162	50	125	80	41	76	43	57	100
Sub Total	**160**	**202**	**180**	**109**	**181**	**350**	**341**	**100**	**313**	**160**	**82**	**152**	**85**	**114**	**200**
Sub Total %	**16**	**20**	**18**	**11**	**18**	**35**	**34**	**10**	**31**	**16**	**8**	**15**	**9**	**11**	**20**
Sustainability															
O&M Expenditure	80	56	60	99	95	100	151	50	125	90	62	76	43	57	50
Staff Salaries	80	56	50	10	95	100	108	10	63	80	62	76	43	57	50
Sub Total	**160**	**112**	**110**	**109**	**190**	**200**	**259**	**60**	**188**	**170**	**123**	**152**	**85**	**114**	**100**
Sub Total %	**16**	**11**	**11**	**11**	**19**	**20**	**26**	**6**	**19**	**17**	**12**	**15**	**9**	**11**	**10**
System Losses															
NRW Reduction	80	79	60	99	86	150	135	30	188	80	256	136	106	200	100
Sub Total	**80**	**79**	**60**	**99**	**86**	**150**	**135**	**30**	**188**	**80**	**256**	**136**	**106**	**200**	**100**
Sub Total %	**8**	**8**	**6**	**10**	**9**	**15**	**14**	**3**	**19**	**8**	**26**	**14**	**11**	**20**	**10**
System Reliability															
No water	80	112	200	495	86	50	54	400	13	100	103	136	106	114	125
Leak-Main Line	100	90	100	10	86	50	22	200	125	80	77	65	106	57	50
Leak – Connection	70	90	70	5	48	25	22	50	13	70	77	65	106	57	50
Defective meters	80	56	50	10	86	50	11	50	13	80	51	65	53	57	25
Low Pressure	60	90	100	10	86	50	22	30	13	80	77	65	106	57	50
Leak Night time	80	56	70	5	67	25	38	50	13	60	51	65	32	57	25
Water Quality	130	112	60	149	86	50	97	30	125	120	103	98	213	171	275
Sub Total	**600**	**607**	**650**	**683**	**543**	**300**	**265**	**810**	**313**	**590**	**538**	**560**	**723**	**571**	**600**
Sub Total %	**60**	**61**	**65**	**68**	**54**	**30**	**26**	**81**	**31**	**59**	**54**	**56**	**72**	**57**	**60**

Table B.7.5 - Aggregated Sub Criteria Responses Corresponding to each Main Criteria

	Form number (61-70)														
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Income Generation															
New Connection	178	150	100	59	200	125	171	70	125	75	100	100	103	50	125
Bill Collection	178	150	200	59	200	102	114	70	125	50	80	100	103	100	125
Sub Total	**355**	**300**	**300**	**118**	**400**	**227**	**286**	**140**	**250**	**125**	**180**	**200**	**205**	**150**	**250**
Sub Total %	**36**	**30**	**30**	**12**	**40**	**23**	**29**	**14**	**25**	**13**	**18**	**20**	**21**	**15**	**25**
Sustainability															
O&M Expenditure	198	200	160	176	200	159	57	125	200	140	60	100	154	100	125
Staff Salaries	127	70	55	59	50	80	57	100	50	80	70	50	103	100	75
Sub Total	**325**	**270**	**215**	**235**	**250**	**239**	**114**	**225**	**250**	**220**	**130**	**150**	**256**	**200**	**200**
Sub Total %	**32**	**27**	**22**	**24**	**25**	**24**	**11**	**23**	**25**	**22**	**13**	**15**	**26**	**20**	**20**
System Losses															
NRW Reduction	132	60	150	235	100	227	57	100	100	150	100	50	77	150	75
Sub Total	**132**	**60**	**150**	**235**	**100**	**227**	**57**	**100**	**100**	**150**	**100**	**50**	**77**	**150**	**75**
Sub Total %	**13**	**6**	**15**	**24**	**10**	**23**	**6**	**10**	**10**	**15**	**10**	**5**	**8**	**15**	**8**
System Reliability															
No water	51	60	60	82	25	45	114	100	50	80	70	100	51	100	75
Leak-Main Line	51	70	100	82	25	45	57	100	50	100	100	100	51	50	75
Leak – Connection	25	80	100	82	100	80	86	90	100	150	70	50	51	50	75
Defective meters	15	60	30	59	25	11	114	100	50	50	80	100	51	50	75
Low Pressure	15	60	15	35	25	34	29	60	50	50	80	50	51	100	75
Leak Night time	15	20	15	35	25	34	114	60	50	50	90	100	51	0	25
Water Quality	15	20	15	35	25	57	29	25	50	25	100	100	154	150	75
Sub Total	**188**	**370**	**335**	**412**	**250**	**307**	**543**	**535**	**400**	**505**	**590**	**600**	**462**	**500**	**475**
Sub Total %	**19**	**37**	**34**	**41**	**25**	**31**	**54**	**54**	**40**	**51**	**59**	**60**	**46**	**50**	**48**

Table B.7.6 - Aggregated Sub Criteria Responses Corresponding to each Main Criteria

	Form number (76-88)												
	76	77	78	79	80	81	82	83	84	85	86	87	88
Income Generation													
New Connection	100	80	75	148	60	75	167	50	194	91	75	80	146
Bill Collection	120	80	100	148	60	75	167	50	167	91	75	80	104
Sub Total	**220**	**160**	**175**	**296**	**119**	**150**	**333**	**100**	**361**	**182**	**150**	**160**	**250**
Sub Total %	**22**	**16**	**18**	**30**	**12**	**15**	**33**	**10**	**36**	**18**	**15**	**16**	**25**
Sustainability													
O&M Expenditure	150	80	50	89	100	125	83	50	111	61	75	80	63
Staff Salaries	100	80	50	89	60	125	83	50	111	61	75	80	63
Sub Total	**250**	**160**	**100**	**177**	**159**	**250**	**167**	**100**	**222**	**121**	**150**	**160**	**125**
Sub Total %	**25**	**16**	**10**	**18**	**16**	**25**	**17**	**10**	**22**	**12**	**15**	**16**	**13**
System Losses													
NRW Reduction	150	55	200	49	149	200	111	200	222	61	100	80	52
Sub Total	**150**	**55**	**200**	**49**	**149**	**200**	**111**	**200**	**222**	**61**	**100**	**80**	**52**
Sub Total %	**15**	**6**	**20**	**5**	**15**	**20**	**11**	**20**	**22**	**6**	**10**	**8**	**5**
System Reliability													
No water	60	100	75	118	75	50	56	100	28	91	80	80	156
Leak-Main Line	60	100	75	118	75	50	56	100	28	91	80	80	52
Leak – Connection	60	100	75	74	75	50	56	100	28	91	80	80	52
Defective meters	20	75	50	10	75	50	56	25	28	91	40	80	52
Low Pressure	60	100	100	49	100	50	56	100	28	91	80	80	52
Leak Night time	20	50	50	10	75	50	56	25	28	91	40	80	52
Water Quality	100	100	100	99	100	100	56	150	28	91	200	120	156
Sub Total	**380**	**625**	**525**	**478**	**572**	**400**	**389**	**600**	**194**	**636**	**600**	**600**	**573**
Sub Total %	**38**	**63**	**53**	**48**	**57**	**40**	**39**	**60**	**19**	**64**	**60**	**60**	**57**

Table .8.1 - Comparison of Main Criteria and Relative Summation of Sub Criteria

	Form number (1-15)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Income Generation															
From sub parameters	18	34	30	21	38	20	35	25	24	13	28	28	18	34	30
From Main Parameters	18	30	30	15	30	20	35	25	25	15	25	30	18	30	30
Sustainability															
From sub parameters	18	117	100	50	110	313	100	106	124	100	150	50	300	25	90
From Main Parameters	18	30	30	20	20	15	20	20	13	20	23	20	18	20	15
System Losses															
From sub parameters	15	19	18	18	11	15	10	13	11	8	5	13	10	17	5
From Main Parameters	25	20	20	35	20	15	20	13	13	25	7	20	10	20	5
System Reliability															
From sub parameters	49	23	30	47	30	50	40	43	53	73	45	32	54	31	50
From Main Parameters	40	20	20	30	30	50	25	43	50	40	46	30	54	30	50

Table B.8.2 - Comparison of Main Criteria and Relative Summation of Sub Criteria

	Form number (16-30)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Income Generation															
From sub parameters	22	35	17	10	21	52	20	33	32	20	25	12	40	5	27
From Main Parameters	30	30	10	30	21	52	25	31	35	35	40	30	60	20	20
Sustainability															
From sub parameters	14	18	10	10	14	21	10	14	16	15	6	23	15	20	11
From Main Parameters	23	20	25	25	14	20	25	29	25	30	20	25	10	40	20
System Losses															
From sub parameters	6	20	10	30	15	5	20	31	42	21	15	11	20	20	19
From Main Parameters	17	25	25	20	15	8	25	8	20	20	10	15	10	20	10
System Reliability															
From sub parameters	58	27	63	50	50	22	50	44	32	50	59	58	35	55	51
From Main Parameters	35	25	40	25	50	21	25	32	20	15	30	30	20	20	50

Table B.8.3 - Comparison of Main Criteria and Relative Summation of Sub Criteria

	Form number (31-45)														
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Income Generation															
From sub parameters	27	19	21	20	16	10	20	31	42	21	15	11	20	20	19
From Main Parameters	30	20	33	25	14	20	30	60	35	25	20	30	30	20	50
Sustainability															
From sub parameters	13	14	18	15	16	15	20	12	21	5	23	11	15	15	16
From Main Parameters	10	10	16	20	20	15	20	20	25	25	30	20	20	20	20
System Losses															
From sub parameters	13	14	10	10	8	10	10	5	15	21	10	8	15	15	10
From Main Parameters	10	30	9	15	38	40	20	10	10	40	40	30	25	30	10
System Relaibility															
From sub parameters	46	53	51	55	60	65	50	52	21	54	53	69	50	50	56
From Main Parameters	50	40	44	40	28	25	30	10	30	10	10	20	25	30	20

Table B.8.4 - Comparison of Main Criteria and Relative Summation of Sub Criteria

Form number (45-60)															
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Income Generation															
From sub parameters	16	20	18	11	18	35	34	10	31	16	8	15	9	11	20
From Main Parameters	23	35	18	20	30	25	30	30	25	20	15	25	50	40	50
Sustainability															
From sub parameters	16	11	11	11	19	20	26	6	19	17	12	15	9	11	10
From Main Parameters	22	15	11	20	30	30	20	10	35	25	25	25	10	10	25
System Losses															
From sub parameters	8	8	6	10	9	15	14	3	19	8	26	14	11	20	10
From Main Parameters	25	15	6	10	20	20	20	10	15	30	30	25	25	10	15
System Reliability															
From sub parameters	60	61	65	68	54	30	26	81	31	59	54	56	72	57	60
From Main Parameters	30	35	65	50	20	25	30	50	25	25	30	25	15	40	15

Table B.8.5 - Comparison of Main Criteria and Relative Summation of Sub Criteria

Form number (61-75)															
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Income Generation															
From sub parameters	36	30	30	12	40	23	29	14	25	13	18	20	21	15	25
From Main Parameters	25	50	15	50	20	20	30	20	30	15	18	20	25	15	45
Sustainability	0														
From sub parameters	32	27	22	24	25	24	11	23	25	22	13	15	26	20	20
From Main Parameters	25	30	20	25	20	20	20	25	40	20	13	20	20	35	10
System Losses	0														
From sub parameters	13	6	15	24	10	23	6	10	10	15	10	5	8	15	8
From Main Parameters	10	10	50	13	10	20	30	25	15	50	10	20	35	35	25
System Reliability	0														
From sub parameters	19	37	34	41	25	31	54	54	40	51	59	60	46	50	48
From Main Parameters	40	10	15	13	50	40	20	30	15	15	59	40	20	15	20

Table B.8.6 - Comparison of Main Criteria and Relative Summation of Sub Criteria

Form number (61-75)													
	76	77	78	79	80	81	82	83	84	85	86	87	88
Income Generation													
From sub parameters	22	16	18	30	12	15	33	10	36	18	15	16	25
From Main Parameters	35	20	25	35	15	25	40	25	30	25	15	25	30
Sustainability													
From sub parameters	25	16	10	18	16	25	17	10	22	12	15	16	13
From Main Parameters	25	20	25	20	25	20	20	25	20	25	15	25	20
System Losses													
From sub parameters	15	6	20	5	15	20	11	20	22	6	10	8	5
From Main Parameters	25	20	25	15	35	25	20	20	20	20	20	25	20
System Reliability													
From sub parameters	38	63	53	48	57	40	39	60	19	64	60	60	57
From Main Parameters	15	40	25	30	25	30	20	30	30	30	50	25	30

Table B.8.6 - Comparison of Main Criteria and Relative Summation of Sub Criteria

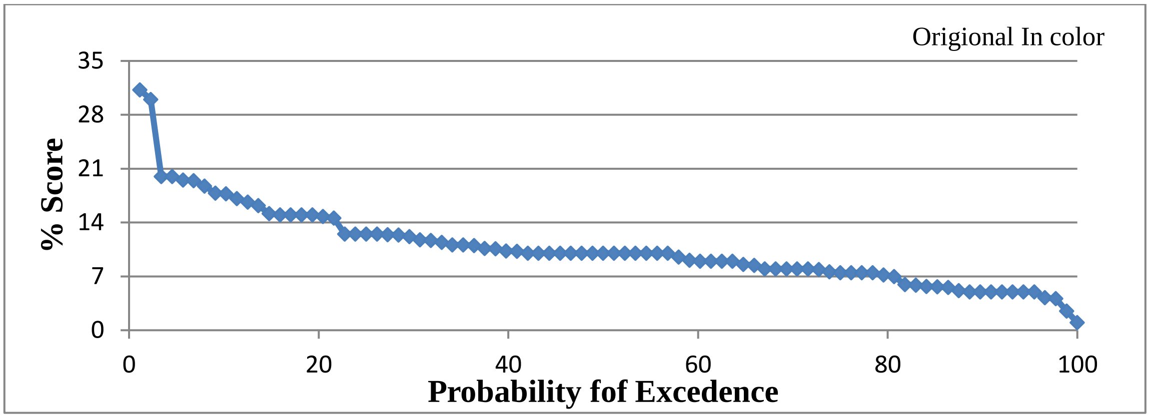
Form number (61-75)													
	76	77	78	79	80	81	82	83	84	85	86	87	88
Income Generation													
From sub parameters	22	16	18	30	12	15	33	10	36	18	15	16	25
From Main Parameters	35	20	25	35	15	25	40	25	30	25	15	25	30
Sustainability													
From sub parameters	25	16	10	18	16	25	17	10	22	12	15	16	13
From Main Parameters	25	20	25	20	25	20	20	25	20	25	15	25	20
System Losses													
From sub parameters	15	6	20	5	15	20	11	20	22	6	10	8	5
From Main Parameters	25	20	25	15	35	25	20	20	20	20	20	25	20
System Reliability													
From sub parameters	38	63	53	48	57	40	39	60	19	64	60	60	57
From Main Parameters	15	40	25	30	25	30	20	30	30	30	50	25	30

APPENDIX C –PROBABIITY CURVES

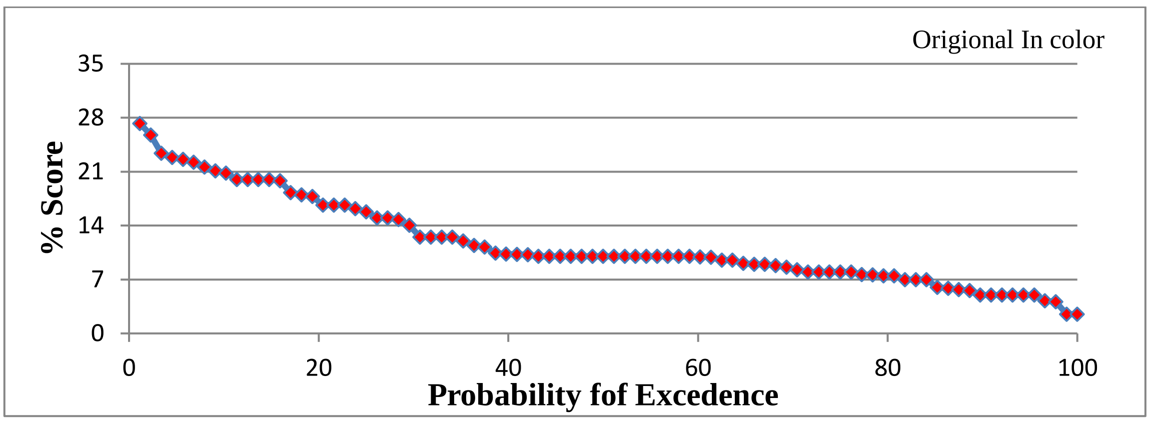
Figure C.1 – Probability of Exceedance curves – Sub Criteria
Figure C.2 – Probability of Exceedance curves – Sub Criteria
Figure C.3 – Probability of Exceedance curves – Sub Criteria
Figure C.4 – Probability of Exceedance curves – Sub Criteria

Table C-1: Pairwise Preferences for Alternatives for Sub Parameters- New Connection
Table C-2: Pairwise Preferences for Alternatives for Sub Parameters- Bill Collection
Table C-3: Pairwise Preferences for Alternatives for Sub Parameters- O&M Expenditure
Table C-4: Pairwise Preferences for Alternatives for Sub Parameters- Staff Salaries
Table C-5: Pairwise Preferences for Alternatives for Sub Parameters- NRW
Table C-6: Pairwise Preferences for Alternatives for Sub Parameters- No water
Table C-7: Pairwise Preferences for Alternatives for Sub Parameters- Main Leak
Table C-8: Pairwise Preferences for Alternatives for Sub Parameters- Connection Leak
Table C-9: Pairwise Preferences for Alternatives for Sub Parameters- Defective Meter
Table C-10: Pairwise Preferences for Alternatives for Sub Parameters- Low Pressure
Table C-11: Pairwise Preferences for Alternatives for Sub Parameters- Leak night time
Table C-12: Pairwise Preferences for Alternatives for Sub Parameters- Water Quality

Sub Criteria –New Connection



Sub Criteria –Bill Collection



Sub Criteria –O&M Expenditure

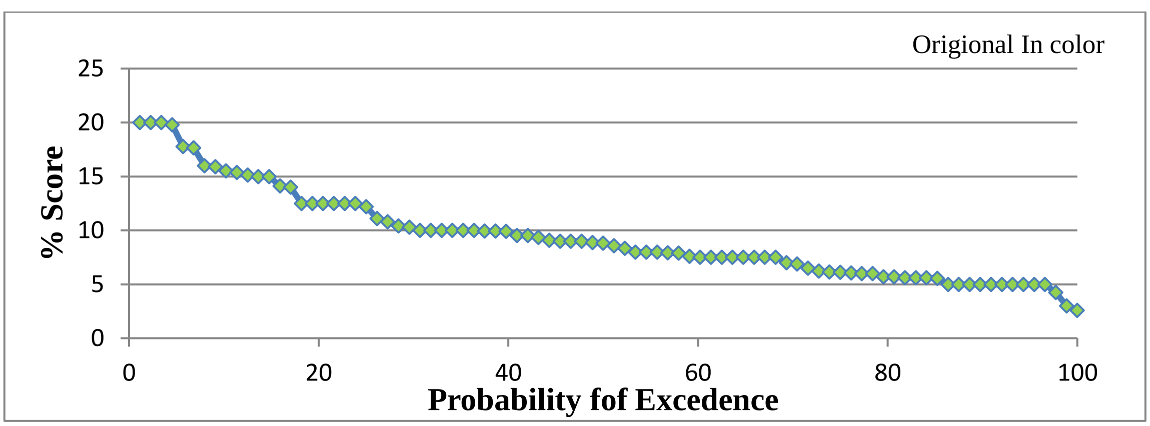
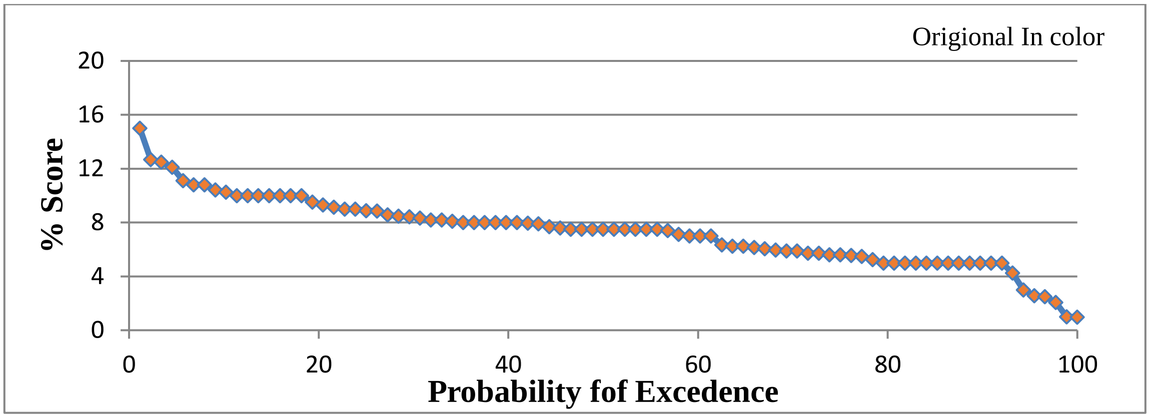
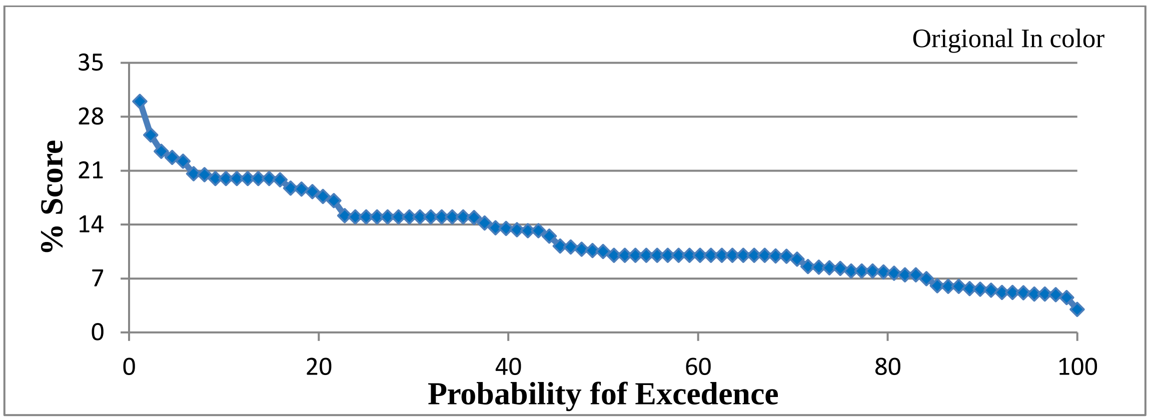


Figure C.1 – Probability of Exceedance curves – Sub Criteria

Sub Criteria –Staff Salaries



Sub Criteria –NRW



Sub Criteria –No Water

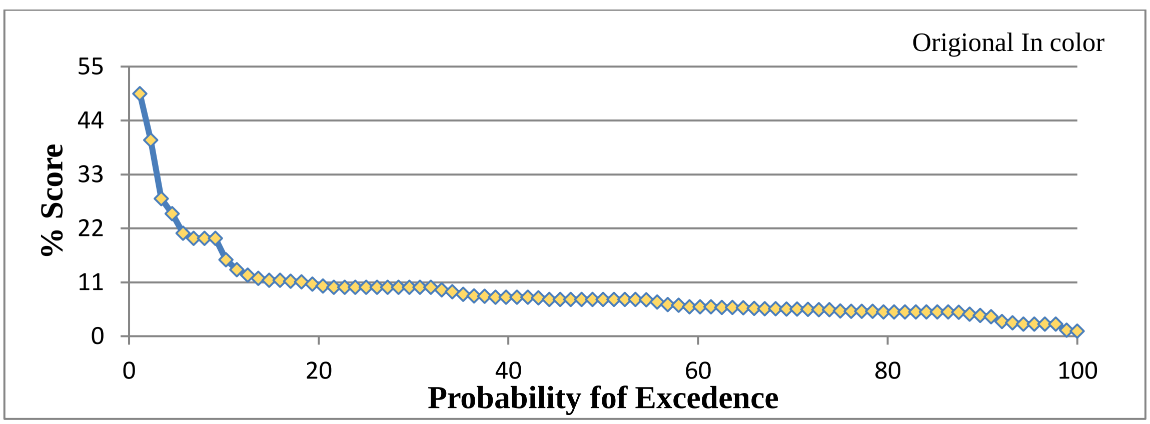
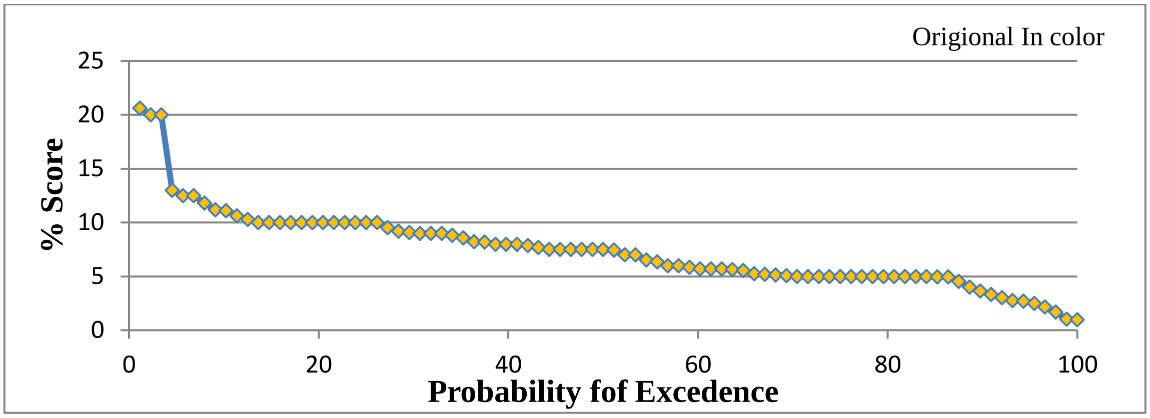
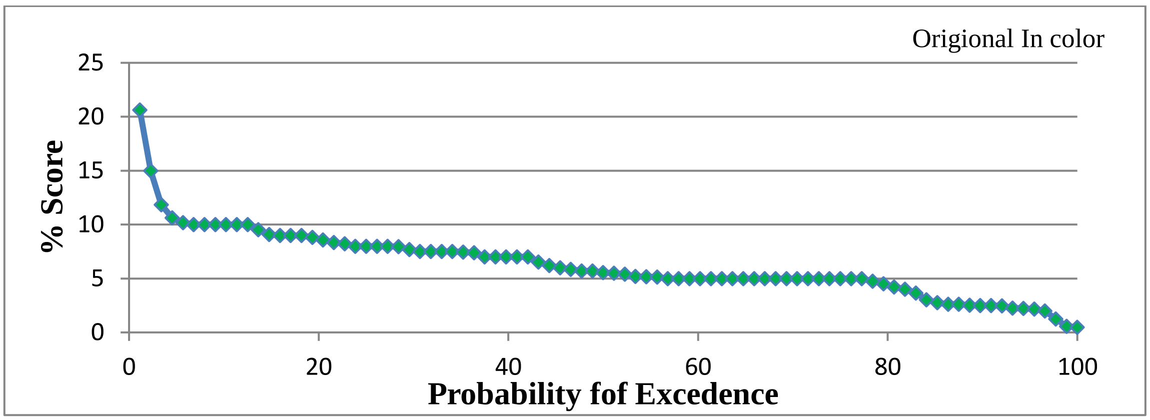


Figure C.2 – Probability of Exceedance curves – Sub Criteria

Sub Criteria –Main Leak



Sub Criteria –Leak Connection



Sub Criteria –Defective Meters

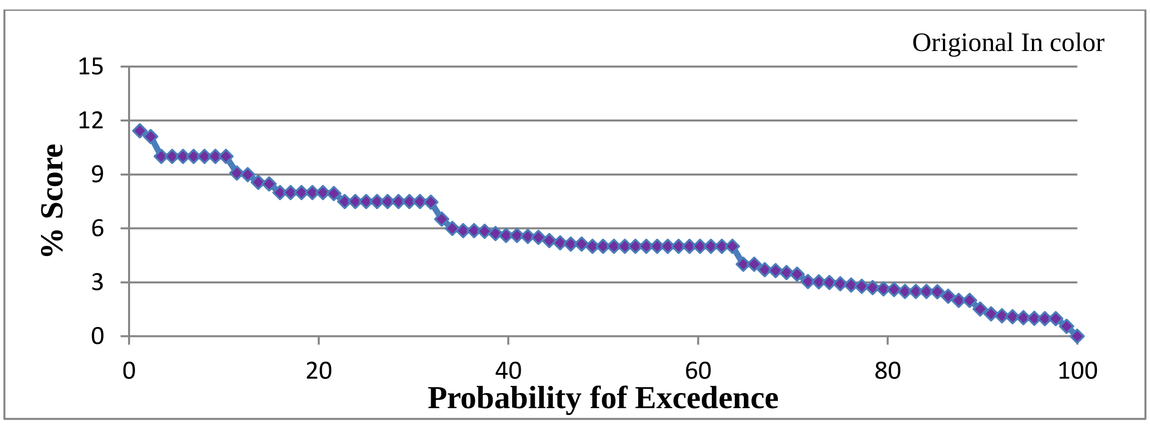
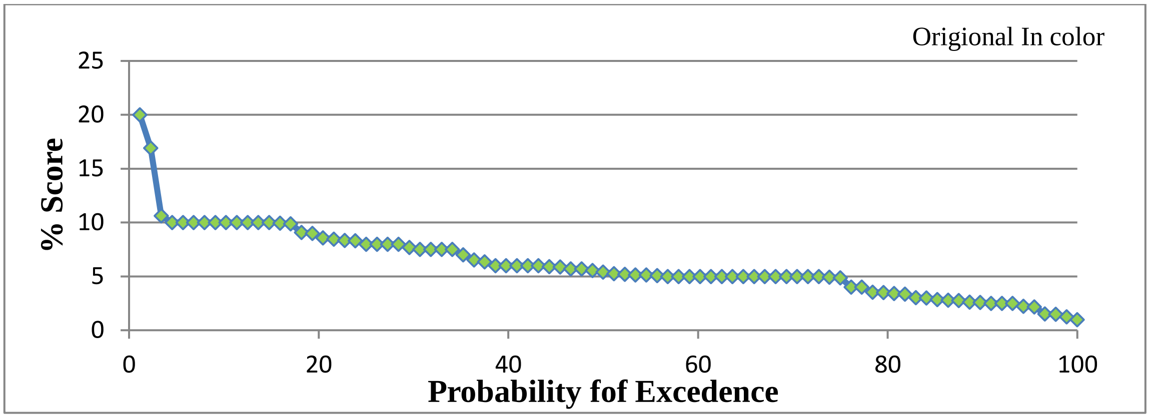
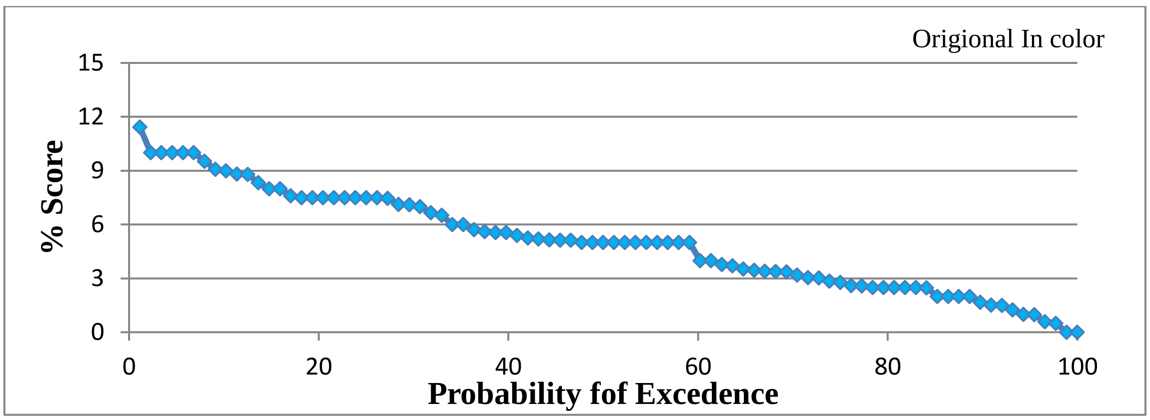


Figure C.3 – Probability of Exceedance curves – Sub Criteria

Sub Criteria –Low Pressure



Sub Criteria –Leak Night Time



Sub Criteria –Water Quality

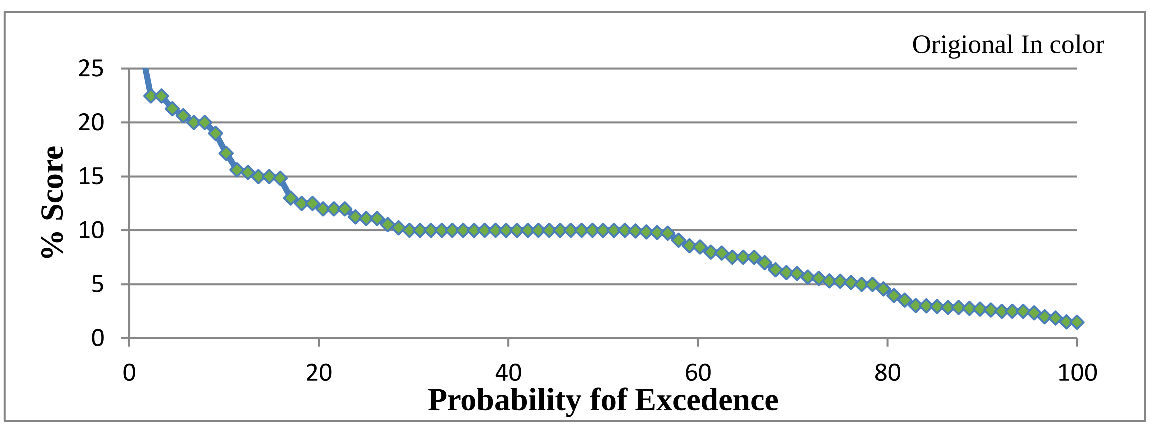


Figure C.4 – Probability of Exceedance curves – Sub Criteria

Table C-1: Pairwise Preferences for Alternatives for Sub Parameters- New Connection

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	2.22	3.92	2.97	2.06	1.61
Zone 2	0.45	1.00	1.76	1.34	0.93	0.73
Zone 3	0.26	0.57	1.00	0.76	0.53	0.41
Zone 4	0.34	0.75	1.32	1.00	0.69	0.54
Zone 5	0.49	1.08	1.90	1.44	1.00	0.78
Zone 6	0.62	1.38	2.43	1.84	1.28	1.00

Table C-2: Pairwise Preferences for Alternatives for Sub Parameters- Bill Collection

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	1.06	1.08	0.81	0.85	1.55
Zone 2	0.95	1.00	1.02	0.77	0.81	1.47
Zone 3	0.93	0.98	1.00	0.75	0.79	1.44
Zone 4	1.24	1.31	1.33	1.00	1.06	1.92
Zone 5	1.17	1.24	1.26	0.95	1.00	1.82
Zone 6	0.65	0.68	0.69	0.52	0.55	1.00

Table C-3: Pairwise Preferences for Alternatives for Sub Parameters- O & M Expenditure

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.19	0.68	0.16	0.67	0.80
Zone 2	5.24	1.00	3.55	0.86	3.53	4.19
Zone 3	1.48	0.28	1.00	0.24	0.99	1.18
Zone 4	6.13	1.17	4.15	1.00	4.12	4.89
Zone 5	1.49	0.28	1.01	0.24	1.00	1.19
Zone 6	1.25	0.24	0.85	0.20	0.84	1.00

Table C-4: Pairwise Preferences for Alternatives for Sub Parameters- Staff Salaries

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.19	0.68	0.16	0.67	0.80
Zone 2	5.24	1.00	3.55	0.86	3.53	4.19
Zone 3	1.48	0.28	1.00	0.24	0.99	1.18
Zone 4	6.13	1.17	4.15	1.00	4.12	4.89
Zone 5	1.49	0.28	1.01	0.24	1.00	1.19
Zone 6	1.25	0.24	0.85	0.20	0.84	1.00

Table C-5: Pairwise Preferences for Alternatives for Sub Parameters- NRW

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	1.25	0.68	1.07	0.67	0.80
Zone 2	0.80	1.00	0.54	0.86	0.54	0.64
Zone 3	1.48	1.84	1.00	1.58	0.99	1.18
Zone 4	0.94	1.17	0.63	1.00	0.63	0.75
Zone 5	1.49	1.85	1.01	1.59	1.00	1.19
Zone 6	1.25	1.56	0.85	1.34	0.84	1.00

Table C-6: Pairwise Preferences for Alternatives for Sub Parameters- No Water

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.26	0.68	0.23	0.67	0.80
Zone 2	3.80	1.00	2.57	0.86	2.55	3.03
Zone 3	1.48	0.39	1.00	0.33	0.99	1.18
Zone 4	4.44	1.17	3.00	1.00	2.98	3.54
Zone 5	1.49	0.39	1.01	0.34	1.00	1.19
Zone 6	1.25	0.33	0.85	0.28	0.84	1.00

Table C-7: Pairwise Preferences for Alternatives for Sub Parameters- Main Leak

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.19	0.68	0.16	0.67	0.80
Zone 2	5.32	1.00	3.60	0.86	3.58	4.25
Zone 3	1.48	0.28	1.00	0.24	0.99	1.18
Zone 4	6.22	1.17	4.21	1.00	4.18	4.97
Zone 5	1.49	0.28	1.01	0.24	1.00	1.19
Zone 6	1.25	0.24	0.85	0.20	0.84	1.00

Table C-8: Pairwise Preferences for Alternatives for Sub Parameters- Connection Leak

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.15	0.68	0.13	0.67	0.80
Zone 2	6.54	1.00	4.43	0.86	4.40	5.22
Zone 3	1.48	0.23	1.00	0.19	0.99	1.18
Zone 4	7.65	1.17	5.17	1.00	5.14	6.11
Zone 5	1.49	0.23	1.01	0.19	1.00	1.19
Zone 6	1.25	0.19	0.85	0.16	0.84	1.00

Table C-9: Pairwise Preferences for Alternatives for Sub Parameters- Defective Meters

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.06	0.68	0.05	0.67	0.80
Zone 2	16.84	1.00	11.40	0.86	11.32	13.45
Zone 3	1.48	0.09	1.00	0.08	0.99	1.18
Zone 4	19.68	1.17	13.32	1.00	13.23	15.72
Zone 5	1.49	0.09	1.01	0.08	1.00	1.19
Zone 6	1.25	0.07	0.85	0.06	0.84	1.00

Table C-10: Pairwise Preferences for Alternatives for Sub Parameters- Low Pressure

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	1.25	0.68	1.07	0.67	0.80
Zone 2	0.80	1.00	0.54	0.86	0.54	0.64
Zone 3	1.48	1.84	1.00	1.58	0.99	1.18
Zone 4	0.94	1.17	0.63	1.00	0.63	0.75
Zone 5	1.49	1.85	1.01	1.59	1.00	1.19
Zone 6	1.25	1.56	0.85	1.34	0.84	1.00

Table C-11: Pairwise Preferences for Alternatives for Sub Parameters- Leak –Night Time

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.20	0.68	0.17	0.67	0.80
Zone 2	5.00	1.00	3.39	0.86	3.37	4.00
Zone 3	1.48	0.30	1.00	0.25	0.99	1.18
Zone 4	5.85	1.17	3.96	1.00	3.93	4.67
Zone 5	1.49	0.30	1.01	0.25	1.00	1.19
Zone 6	1.25	0.25	0.85	0.21	0.84	1.00

Table C-12: Pairwise Preferences for Alternatives for Sub Parameters- Water Quality

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Zone 1	1.00	0.24	0.68	0.20	0.67	0.80
Zone 2	4.24	1.00	2.87	0.86	2.85	3.39
Zone 3	1.48	0.35	1.00	0.30	0.99	1.18
Zone 4	4.96	1.17	3.36	1.00	3.34	3.96
Zone 5	1.49	0.35	1.01	0.30	1.00	1.19
Zone 6	1.25	0.29	0.85	0.25	0.84	1.00

The findings, interpretations and conclusions expressed in this thesis/dissertation are entirely based on the results of the individual research study and should not be attributed in any manner to or do neither necessarily reflect the views of UNESCO Madanjeet Singh Centre for South Asia Water Management (UMCSAWM), nor of the individual members of the MSc panel, nor of their respective organizations.