MULTICRITERIA DECISION MODELLING FOR MANAGEMENT OF WATER SUPPLY SYSTEM IN THE PILIYANDALA – KESBEWA WATER SUPPLY SYSTEM, COLOMBO DISTRICT, SRI LANKA

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Thesis submitted in partial fulfilment of the requirements for the degree Master of Science in Water Resources Engineering and Management

Supervised by
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DECLARATION

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ABSTRACT

Twenty Two management zones spatially distributed in the Piliyandala – Kesbewa Water Supply System (WSS) undergo problems such as frequent pipe bursting, scaling in old pipes, Non Revenue Water (NRW) issues and pressure drops. Importance of managing a water supply system is to provide sustainable water supply with acceptable quality at an affordable price in order to match stakeholder requirements. Managing a water supply system requires a careful consideration of organizational expectations, stakeholder requirements and system sustenance needs etc. Therefore a multicriteria decision support model is most appropriate to manage a water supply system. Piliyandala – Kesbewa WSS (32 km^2) was selected as a case study to investigate the applicability of a multicriteria decision model. The Piliyandala – Kesbewa WSS has 24,309 connections for an approximate population of 106,960.

The present work identified management concerns, evaluated the present prioritisation techniques, and developed a Multicriteria Decision Analysis (MCDA) model framework in order to manage the Piliyandala – Kesbewa Water Supply System. A literature survey and a questionnaire survey among a sample of 78 water supply area management engineers enabled the identification of four main criteria and 15 sub criteria as the model components fulfilling water supply system management objectives.

Analytical Hierarchical Process (AHP) was selected because it provides measures of judgement consistency, derives priorities among criteria and alternatives, while simplifying the determination of preference ratings among decision criteria with the use of pairwise comparisons. Main water supply system management parameters were identified and refined using a survey among experienced water supply system managers.

MCDA models were developed for Overall Management objectives. Model calibration identified weights of 0.64, 0.20, 0.07 and 0.09 respectively for the main criteria namely, Income Generation, System Sustainability, System Losses and System Reliability. Entire set of sub criteria supporting the main set were identified as New Connections, Bill Collection, Operation & Maintenance, Salaries & Overtime, Transport, Non Revenue Water, Low Pressure, No water, Water Quality, Defective Meters, Leaks of Mains, Leaks of Water Connections, Leaks near Meter, Night Time Leaks, and Stop Valve Leaks. Respective sub parameter weights were 0.317, 0.326, 0.142, 0.046, 0.012, 0.064, 0.016, 0.020, 0.024, 0.009, 0.011, 0.004, 0.003, 0.004, and 0.002.

MCDA model with main and sub criteria together with 22 management zones, provided a priority order for overall management. Model verification compared the MCDA priority order with the management priority at field level. The trend line showing the spatial variability of priority from MCDA model closely matched with the Area Engineer's prioritisation exhibiting the satisfactory level of model verification. The AHP model incorporating stakeholder pairwise combinations revealed that average of stakeholder preferences would be a satisfactory starting indicator of the success of MCDA model development.

Priority order of overall management is obtained for management zones. Field identified priority indicators of each management zone differed from the AHP model indicators demonstrating a lack of guidelines for the management at field level and the lack of a clear link of objectives at various levels of management. Very low priority for System Losses and System Reliability reflects a deficiency in System Management.

MCDA model hierarchy and weights provide a clear indication for water supply organisations to evaluate whether management objectives are suitably achieved during system operations. This research clearly demonstrated the suitability and method of development of a AHP Multicriteria Decision Model for Water Supply System Management. However it is recommended to carryout similar studies at other systems while addressing the weaknesses with respect to the guidelines and stakeholder assessments.

Key Words:

Water Management Options, Water Supply System, MCDA, AHP, Multicriteria Model, Stakeholder Assessment, Criteria

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LIST OF ABBREVIATIONS

Abbreviation	Description
AE	Area Engineer
AHP	Analytical Hierarchy Process
CBO	Community Based Organisation
CKD	Chronic Kidney Disease
CP	Compromise Programming
CPIV	Composite Performance Index Value
CR	Consistency Ratio
CWS	Community Water Systems
DOCS	Department of Census and Statistics
EA	Engineering Assistant
EPANET MSX	EPANET Multi – Species Extension
GA	Genetic Algorithms
LAs	Local Authorities
MAE	Mean Absolute Error
MCDA	Multicriteria Decision Analysis
MCDM	Multicriteria Decision Making Technique
NRW	Non Revenue Water
NWSDB	National Water Supply & Drainage Board
O&M	Operation and Maintenance
R&D	Research & Development
SCE	Shuffled Complex Evolution
UNDP	United Nations Development Programme
UWOT	Urban Water Optioneering Tool
WSS	Water Supply System

LIST OF APPENDICES

1. INTRODUCTION

1.1 General

Importance of managing a water supply system is to provide sustainable water supply with acceptable quality at an affordable price to match stakeholder requirements. A reliable good quality water supply significantly contributes to the National economy of any country. Guidelines for better management of water supply systems is important especially because the governments are now opting for stakeholder based operation and management with a view to reduce the burden on state coffers. At scheme level, if a water supply system can be well managed, then there is a high likelihood of ensuring stakeholder satisfaction, and sustenance of the scheme on its own. This will also enable the establishment of suitable tariffs based on their performance without generalising such tarriffs for all systems in the country.

Water supply system management involves the maintenance of a sound pipe network that is suitable to supply water with adequate pressure and quantity within the service extent. These issues are both technical and social. Out of these, reduction in flow rates could be caused by the increased frictional resistance due to scale deposition in water supply pipes (Ratnasooriya & Wijesekera, 2009). Pipe bursting recorded frequently in water supply systems can be either due to maintenance issues or a situation where the loading on pipes was excessive (Mudalige, 2013). Concerns of Non Revenue Water (NRW) is a major problem in the water supply systems. High NRW not only reduces the income but also causes many other adverse effects such as reduction of the level of service and creates the necessity for additional supplies (Fernando, 2014).

1.2 Water Supply Systems in Sri Lanka

Water supply system management in Sri Lanka vary between urban and rural systems. Rural Water Supply Systems are managed by Community Based Organisations (CBOs) and Local Authorities (LAs) under the NWSDB technical assistance. CBOs or LAs are responsible for collecting tariffs from the people for Operation and Maintenance of the system. Urban Water Supply Systems are the

central systems with components for water purification, water quality control, transmission and distribution to the consumers. NWSDB is totally responsible for management, tariff collection and O&M of urban systems (NWSDB-1, 2009).
Management tools used by the NWSDB to improve operational efficiency, quality of services and productivity of the organisation are with respect to NRW Management, Energy Management, Supplies and Stores Management, Research and Development (R&D), Information Technology, Policy Formulation and Chronic Kidney Desease Program (NWSDB-1, 2009). According to the NWSDB-2 (2014, December), cumulative performance indicators were O&M staff /1000 connections, Billing Collection Efficiency, Unit Revenue, Ratio of Recurrent Expenditure/Billing, % Failure of Bacteriological Tests and Recurrent Cost per unit produced.

Water supply delivery management involves many factors, qualitative and quantitative, tangible and intangible, interest group and stakeholder aspirations (Okeola & Sule, 2012). Prieto, Murado, Bartlett, Magette and Curran (2014) presented a periodic hourly-based model using 15 min flow data and tested by investigating daily water consumption from selected user categories in Sligo, Ireland. Benefits of the model for water utility managers and researchers were stated as the achievement of optimal regulation and pumping in water supply schemes for planning and design purposes, to control unexpected scenarios, to enhance performance of water distribution systems and to locate possible network failures. Liong and Atiquzzaman (2004) presented that EPANET, a widely used water distribution network simulation model can be linked with a powerful optimisation algorithm used for the design of a cost effective water distribution network. Modelling of Chlorine residual to manage disinfectant concentration throughout the network in water supply systems has been identified as a significant water quality concern (Monteiro et al., 2014).

Chérifa (2012) reviewed the problems of urban water supply in the urban cluster of Tlemcen and modelled the system in order to help improving the status of water supply. Makropoulos, Natsis, Liu, Mittas and Butler (2008) described the development of a decision support tool UWOT (Urban Water Optioneering Tool) to facilitate the selection of a combination of water saving strategies and technologies and to support the delivery of integrated, sustainable water management for new

developments. Sharma, Gray, Diaper, Liston and Howe (2008) presented the outcomes of a study examining the effects of various water servicing options on water resources and the environment, for two townships in Canberra using three modelling tools. Compromise programming was applied to aid decision makers when selecting the best possible alternatives for distribution of both available and transmitted water (Abrishamchi, Ebramhimian, Tajrishi & Marino, 2005).

There are many publications on the water supply sector in Sri Lanka. Samarasinghe (2007) carried out a research to evaluate the small town water supply systems in order to set plans and to minimize the shortcomings for future and ongoing projects in Sri Lanka. Mimrose, Gunawardana and Nayakkorala (2011) carried out a research to assess the sustainability of community based rural water supply projects using a methodology adapted by the United Nations Development Programme (UNDP) and World Bank and used five indicators such as physical condition, operation and maintenance, consumer satisfaction, financial management and willingness to sustain the system. The results show that 14 Community Water supply Projects out of 20 were sustainable in Kandy district.

1.3 Management Concern

Most of the urban and rural water supply systems in Sri Lanka have frequent pipe bursting, scaling in old pipes, NRW issues and pressure drops. Therefore it is necessary to investigate the possibility of using a mathematical model for the prioritisation of system management options.

However in publications concerning Sri Lanka, and in most literature found as reviewed publications, a notable omissions or a gap is the need of an easy to use quantitative multicriteria model that would enable incorporation of stakeholder concerns for system management.

Therefore an investigation of the potential of multicriteria decision modelling for water supply systems management was undertaken in order to support systematic rational and efficient management of the large number of water supply systems under the jurisdication of National Water Supply and Drainage Board.

As a case study, the NWSDB managed, Piliyandala – Kesbewa Water Supply System was chosen. Kesbewa is an area in the Colombo district in Sri Lanka and the Government of Sri Lanka has invested funds for future water supply developments. The project area consists of urban, semi urban and rural lands that would enable capturing of management factors associated with each type. Proximity of the study area was a concern with respect to field work. This was also a reason to select Kesbewa WSS as the project area.

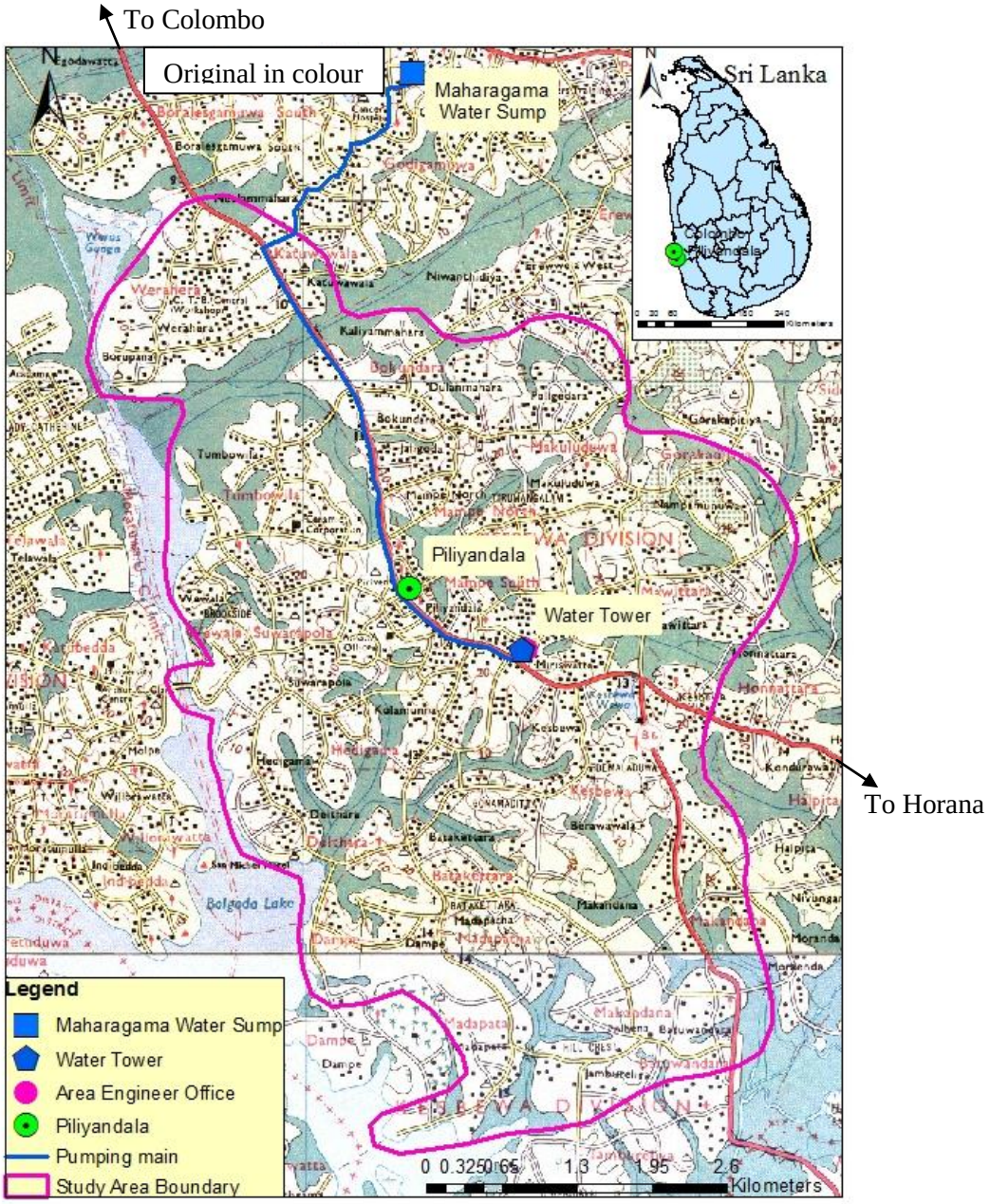

Figure 1.1 : Study Area Map

2. OBJECTIVES

2.1 Overall Objective

The Overall objective of the present research is to identify management concerns, evaluate the present prioritisation techniques, develop a Multicriteria Decision Analysis model as a case study and to make recommendations to efficiently and effectively manage pipe borne Water Supply Systems.

2.2 Specific Objectives

The specific objectives of the present work can be listed as follows.

1. Identification of the current research issues and concerns, and MCDA modelling options through a comprehensive literature survey.
2. Determination of water supply system management criteria and identification of decision alternatives.
3. Development of a MCDA model, calibration of model weights and verification with field data.
4. Making recommendations for the use of MCDA models for pipe borne water supply system management.

3. LITERATURE REVIEW

3.1 Water Management in Water Supply Schemes

Abrishamchi et al. (2005) presented water management objectives when selecting the best possible alternatives for distribution of both available and the transmitted water in the city of Zahidan in Iran using Multi Criteria Decision Making Technique (MCDM) of Compromise Programming (CP) for urban water management. Experience in this project offers a favourable view of the systems approach to water management in Iran. Results obtained revealed that the method used in this study is capable of solving urban water management problems.

Prieto et al. (2014) applied a periodic hourly-based model with meaningful parameters developed to analyse and forecast water demand as a function of time, thus enabling a better understanding of the consumption pattern and the condition of pipe network. Flow data used was obtained in 15-min intervals and averaged in different time periods for analysis. This model provides a quick analysis of data and benefit water utility managers and associated research. In addition, model parameters can be used as standard criteria for water utilities to compare the water demand between different areas, identify complex trends and analyse the pipe network for managing, auditing and monitoring purposes.

Sharma et al. (2008) presented the water management objective as the outcomes of a study examining the effects of various water servicing options on water resources and the environment, for two townships in Canberra, one existing and one green field site. Three modelling tools were used to study the effects of various alternative water servicing scenarios, including demand management options, rainwater tanks, greywater use, on-site detention tanks, gross pollution traps, swales and ponds. Results showed that potable water reductions are best achieved by demand management tools or a combination of greywater and rainwater use for existing suburbs, while third pipe systems are preferred for greenfield sites. Also, Environment Australian Capital Territory (Act) was amended to include planning controls to facilitate installation of raintanks and greywater systems, and commenced a government funded rebate scheme for raintanks as a result of this study.

Raich-Montiu et al. (2014) presented integrating new water sources and blending options along the distribution zones of the Barcelona Metropolitan Area. Effect of membrane technologies, influence of the type of water source on the disinfection and water aggressiveness toward the network materials had been assessed. Chérifa (2012) presented an approach to the urban cluster network of Tlemcen based on a situation analysis of urban water supply by identifying the needs of the system, analysing feasibility, considering technical measures of performance and modelling different functions and sub systems of the water supply system. This demonstrated the decomposition of the system.

3.2 Critical Management Factors

Makropoulos et al. (2008) used Genetic Algorithms (GA) to provide optimisation capabilities to Urban Water Optioneering Tool (UWOT) for sustainable option selection in integrated urban water management. UWOT was applied to the problem of selecting water-related technologies for a new UK urban development, to test the water balance model and others of the decision support interface. Indicators used for the study are potable water demand, waste water produced and runoff.

Elsheikh, Sales, Rashwan and El-Samadoni (2013) described optimizing its design and extension considering the effect of aging of network and the most practical approach for its future configuration. System optimization was carried considering main and secondary loops that included 588 pipes. Calibration was conducted through three types of readings namely static pressure fire flow tests and extended period readings. The model had been calibrated through by defining minimum cost design as objective function satisfying constraints and considering future requirements. Calibrated model for the steady state field measurements network produced a mean square error of 0.00814.

Water management alternative evaluation and decision making study based on the performance of the urban water supply scheme for Offa, Nigeria had used 19 Performance Indicators (Okeola & Sule, 2012).

Ataoui and Ermini (2015) proposed a methodology for analysing and computing the overall performance of water distribution system based on a hierarchical system

approach by evaluating performance indicators of reliability, resiliency and vulnerability. Indicators were assessed considering three aspects namely, water pressure, available flow and free residual Chlorine concentration which can be divided into hydraulic and quality aspects to obtain overall performance of water distribution system.

3.3 Model Selection

MCDA showed a new way to reach the compromise between socio – economic and technical points of view at the stage of WSS programming (Roy, Slowinski & Treichel, 1992). Saaty (1977, 1994) developed Analytical Hierarchical Process (AHP) in 1970s. AHP has broad application and helps decision makers choose the best solution from several options and selection criteria (Alexandar, 2012).

Triantaphyllou and Mann (1995) presented that AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. AHP is a decision support tool which can be used to solve complex decision problems with a multi-level hierarchical structure of objectives, criteria, sub criteria and alternatives.
Overall objective was at the highest level and the criteria & respective sub criteria used to choose among alternatives were at the lowest levels. Calibtation of pairwise comparison was carried out to ensure the consistency of judgement (Okeola et al., 2012).

3.4 MCDA Modelling

Many applications of Multicriteria Decision Making (MCDM) techniques show that they are well-suited for water resources planning as efficient decision making tools (Abrishamchi et al., 2005). An appropriately developed Multicriteria Decision Analysis (MCDA) model for the management of water supply systems will support improving operational efficiency, quality of services and the productivity (Roy et al., 1992 and Triataphyllou & Mann, 1995).

AHP was selected as the 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 preference ratings among decision criteria with the use of easy pairwise comparisons. Özkan, Basligil and Sahan (2011) presented the use of Analytical Hierarchy Process (AHP) for supplier selection methodology with 4 main criteria and 16 sub criteria to select the best supplier out of three. Morais and Almeida (2006) described the application of multicriteria decision aid for choosing a priority city to receive a water supply system. EPANET, a multicriteria water distribution network simulation model has been used for the cost effective design of a water distribution network to deal with both the steady state and extended period simulation by linking with a powerful optimization algorithm (Liong & Atiquzzaman, 2004). Monteiro et al. (2014) used the EPANET Multi-Species Extension (EPANET MSX) for modelling of residual Chlorine in water supply systems. First order decay kinetics are currently often used to describe both bulk and wall Chlorine consumption. Makropoulos et al. (2008) applied the UWOT, a decision support tool to select from a combination of water saving strategies and technologies for the integrated and sustainable water management of new developments. The tool based on a water balance model uses quantitative and qualitative sustainability criteria and indicators to compare between alternative composite water management strategies while preserving the multi objective aspects. Indicators to evaluate the performance of water distribution system were reliability, resiliency and vulnerability (Ataoui and Ermini, 2015) and physical condition, O&M, consumer satisfaction, financial management and willingness to sustain the system.

3.5 Water Supply System Management in Sri Lanka

Arachchi, (2015) presented 3 dependent variables (productivity factor for operational aspect, productivity factor for financial stability and productivity factor for social aspect) and 12 independent variables (Number of water connections per 1,000 population, Piped water connected coverage %, Per capita water consumption, Water quality, Stock efficiency, Accounts receivable, Operating ratio, Energy cost

/cum, Estimated bills, Defective meters, Staff per 1,000 connections, NRW) to measure the NWSDB performance. According to the trend and behaviour pattern of partial performance indicator, an overall performance indicator was developed by Arachchi, (2015).

Mimrose et al. (2011) carried out a research on 20 community managed water schemes in Kandy district to assess the sustainability of community based rural water supply projects. Participatory research methodology tools were used for the assessment based on 05 sub indicators. They were physical condition, operation & maintenance, consumer satisfaction, financial management and willingness to sustain the system. 14 out of 20 schemes were found to be sustainable indicating that the strategies followed during the project implementation have succeeded.

Wijegunawardana, (2010) carried out a study intended towards the development of a Composite Performance Index Value (CPIV) to measure the performance of Community Water Systems (CWS), by collecting and refining knowledge from a group of expertise. The index CPIV has produced an assessment for eleven key performance areas of a CWS which includes variables in access, use, environment, finance and management and user capabilities with the integration of physical, social, economic and environmental aspects for water management. The index simplifies the complexity of various issues of CWS when evaluating the performance and identifies the need prioritisation.

3.6 Summary of Management Criteria

Literature identified management criteria summerised and listed in Table 3.1.

Table 3.1: Main and Sub criteria for WSS Management from Literature

#	Reference	Main Criteria	Sub Criteria
1	Mimrose et al. (2011)	Physical Condition, Operation and Maintenance, Consumer Satisfaction, Financial Management, Willingness to sustain the system	-
2	Prieto et al. (2014)	NRW	-
3	Fernando (2014)	NRW	-
4	Ataoui and Ermini (2015)	Reliabilty, Resiliency, Vulnerability	-

#	Reference	Main Criteria	Sub Criteria
5	NWSDB-1 (2009)	Average Household Monthly Consumption (cum per house connections) , Average Household Billing per month.(Rs.), Total Revenue (Rs.million), Total Recurrent Expenditure (Rs. Million), Non Revenue Water (%), O &M staff / 1000 connnections, Total staff / 1,000 Connections, Average Recurrent cost of water production (Rs./cu.m.), Collection effieiency	-
6	NWSDB-2 (2014, December)	NRW, O &M staff / 1000 connnections, Collection Efficiency (Collection/ Billing), Unit Revenue (Rs. / m3), Recurrent Expenditure / Billing, % Failure of Bacteriological Tests on drinking water, Recurrent Cost per Unit Produced (Rs. / m3)	-
7	Okeola and Sule (2012)	Environmental (Water Resource)	Withdrawal, Quality, Reliability, Vulnerability
		Economic	Financial viability, Economic of sale, Securing of investment resources, Minimization of Production cost
		Technical (Infrastructures)	Access to advance technology, Expertise employee, Operational efficiency
		Institutional	Legal framework, Policies, Regulatory control, Participation
		Socio-cultural	Public health and safety, Accessibility, Coverage, Intergenerational equity
8	Abrishamchi et al. (2005)	Total cost, Public appraisal, Political impact, Water Quality, Health impact, Flexibility, Water demand control, time of water shortage, Population Impact	-
9	Karunasena (2015)	Service Indicator	Number of water connections per 1,000 population, Piped water connected coverage %, Per capita water consumption, Water Quality
		Financial Indicator	Stock efficiency, Accounts receivable, Operating Ratio, Energy cost /cum
		Operational Indicator	Estimated bills, Defective meters, Staff per 1,000 connection

4. METHODOLOGY

4.1 General

The Methodology used for the study is shown in Figure 3.1. There are eight chapters as Introduction, Objectives, Literature Review, Methodology, Data Collection and Checking, Analysis and Results, Discussion, Conclusions and Recommendations. The problem to be solved and Objective Identification are in the Introduction chapter. A Literature Review was carried out and presented in a seperate chapter.

A data collection form was designed for the field survey of system management parameters among NWSDB water supply systems. Data collection form was tested with the use of NWSDB officials responsible for management of water supply systems. The survey was carried out to identify main parameters used to manage water supply systems in NWSDB. Main water supply system management parameters were identified and refined using a survey among experienced water supply system managers. Sub parameters for each main parameter were identified. MCDA model structure was conceptualized using Main criteria, Sub criteria and Management zones.

MCDA model was developed, and associated weights were checked for the consistency. During model calibration, parameter weights finalisation for the study area from a number of consistent alternative combinations was done using the field data. Verification was carried out by comparing model outputs with the observed spatial variability of management priority.

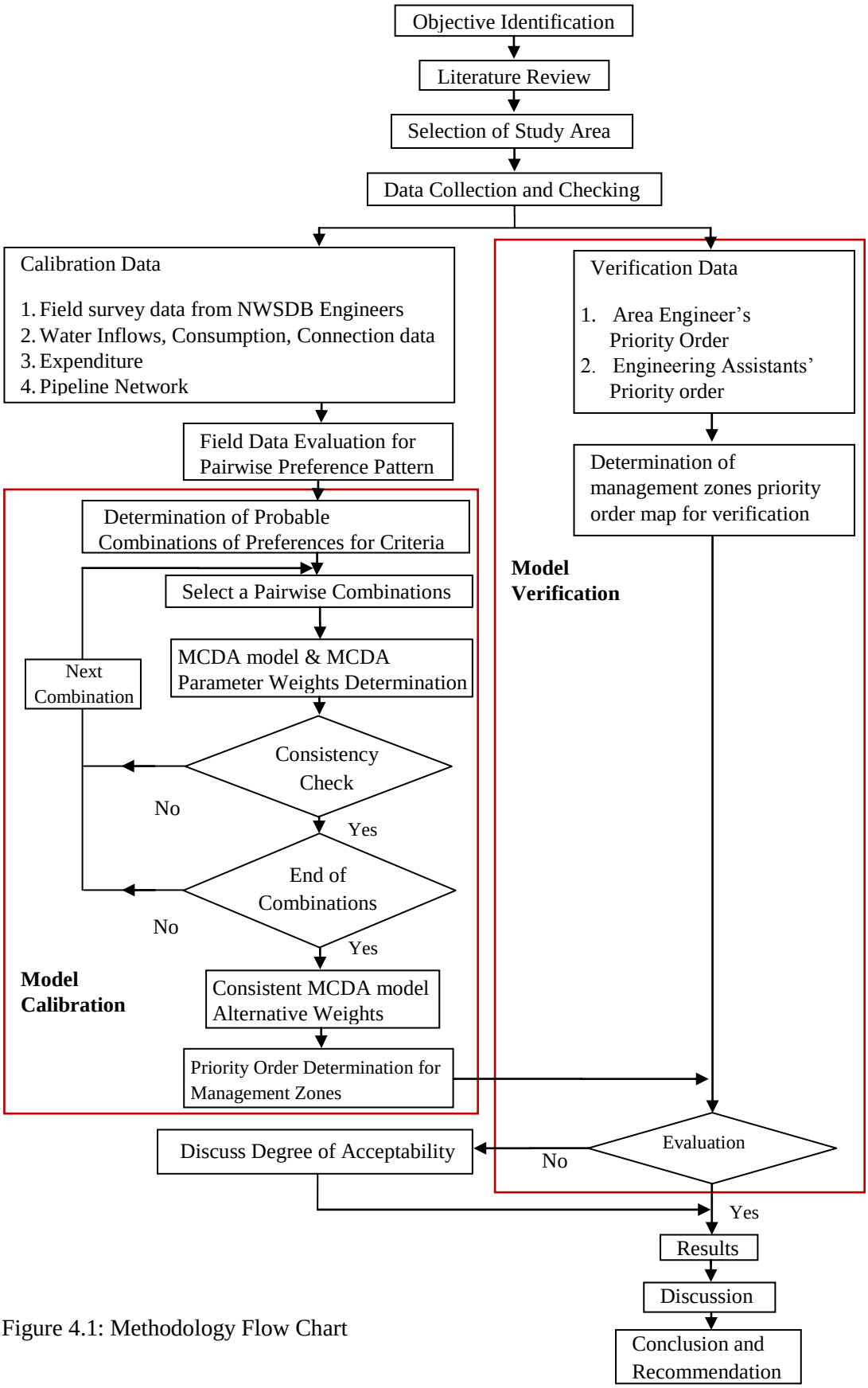

Figure 4.1: Methodology Flow Chart

5. DATA COLLECTION AND CHECKING

5.1 Data Collection

5.1.1 Study area

A semi urban water supply system of Kesbewa Divisional Secretariat Division in Colombo District, Sri Lanka was selected for the study which is Piliyandala water supply system. The area covered by this water supply scheme is 32 km^2 and number of connections up to December 2014 is 24,309 (DOCS, 2012). According to the Census & Statistics data, family size of the area is 4.4 (DOCS, 2012).

Piliyandala – Kesbewa water supply system is fed by the Piliyandala water tower which has the capacity of 2230 m^3, a height of 32.2 m and diameter of tower is 9 m. Minimum and maximum water levels of the tower are 42.1 m MSL and 50.1 m MSL respectively. From 2001 to 2015, water has been supplied to the tank from Maharagama Water sump through the DI transmission main which has a diameter 500 mm. Study area is shown in Figure 5.1.

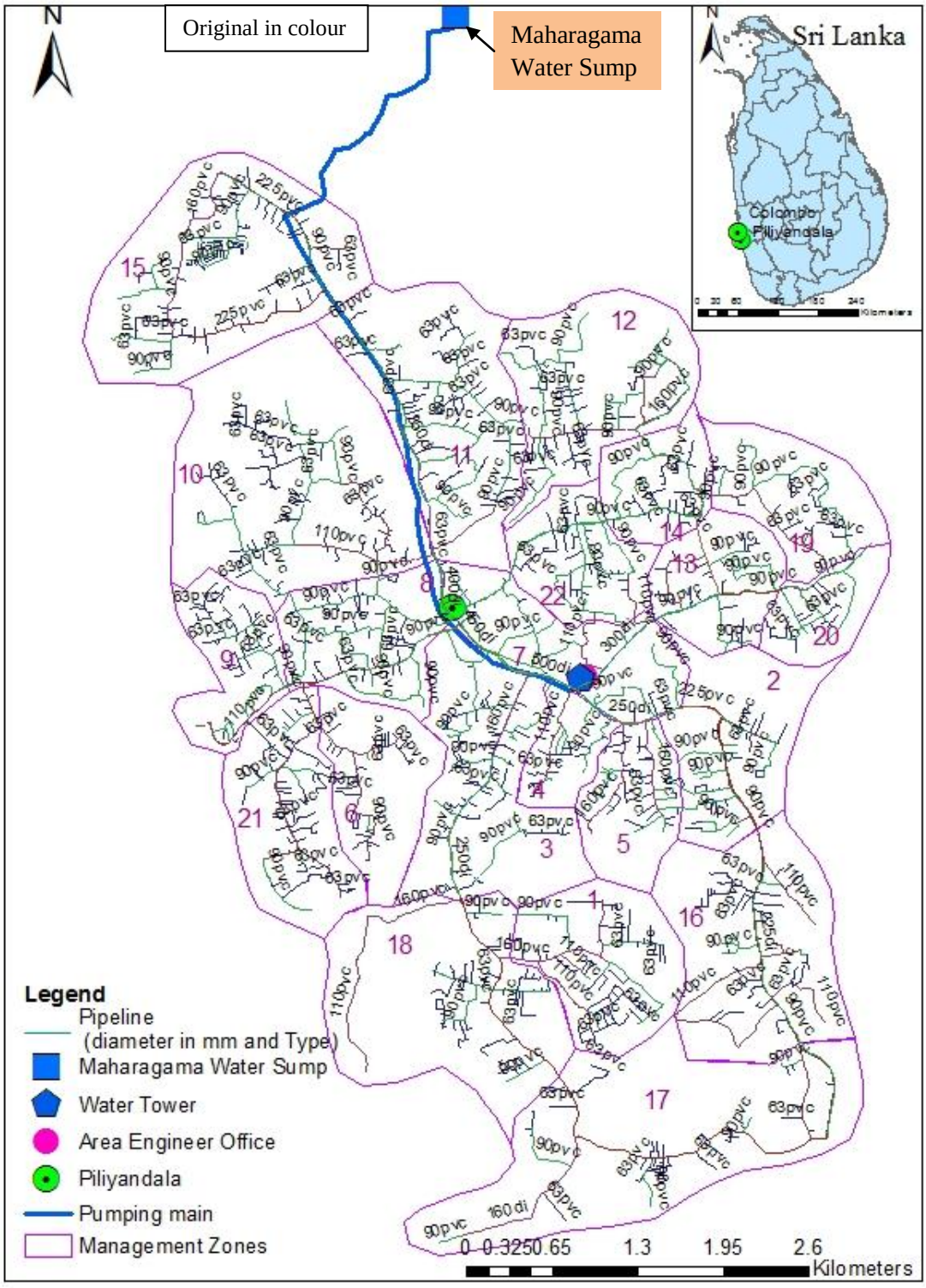

Figure 5.1 : Existing Water Supply Network of Study Area

5.1.2 Water supply system data

The data collected from the NWSDB head office and the Kesbewa field office are as listed in Table 5.1.

Table 5.1 : Water Supply System Data

No.	Data Type	Data Period	Resolution	Data Source
1	Existing Water Supply Network (Figure 5.1)	2014	-	Area Engineer's Office, NWSDB, Kesbewa
2	Water Inflows to Piliyandala Water Tower (Figure 1.1)	2005-2014	Monthly	Area Engineer's Office, NWSDB, Kesbewa
3	Consumption Data	2001-2014	Monthly	Manager's Office - Kottawa
4	Consumer Complaints	2014-2015	Daily	NWSDB Online Database
5	Expenditure for Piliyandala – Kesbewa WSS	2011-2015	Yearly	Finance Section, NWSDB Head Office
6	Identification of Management Zones	2015	Management zones	Area Engineer's Office, NWSDB, Kesbewa
7	Map of System Dockets (Figure 5.2)	2015	Dockets	Area Engineer's Office, NWSDB, Kesbewa
8	Priority order of Management zones (Table 5.2, Figure 5.4)	2015	Numbers	Area Engineer's Office, NWSDB, Kesbewa

In a water supply system, a docket is a collection of house connections arbitrary selected by considering supply nodes, meter reader accessibility, billing convenience etc. In the Piliyandala – Kesbewa Water Supply System there are 174 number of dockets in the system (Figure 5.2).

There are 03 Engineering Assistants (EA) working under the Area Engineer (AE) for the management and technical support of Piliyandala – Kesbewa WSS.

Management zones for Piliyandala – Kesbewa WSS (Figure 5.3) were identified with the consultation of Area Engineer. The Area Engineer intimated that the zones are identified by considering the number of meter readers in the water supply system, pipeline network, number of connections, roadsides, accessibility, elevation, etc.

22 management zones were identified for the Piliyndala – Kesbewa WSS and characteristics of Piliyandala Kesbewa WSS are shown in Table 5.2.

Table 5.2 : Characteristics of Management Zones

Management Zone ID	Number of Dockets	5 Years Average Consumption, l/s	Forecasted Population 2014
Z1	2	70328	7349
Z2	7	94515	8060
Z3	18	508399	9976
Z4	4	107643	2456
Z5	3	110399	4596
Z6	4	68678	4462
Z7	7	114279	6750
Z8	9	249487	6639
Z9	8	206834	3589
Z10	12	332645	11913
Z11	13	228474	6814
Z12	8	110192	5441
Z13	5	105032	1921
Z14	4	73661	4695
Z15	15	506632	9354
Z16	11	267423	8756
Z17	7	123889	8584
Z18	9	328628	4710
Z19	3	96200	3446
Z20	5	91909	1402
Z21	10	213208	5965
Z22	4	118234	4139

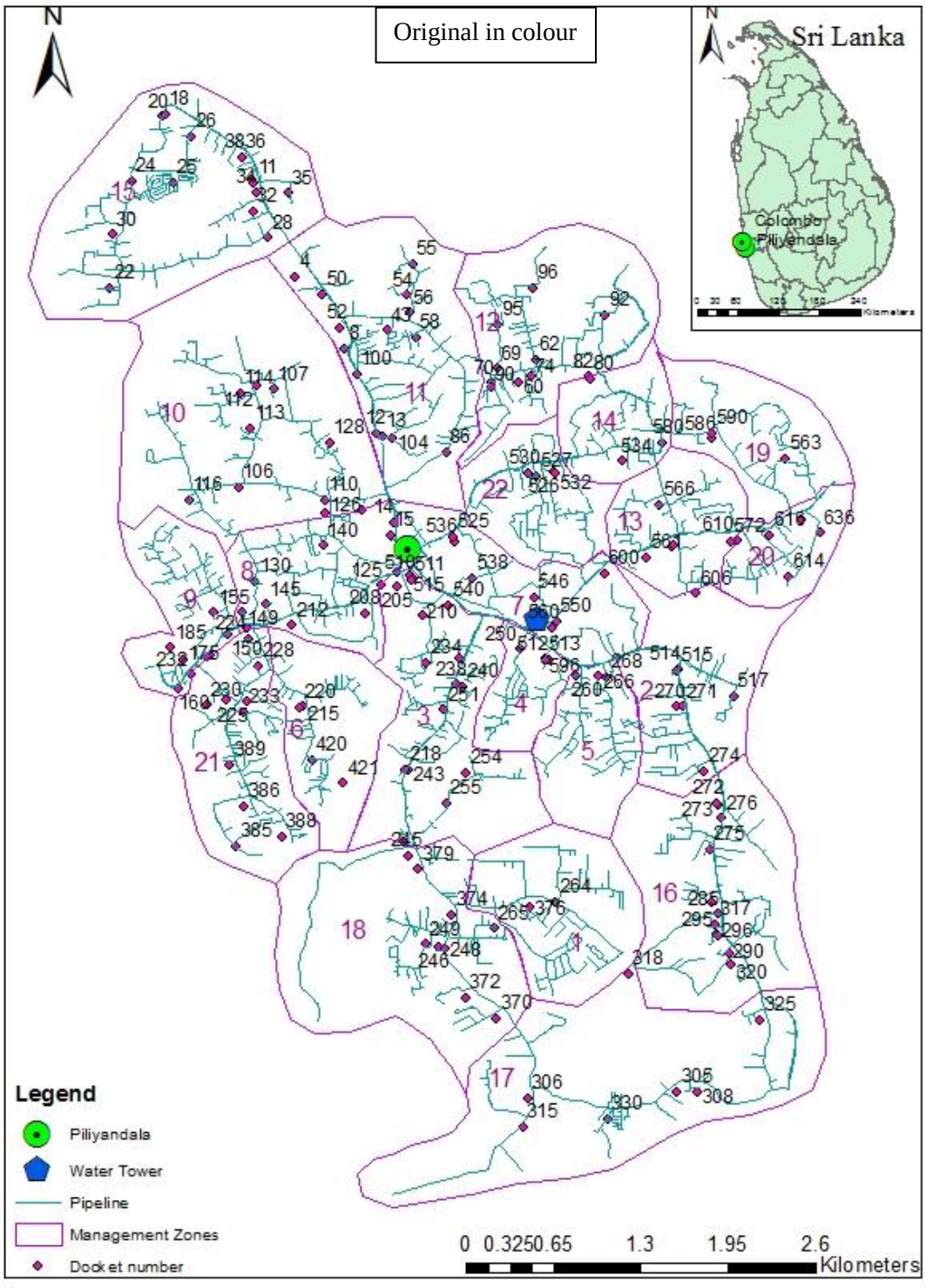

Figure 5.2: Piliyandala Kesbewa WSS – Spatial Variability of Dockets

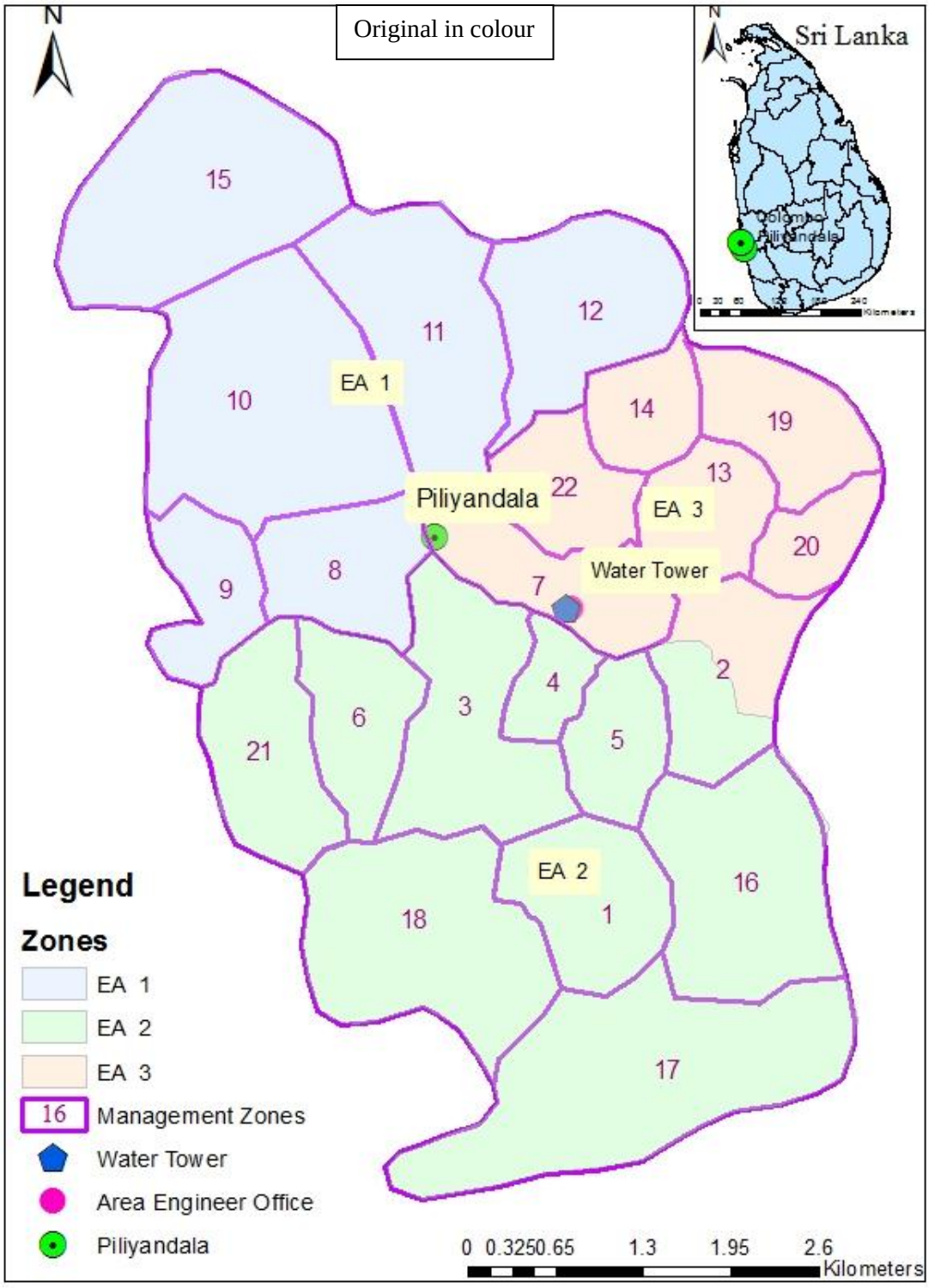

Figure 5.3: Piliyandala Kesbewa WSS - Management Zone Distribution

5.1.3 Area Engineer’s priority

Priority order of management zones of Piliyandala – Kesbewa Water Supply System obtained from the Area Engineer is shown in Table 5.3 and Figure 5.4.

Table 5.3 : Area Engineer’s Priority Order

Management Zone ID	Area Engineer's Priority Marks (1-10 scale)	Area Engineer's Priority Order
Z1	8	3
Z2	4	7
Z3	3	8
Z4	2	9
Z5	1	10
Z6	9	2
Z7	4	7
Z8	5	6
Z9	7	4
Z10	6	5
Z11	7	4
Z12	8	3
Z13	1	10
Z14	3	8
Z15	9	2
Z16	8	3
Z17	10	1
Z18	9	2
Z19	2	9
Z20	1	10
Z21	8	3
Z22	6	5

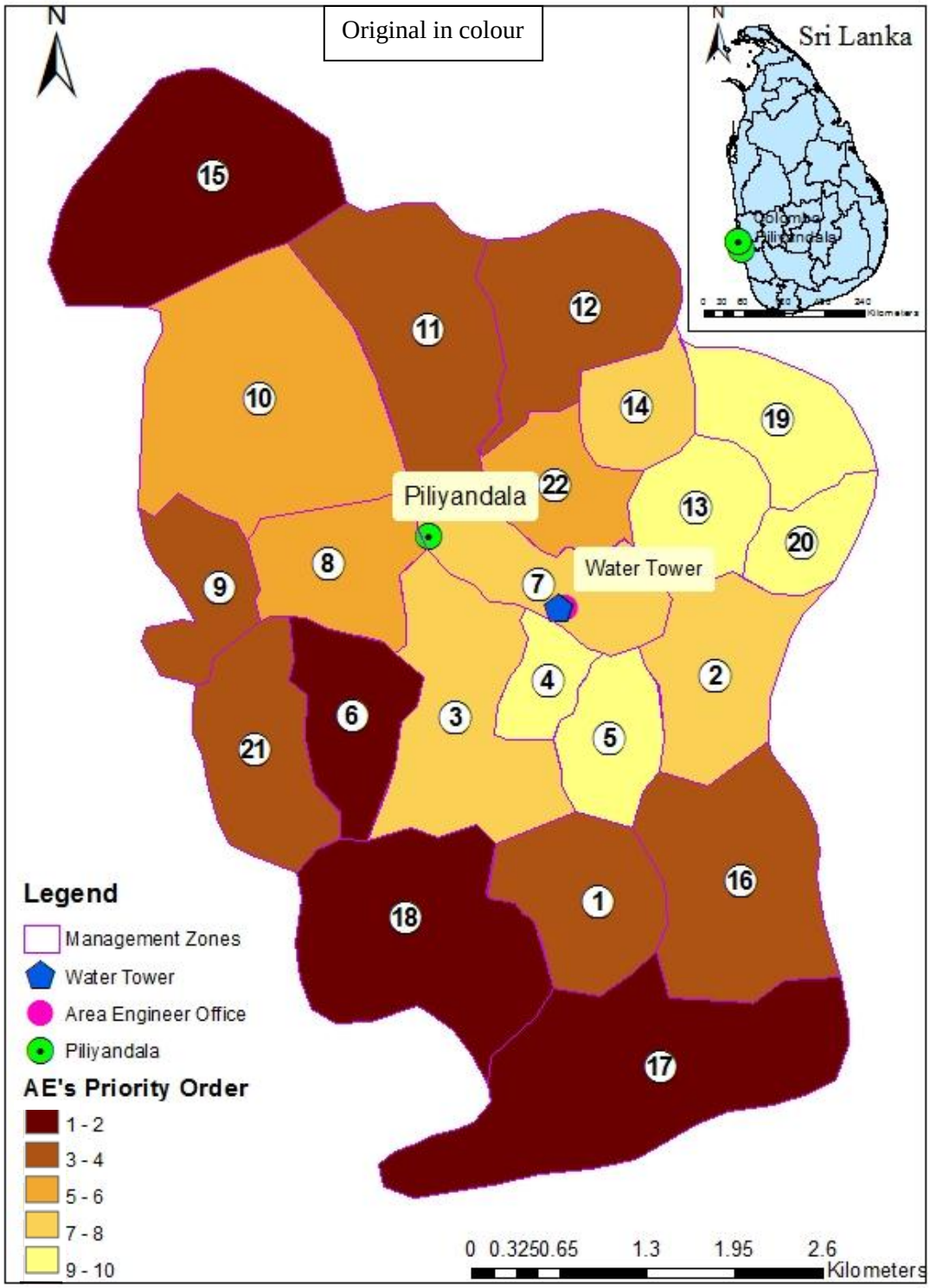

Figure 5.4: Area Engineer's Priority Order

5.1.4 Stakehoder survey

5.1.4.1 General

In case of Water Supply System Management, it is important that concerns of all stakeholders are sufficiently incorporated to ensure System Sustainability. In this task the organizational requirements and the recipient stakeholder interests must be looked after. As such it is very important to incorporate concerns of the NWSDB by involving the system managers and also field level managers to capture pressing concerns of water supply recipients. Hence a representative sample of NWSDB Managers and Engineers from Operations & Maintenance, Planning & Designs, Construction, Project Management, etc., were used as stakeholders.

5.1.4.2 Main and sub parameters

Initially the parameters influencing Water Supply System management was identified through the literature survey (Table 3.1). This was followed by preliminary discussion with the senior management of NWSDB who had vast experience on managing water supply systems. The group involved in the discussions are indicated in Table 5.4. The group after detailed discussions on parameters recommended the division of criteria into two as main and sub groups. List of main and sub parameters identified during discussions are in Table 5.5. The sub parameters for System Reliability was taken from Consumer Complaints recorded in the NWSDB online database.

Table 5.4 : Stakeholder Group for Preliminary Discussions

#	Name	Designation	Division
1	S.G.J Rajkumar	Deputy General Manager	Development
2	D.M.S.S. Dissanayake	Area Engineer – Kolonnawa	Regional Support Centre (Western)
3	B.A Fernando	Senior Engineer	Planning and Design Section
4	P. Fernando	Deputy General Manager	Water Supply Projects
5	M.S.M Riswan	Chief Engineer	Development

Table 5.5 : Preliminary List of Main and Sub Parameters

#	Main Criteria	#	Sub Criteria
1	Income Generation	1	New Connections
		2	Bill collection
2	System Sustainability	3	Operation and Maintenance Cost
		4	Salaries and Overtime Cost
		5	Transport Cost
3	System Losses	6	Non Revenue Water (NRW)
4	System Reliability	7	Low Pressure
		8	No water
		9	Water Quality
		10	Defective Meters
		11	Leak - Mains
		12	Leak - Connections
		13	Leak - Near meter
		14	Leak - Night time
		15	Leak -Stop valve

5.1.4.3 Development of questionnaire

The preliminary study revealed that 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.

Stakeholder Data collection form was designed to capture data in three stages. In this data collection program several methods were used to capture the degree of importance given to each criteria.

1. Identification of Main Parameters
2. Identification of Priorities
   - 2.1 Sub Parameters
   - 2.2 Main Parameters

The questionnaire used for the Stakeholder Survey are in Annex B 1, B 2.1, and B 2.2 (Annex B).

5.1.4.4 Selection and responses received

One hundred data collection forms were distributed among Engineers from various divisions in the NWSDB. Distribution within each division was restricted only to those who had water supply system management experience. Seventy eight forms were collected for analysis. Responses received for the Survey is summarized in Table 5.6.

Additional respondent details are in Table B.1.1 and B.1.2 of Appendix B. A typical respondent filled data sheet set is in Appendix B 3, B 4.1 & B 4.2.

The Stakeholder confirmation of main and sub parameters are listed in Table B.2.1 – B.2.3 which the details of "other" parameters expressed by stakeholders are in Table B.3.1 and B.3.2 (Appendix B). Priority scores given by each stakeholder for Main (Table B.4.1 – B.4.5) and Sub (Table B.5.1 – B.5.5) criteria are in Appendix B.

Table 5.6 : Summary of Stakeholder Survey Responses

#	NWSDB Division	Number of Data Collection Forms	
		Distributed	Colloected
1	Development	5	4
2	Planning and Design	35	29
3	Corperate Planning	5	3
4	Additional General Manager Offices	5	4
5	Policy and Planning	5	3
6	Sewerage	1	1
7	Opeeration and Maintenance	25	20
8	General Manager Office	2	1
9	Research and Development	5	3
10	Mapping	5	5
11	Water Supply Projects	1	1
12	Corperate Services	1	1
13	Rural Water Supply	2	1
14	Non Revenue Water	1	1
15	Planning and Strategy	2	1
	Total	100	78

5.2 Data Checking

5.2.1 Missing data, pattern and trends

Cheking of all data was carried out in a systematic manner. Checks investigated missing data, observed the patterns, screened for inequilities and incompatibilities. Also the cumulative behaviours were observed to capture any unexpected or unacceptable trends in the stakeholder behaviour wih respect to water utilization. Graphical plots of base data showed that there are no missing values in the inflows to the Piliyandala water tower, consumption, Consumer complaints and Expenditure data. Inflows and consumption data are in Table 5.7.

Table 5.7 : Inflow and the Consumption Data

Year	No. of Connections	Inflow m3	Total Consumption m3	Inflow per connection m3/year	Consumption per connection m3/year
2001	5	Not available	2101	-	245.12
2002	7061		1299989		184.11
2003	9458		1856771		196.32
2004	10201		2050951		201.05
2005	10193	2102410	2029577	206.26	199.11
2006	10173	2219611	1905197	218.19	187.28
2007	13426	3388414	2587921	252.38	192.75
2008	14083	3793591	2996553	269.37	212.78
2009	16273	3584918	3129186	220.3	192.29
2010	18150	4255201	3415789	234.45	188.2
2011	19777	5121111	3808405	258.94	192.57
2012	21322	5699519	4244545	267.31	199.07
2013	22487	6681450	4402063	297.13	195.76
2014	24309	6761413	4756608	278.14	195.67

Figure A.8 – A.10 shows a comparison of inflows to the main supply tank and the consumption data. Figure A.1 – A.3 shows the inflow data and Figure A.4 – A.7 shows the consumption data separately.

Yearly consumption and the number of connections for each year drawn in Figure 5.5 shows that from 2001 to 2014 the total consumption varies similar to the number of connections.

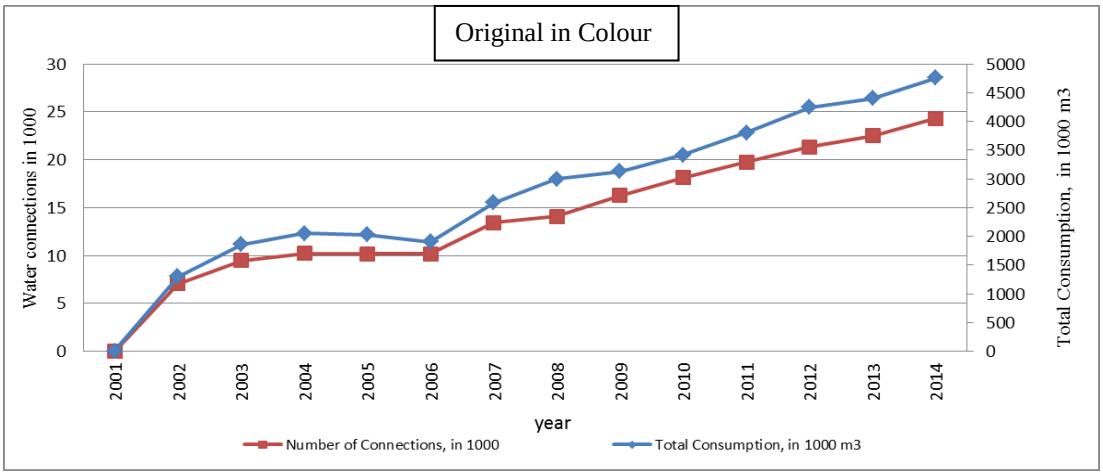

Figure 5.5: Water Consumption and Water Supply Connections

Monthly Water Inflows to the Piliyandala Water Tower are drawn in Figure 5.6a. In the considered 10 years period, a regular water inflow pattern within a year could not be observed. It could be observed that Inflow to the Piliyandala Tower as expected has increased with the time. Variation of monthly inflows over the years from 2005 – 2014 is shown in Figure 5.6b.

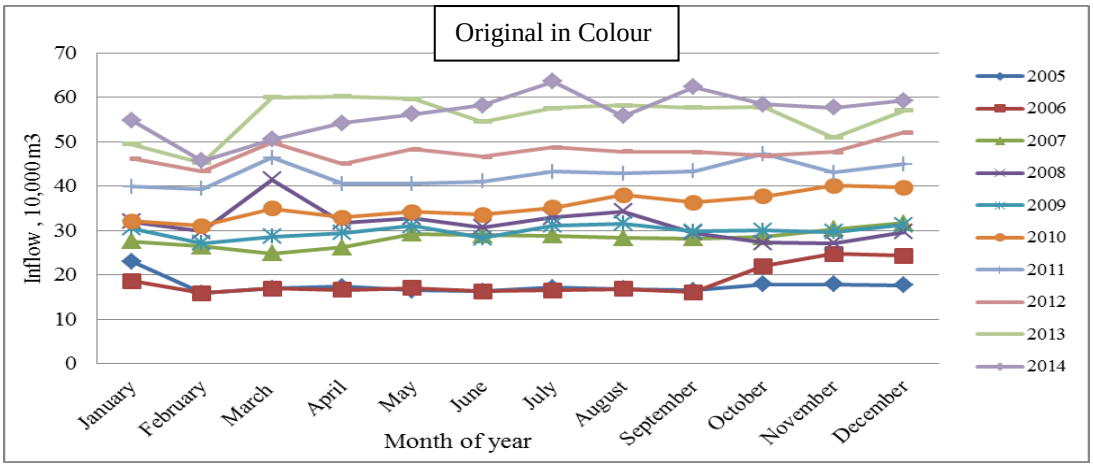

Figure 5.6a : Monthly Variation of Water Inflows to the Piliyandala Water Tower (2005-2014)

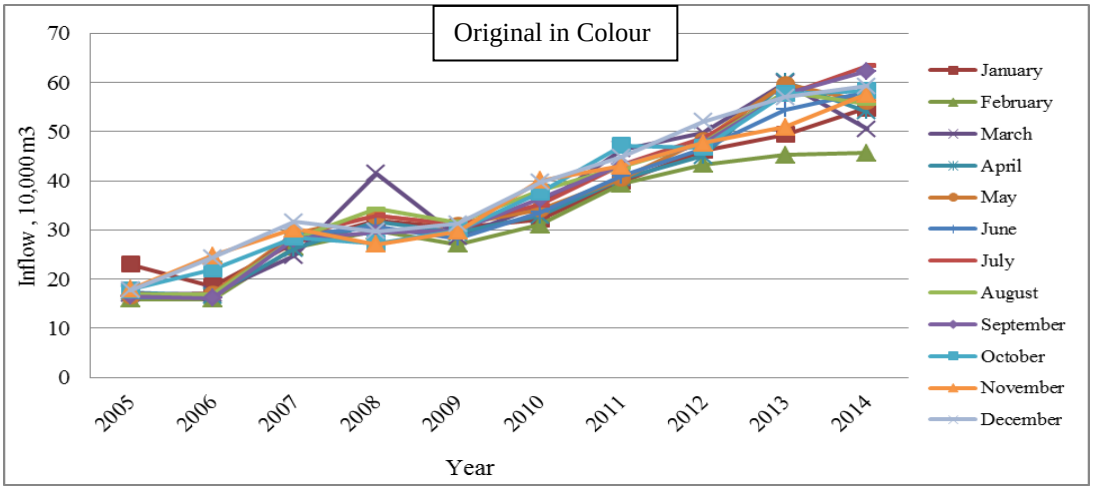

Figure 5.6b: Annual Variation of Water Inflows to the Piliyandala Water Tower

5.2.2 Comparison with Annual Report

Collected Data were plotted and numerical values were computed to check with the general information provided in the Annual Report. According to water consumption data, average yearly consumption per connection was 198.7 m3. Consumption data had increased with time. Inflows and Consumption data were checked for magnitude, pattern, extremes and inequalities of the data. The water supply scheme which was started in 2001 had a record of 2101 m3 as the annual consumption. Average, Maximum and Minimum values of inflow and consumption were obtained and graphs were drawn. Consumption rate per connection (data period 2001 – 2014) and Inflow rate per connection (data period 2005 – 2014) were also checked. Consumption data had increased with the number of connections. Consumer complaints of year 2014 to year 2015 were obtained from the 24 hr online database of NWSDB. Yearly expenditure for Piliyandala – Kesbewa WSS were obtained from NWSDB Income and Expenditure report of 2015. Water inflows to the Piliyandala Water Tower and the total water consumption are in the Figure 4.10. According to the NWSDB-2 (2014), Non Revenue Water for the WSS was calculated.

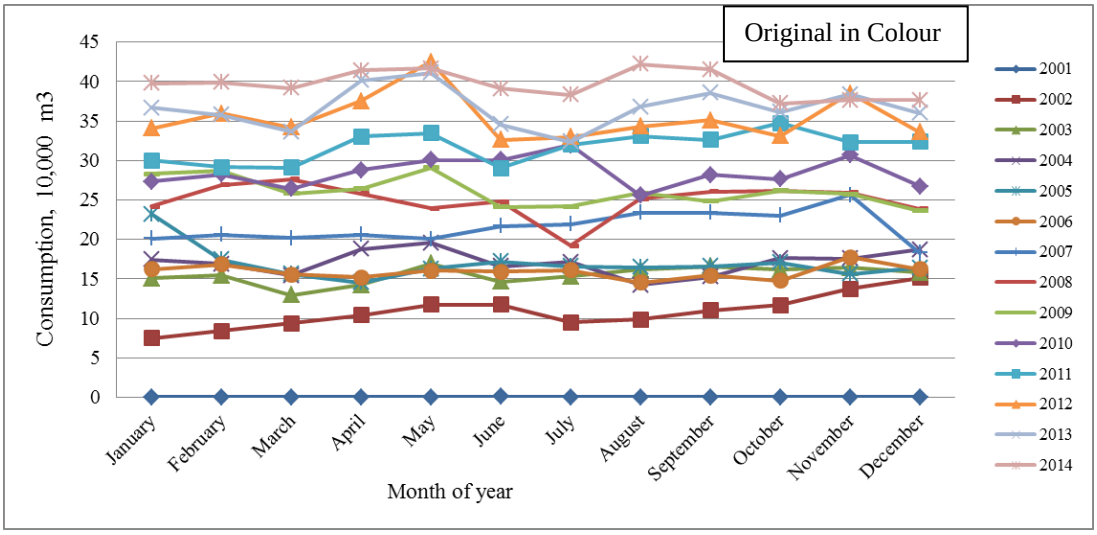

Figure 5.7: Monthly Distribution of Water Consumption

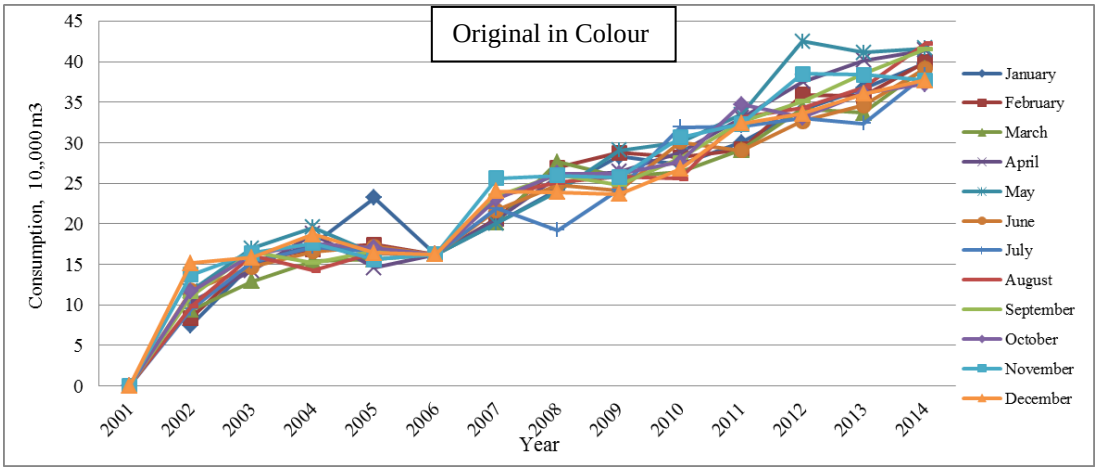

Figure 5.8: Annualy Distribution of Water Consumption

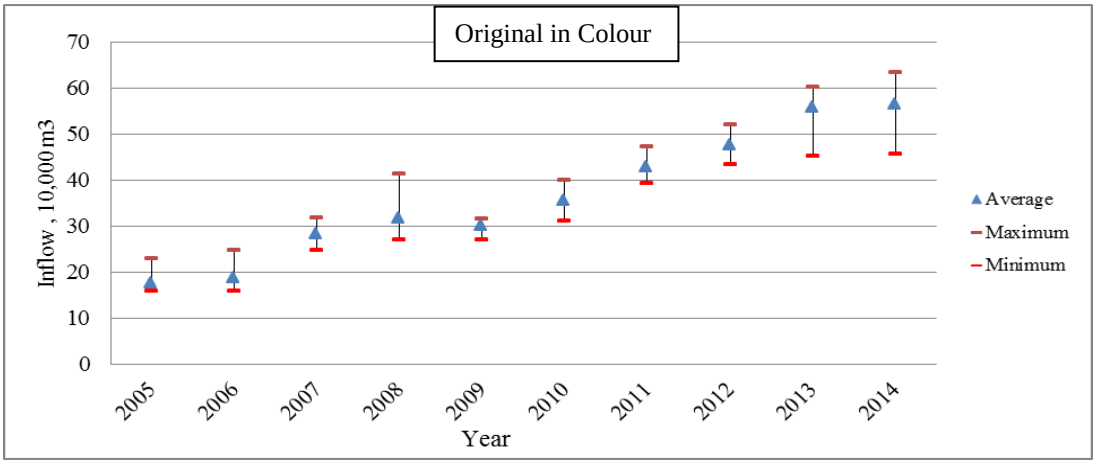

Figure 5.9 :Water Inflows to the Piliyandala Water Tower

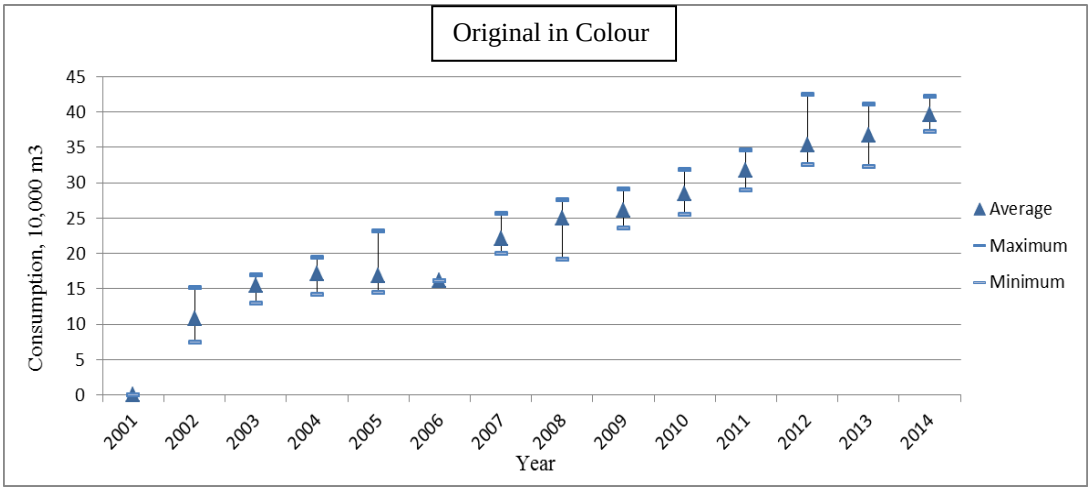

Figure 5.10 :Water Consumption in Piliyandala – Kesbewa WSS

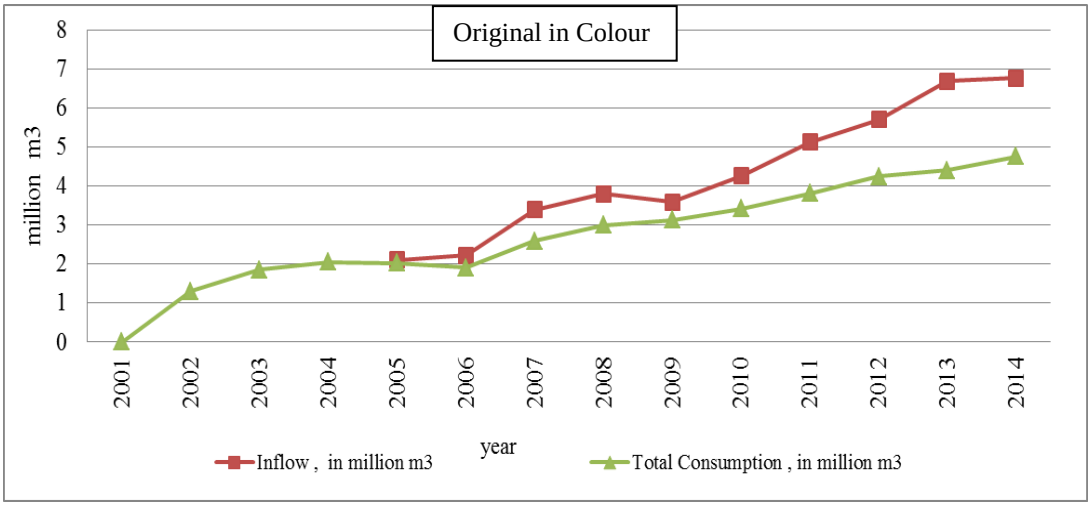

Figure 5.11: Comparison of Water Inflows with the Water Consumption

Consumption data were checked against inflow data. The differences in each year were compared with Non-Revenue Water (NRW) percentages calculated and published in NWSDB Annual Report (NWSDB-3). NRW for the year 2013 was 34.12% and this agreed quite well with the NWSDB Annual Report value of 33.43%

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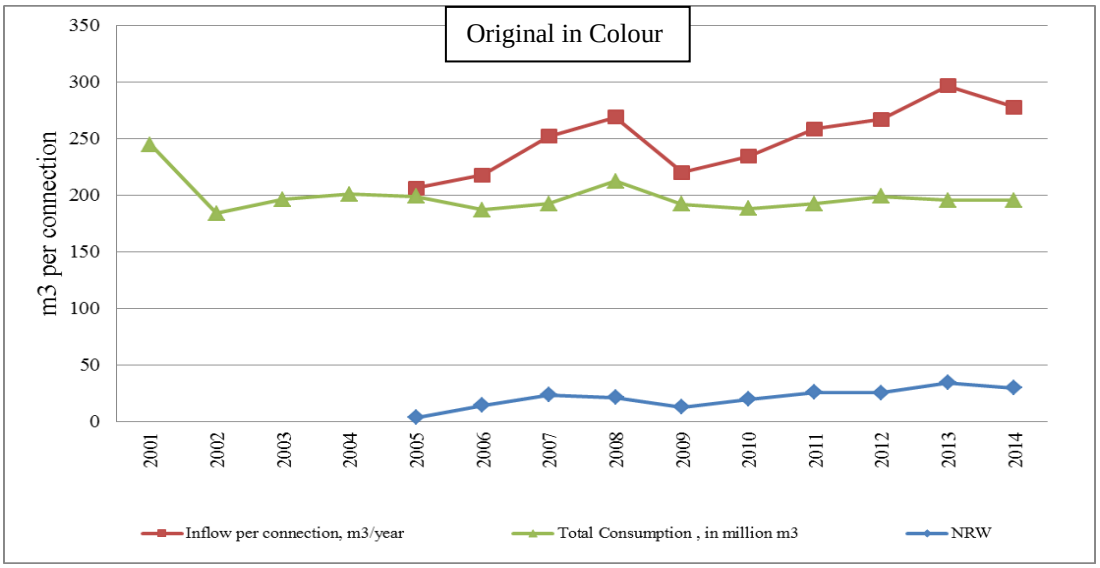


Figure 5.12: Water Inflow per Connection and the Consumption per Connection

Table 5.8: NRW Percentage of the Piliyandala – Kesbewa WSS

Year	Inflow per connection, m3/year	Consumption per connection, m3/year	loss per connection, m3/year	NRW %
2001	Not available	245.12	-	-
2002		184.11		
2003		196.32		
2004		201.05		
2005	206.26	199.11	7.15	3.46
2006	218.19	187.28	30.91	14.17
2007	252.38	192.75	59.62	23.62
2008	269.37	212.78	56.60	21.01
2009	220.30	192.29	28.01	12.71
2010	234.45	188.20	46.25	19.73
2011	258.94	192.57	66.38	25.63
2012	267.31	199.07	68.24	25.53
2013	297.13	195.76	101.36	34.12
2014	278.14	195.67	82.47	29.65

Average consumption per connection per year was calculated as 198.7 m3/year/connection. According to the guidelines of NWSDB (NWSDB-4, 1989), consumption per connection per year is calculated as 192.7 m3/year. The guideline recommended per capita consumption is 120 l/capita/day and the family size as 4.4.

Avearage Monthly Household Consumption from base data of Piliyandala –Kesbewa is 16.56 m3/connection while Average Household Monthly Consumption as per guideline is 16.9 m3 (NWSDB - 3).

5.2.3 Stakeholder responses

During the design of questionnaire a key factor under consideration was the ease of obtaining stakeholder responses. Hence requested scores for main criteria was out of a total value amounting to 100 (Table B.4.1 – B.4.5). In case of sub criteria, the stakeholders were requested to score each item to total as 1000. (Table B.5.1 – B.5.5). These data were checked for sum total and disparities in recording were verified and disbursed to match the stipulated total. The corrected main criteria responses were in order. The corrected sub criteria are in Table B.6.1 – B.6.5 (Appendix B)

Furthermore, the main criteria responses were compared with those aggregated with the use of sub criteria responses corresponding to each main criteria (Table B.7.1 – B.7.5). The comparison (Figure C.1, Table B.8.1 – B.8.4) showed that the sub criteria responses cannot be related to the main criteria responses obtained directly. This reflected that the stakeholders had provided a relative degree of importance corresponding to each sub criteria and therefore those values (Table B.5.1 – B.5.5) should only be used to identify pairwise comparisons.

6. ANALYSIS AND RESULTS

6.1 MCDA Conceptualisation

Review of Literature enabled the selection of Analytical Hierarchy Process (AHP) as the tool for the MCDA model. The criteria from the situation analysis is in section 3.6 (Table 3.1). Based on the Literature Survey, a conceptual AHP framework for criteria (Figure 6.1) was selected for the present work. In this framework spatially distributed management zones were taken as the alternatives.

In the Piliyandala – Kesbewa WSS, other than the Area Engineer, there are three Engineering Assistants and 11 Meter Readers. The Management priority with respect to spatial regions is not documented. Field work revealed that the prevailing time tested zoning had been determined in consultation with the Engineering Assistants and Meter Readers. The Identification details are also mentioned in Table B.3.1 and B.3.2 (Appendix B). In a similar manner the prioritization of management zoning had not be carried out in a formal manner. Upon inquiry it could be identified that the prioritisation was semi methodical and therefore was carrying a mismatch between the choice of Engineering Assistants and the Area Engineer. In case of WSS management, the Area Engineer is the Incharge. Therefore in this work, the Area Engineer was requested to priotize the management zones in a scale of 1-10 based on the past management experience the organisational vision and the Recipient Stakeholder aspirations. The field identified priority zoning as discussed above are in Figure 5.4.

Criteria associated with the WSS project management are shown in Table 3.1. The Management zones associated with the project area are in Table 6.7. Accordingly the conceptual MCDA for the Stakeholder Survey was identified and is shown in Figure 6.2.

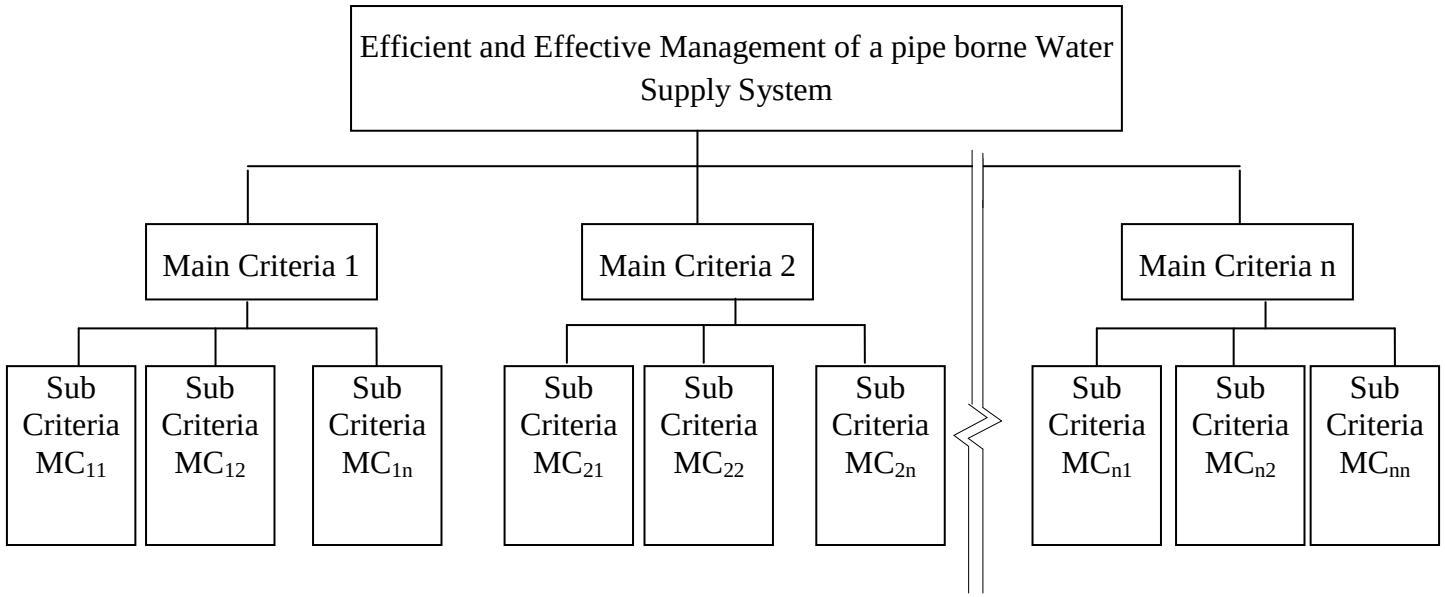


Figure 6.1 : MCDA Model Framework for Main and Sub Criteria

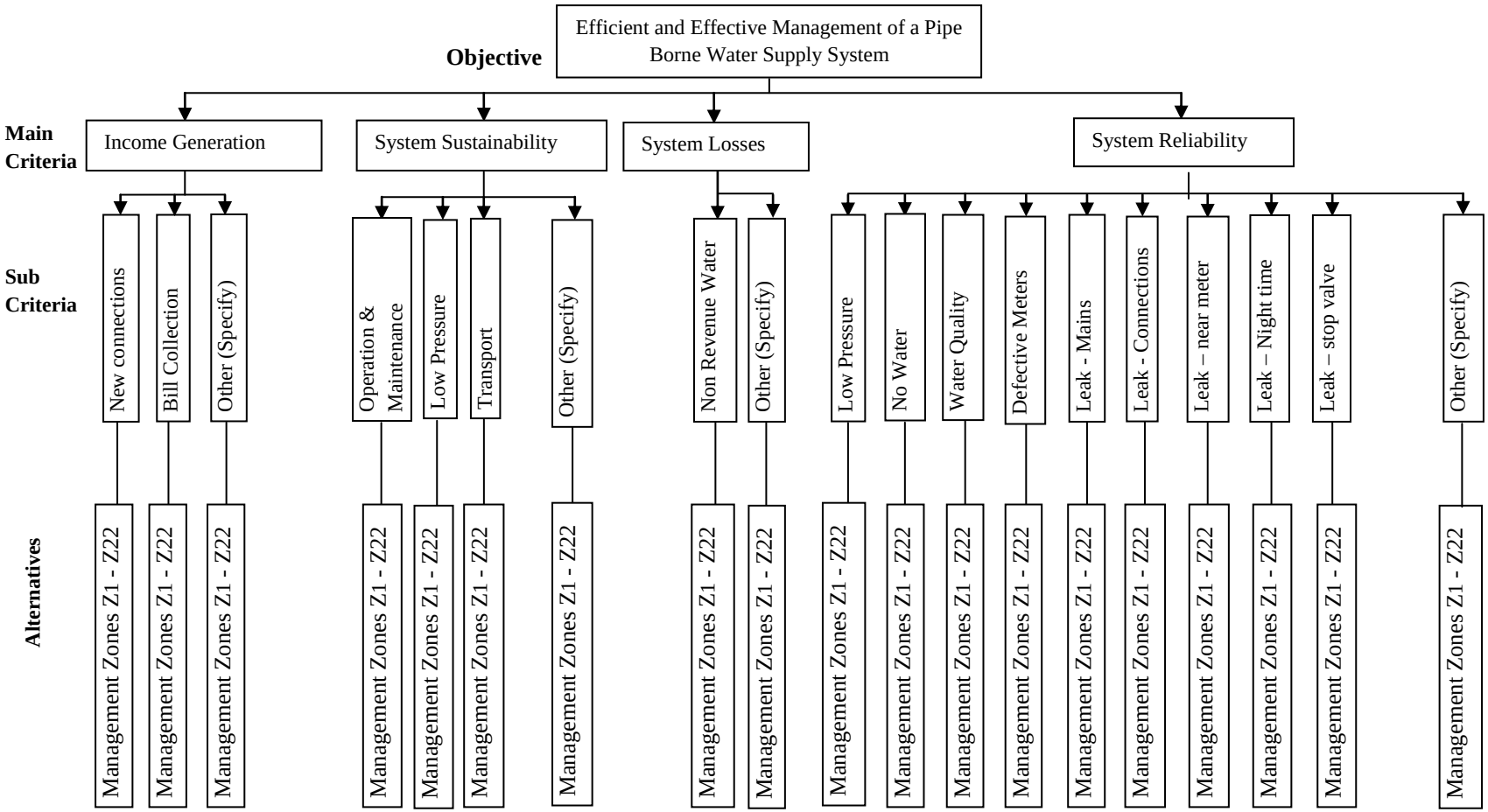


Figure 6.2: Conceptual MCDA for Questionnaire Development

6.2 Criteria Identification

6.2.1 Stakeholder responses

6.2.1.1 General

Piliyandala Kesbewa WSS area is approximately 33 km^2 with a water supply coverage of 44% . Population density was 3621 persons/ km^2. Number of connections in 2014 was 24309 Water Supply. Average daily supply between 2010 to 2014 was 15,627 m^3. Accordingly average per day consumption is 120 litres per capita. In the project area, the average annual operation and maintenance cost was approximately Rs. 5.6 million while salaries and overtime costs and transport costs were approximately Rs. 2.5 million and 0.8 million respectively. The average NRW per year over the five years period between 2010 – 2014 was 26.9%.

6.2.1.2 Survey sample

Stakeholder sample (Table 5.5, B.1.1) consisted of 78 NWSDB engineers. The classification of sample according to designation and work experience are in Table 6.1 and 6.2 respectively.

Table 6.1 : Stakeholder Sample used for Parameter Identification

NWSDB Position	
Additional General Manager	2
Deputy General Manager	2
Assistant General Manager	7
Chief Engineers	31
Senior Engineers	36
Total	78

Table 6.2 : Work Experience of the Sample used for Parameter Identification

Type of Experience of Officers	
Operation & Maintenance	20
Planning & Design	29
Construction	4
Project Management	5
Other	20
Total	78

6.2.1.3 Main criteria

The four main criteria identified from the survey data were i) Income Generation ii) System Sustainability iii) System Losses and iv) System Reliability (Table B.8.1 – B.8.4). Comparison of questionnaire responses did not show a relationship between those for main criteria and the sub criteria. The stakeholder preferences for main criteria and associated sub criteria were compared to evaluate the more consistent stakeholder response (Figure C.1 in Appendix C). The absolute error between the two were used as the indicator. The main criteria scores were recognised as those with better reliability.

Accordingly % exceedance of probability curves for the main criteria scores were plotted (Figure 6.3a). Since the sample contained important stakeholders from various perspectives, the variability of responses needed attention. In order to overcome the issue of high variability, the present work classified the responses as high, medium and low. Subdivisions were carried out observing the breaks in the exceedance curves. Sub criteria scores were also plotted in a similar manner (Figure 6.3b)

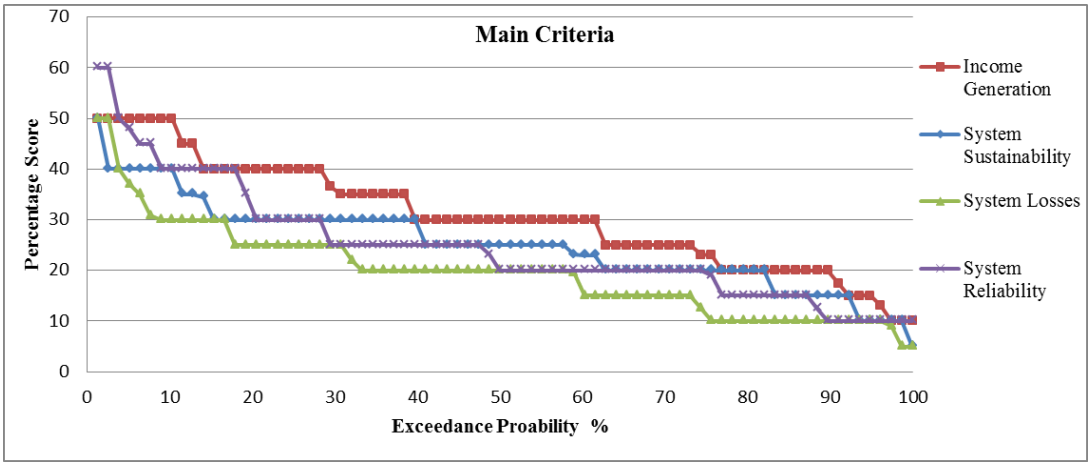


Figure 6.3a : Comparison of Stakeholder Responses for Main Criteria

Classification was carried out by visually observing the breaks in the probability of exceedance curves. Classifications given to each main criteria are shown in Figure C.2 other than the three response classes, another class was defined as the average of all. Classified average scores for each main criteria are in Table 6.3.

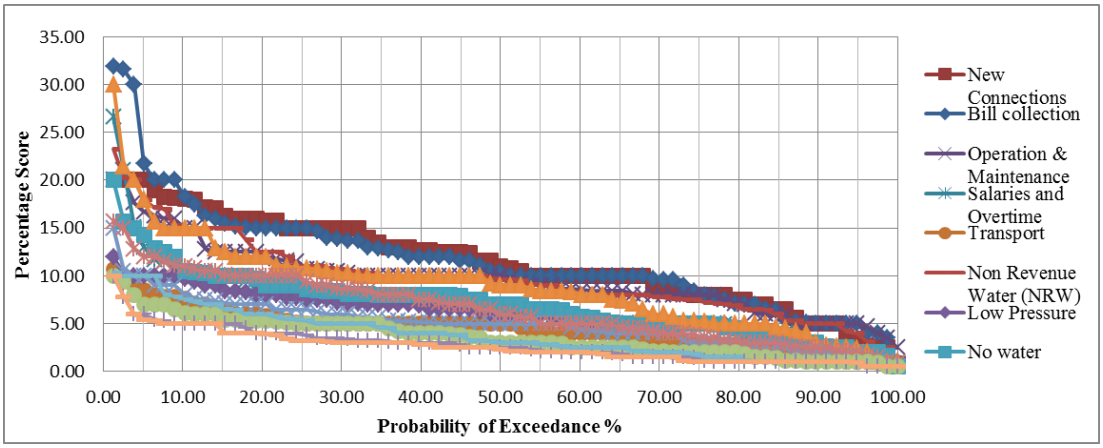


Figure 6.3b : Comparison of Stakeholder Responses for Sub Criteria

Table 6.3 : Classification of Stakeholder Responses for Main Criteria

Description of Classification	Main Criteria			
	Income Generation	System Sustainability	System Losses	System Reliability
Class I – High Response	44.09	33.37	30.32	39.68
Class 2 – Medium Response	31.60	24.65	20.07	22.17
Class 3 – Low Response	19.89	16.50	11.45	12.83
Class 4 - Average of all Response	30.62	24.98	19.69	24.71

6.2.1.4 Sub criteria

Stakeholder responses for sub criteria were in Table B.5.1 – B.5.5 (Appendix B). The Probability of exceedance of stakeholder responses for each parameter and the classifications are shown in the Figures C.3, C.4, C.5 and C.6 (Appendix C). The corresponding values are in Tables 6.4a and 6.4b.

Table 6.4a : Classification of Stakeholder Responses for Sub Criteria

	New Connections	Bill collection	Operation and Maintenance	Salaries and Overtime	Transport	Non Revenue Water (NRW)	Low Pressure	No water	Water Quality
Class 1 - High Response	16.86	18.74	14.46	10.64	7.41	15.79	8.37	12.22	15.84
Class 2 – Medium Response	11.33	11.09	7.00	6.77	4.74	10.04	5.46	7.77	9.51
Class 3 – Low Response	5.94	5.66	2.50	3.87	2.28	6.25	2.28	3.91	4.18
Overall Average	**11.37**	**11.69**	**9.62**	**6.88**	**4.44**	**9.71**	**6.05**	**7.04**	**8.96**

Table 6.4b : Classification of Stakeholder Responses for Sub Criteria

	Defective Meters	Leak - Mains	Leak - Connections	Leak - near meter	Leak - Night time	Leak -stop valve	Total
Class 1 - High Response	7.84	10.56	5.96	5.26	6.67	5.19	100
Class 2 – Medium Response	4.79	5.78	3.24	2.74	3.15	2.63	100
Class 3 – Low Response	2.18	2.49	1.46	1.09	1.27	1.09	100
Overall Average	**4.99**	**6.53**	**3.59**	**2.76**	**3.76**	**2.60**	100

6.3 MCDA Model Framework

6.3.1 Main criteria

The four classes of main criteria were then evaluated to identify the probable grouping of main criteria weights. Sixteen groups are shown in Table 6.5. The graph indicating the groups demonstrated the presence of three combinations showed by the trend lines in Figure 6.4.

Each of these combinations demonstrates a set of main criteria priorities for the determination of pairwise comparisons in AHP.

6.3.2 Priority combinations

The three priority combinations determined as mentioned above, requires a critical evaluation of the responses. Therefore considering the ease of identification the average of all responses was treated as a priority combination (combination C4). Since the responses were having a similar diversification demonstrated by almost equally competent water managers, the average case could be treated as a rational selection. The four probable combinations pertaining to stakeholder prioritization are shown in Table 6.6.

Table 6.5 : Possible Priority Score Groups for Main Criteria

	Main Criteria Priority Score					
Grouping	Income Generation	System Sustainability	System Losses	System Reliability	Total	Combination
1	43.3	32.8	11.3	12.6	100	C1
2	43.4	24.3	19.7	12.6	100	
3	43.1	24.1	11.2	21.7	100	
4	32.3	34.1	20.5	13.1	100	
5	32.1	33.8	11.6	22.5	100	
6	31.8	24.8	30.5	12.9	100	
7	32.1	25.0	20.4	22.5	100	C2
8	31.4	16.4	30.1	22.0	100	
10	20.6	34.6	31.4	13.3	100	
11	20.8	34.9	21.0	23.2	100	
13	20.5	25.4	31.2	22.8	100	
9	31.8	16.6	11.5	40.0	100	C3
12	19.1	32.0	11.0	38.0	100	
14	19.1	23.6	19.2	38.0	100	
15	20.8	25.8	12.0	41.5	100	
16	20.7	17.2	20.9	41.3	100	

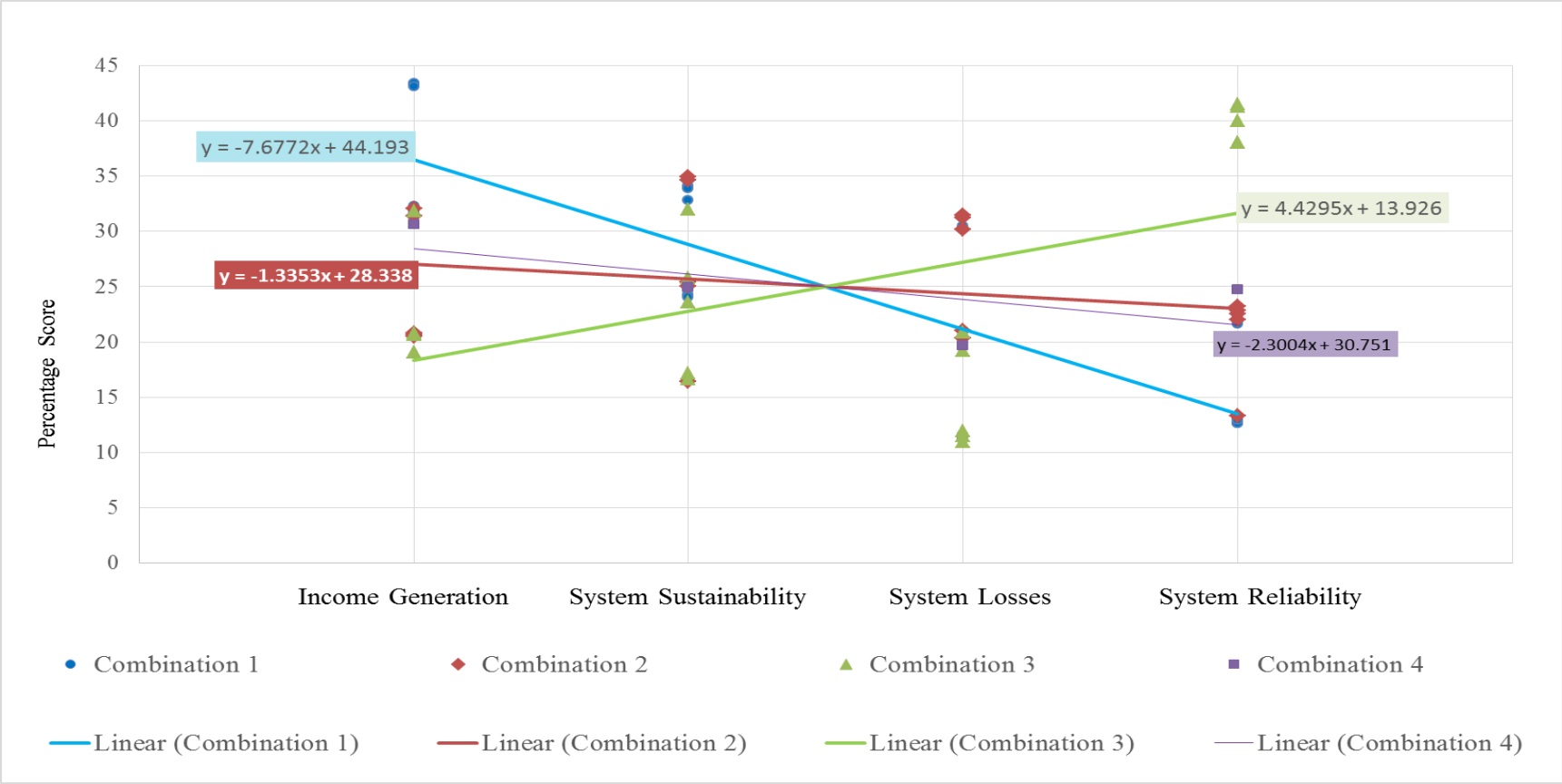


Figure 6.4 : Main criteria Response Groupings and Representative Combinations

Table 6.6 : Main Criteria Score Combinations from Stakeholder Survey

	Main Criteria				
Options	1. Income Generation	2. System Sustainability	3. System Losses	4. System Reliability	Total
Combination 1 (C1)	37.7	29.0	17.4	15.9	100
Combination 2 (C2)	25.1	27.3	26.8	20.8	100
Combination 3 (C3)	22.3	23.0	14.9	39.8	100
Combination 4 Overall Average (C4)	30.62	24.98	19.69	24.71	100

6.4 Alternatives

6.4.1 Management zones

Twenty two Management zones of Piliyandala – Kesbewa WSS (Table 6.7) were identified with the field level maps (Figure 5.3) and discussions with Area Engineer, Engineering Assistants and Water Meter Readers.

In the developed MCDA model, it is necessary to identify pairwise comparison of management zones to determine associated weights. However in an environment when there is a lack of designated guidelines for priority concerns, it is necessary to identify a rational approach for this purpose. Accordingly major influencing indicators that could be quantified were selected. Each sub parameter was linked to one or more service delivery factors using the judgement that was confirmed through consultation with senior NWSDB managers.

Table 6.7 : Details of Management Zones in Piliyandala – Kesbewa WSS

Management Zone ID	Area included
Z1	Batakettara South, Polgaha Kottanuwa road, Devala road, Pragathi Mawatha, Gonamaditta road(part), Ekamuthu Uyana, Newcity 2, Doolammahara
Z2	Kesbewa East, Liberty Park, Vihara Mawatha
Z3	Madapatha road, Kolamunna, Atigala Mawatha, Bandipitiya road, Swarnapayawatta, Gedabuwana road, Millagahawatta road, Hedigama road
Z4	Gedabuwana road, 5th cross street
Z5	Mandawila road,Gonamaditta road(part), lake road
Z6	Weera Uditha Mawatha, Prajamandala road, New Hadigama road, Doowawatta road
Z7	Awasa road, Kottawa road, Ethulgewatta road, Kopiwatta road, Mampe West, Vishwakalawa road, Devala road, Halgahapokuna road, Old Kesbewa road, Wata Mawatha
Z8	School lane, Thumbovila West, Suwarapola, Church road, Bauddhaloka Mawatha, Jayanthi road, Kudamaduwa road
Z9	Wewala West, Gangabada road, Saman Mawatha
Z10	Thumbovila South, Karadiyana road, Church road, Murakutiya road, Thumbovila road, Gangarama road, Samagipura, Battiyawatta road
Z11	Bokundara, Colombo Horana road, Sirimangalawatta road, Makuludoowa road, Jaya Mawatha, Weera Mawatha, Arawwala Bokundara road, Pasal Mawatha, Rathna Mawatha
Z12	Koskanattha road, Abeyrathna Mawatha, MihiraMawatha, Priya Mawatha, Paligedara, Kaliyammahara, Devala road, Weda Mawatha, Niwanthidiya
Z13	Mavittara North & South, Kottawa road, Gurugama, Gammanawatta road, Kesbewa Kosgashandiya road, Pinidiyagara Watta road, Samindu lane, Nidahas Mawatha
Z14	Makuludoowa, Galawilawatta road, Mavittara North, Maharagama road
Z15	Werahera South, Katuwawala, Neelammahara
Z16	Bandaragama road, Sudarshana road, Wijithapura, Batuwandara
Z17	Madapatha road, Ferry road, Polhena, Madapatha
Z18	Delthara East, Kotagedara road, Saraboomi, Madapatha road, Dampe road
Z19	Nampamunuwa, Jayanthi Vidyala Mawatha, Gorakapitiya road, Siddamulla
Z20	Honnanthara, Vihara Mawatha, Kamhala road, Samupakara Mawatha
Z21	Meegahawatta road, Dampe road, Thotupola road, Suwarapola West, Hedigama
Z22	Mampe, Vishwakalawa, Delthara, P.S Perera Mawatha, Prabudu Mawatha, Piliyandala by pass road

6.4.2 Income Generation

Income Generation in a Water Supply System is through the provision of (i) new connections and (ii) supply of drinking water (Bill Colection).

1. New Connection Potential :

In this study it was assumed that the New Connection Potential can be used to represent the zonal prioritization attraction to a water supply system management. Accordingly the new water supply connection potential was taken as directly proportionate to the uncovered and covered population and inversely proportionate to the prevailing number of connections. For this evaluation, data of Piliyandala – Kesbewa WSS from 2010 to 2014 were used (Table 6.8).

Table 6.8 :Total Population per Water Supply Connection

Management Zone ID	No. of Water Supply Connections (5 year average)	Covered & uncovered Population (5 year average)	Total Population/ Water Supply Connection
Z1	371	7348	20
Z2	486	8058	17
Z3	2594	9974	4
Z4	568	2456	4
Z5	581	4596	8
Z6	361	4461	12
Z7	608	6749	11
Z8	1088	6638	6
Z9	1054	3589	3
Z10	1710	11911	7
Z11	1029	6813	7
Z12	586	5441	9
Z13	551	1921	3
Z14	419	4694	11
Z15	2524	9353	4
Z16	1476	8755	6
Z17	726	8583	12
Z18	1665	4709	3
Z19	527	3445	7
Z20	486	1402	3
Z21	1127	5964	5
Z22	674	4138	6

2. Bill Collection

In case of Bill Collection, the assumption was that it is proportionate to the water consumption by stakeholders. This was because the bill payments are staggered in time and hence would lead to a distorted picture of income generation in a particular period. The average water supply consumption between 2010 – 2014 at each management zone is in Table 6.9.

Table 6.9 :Average Consumption

Management Zone ID	Consumption 5 years average (m^3)
Z1	70328
Z2	94515
Z3	508399
Z4	107643
Z5	110399
Z6	68678
Z7	114279
Z8	249487
Z9	206834
Z10	332645
Z11	228474
Z12	110192
Z13	105032
Z14	73661
Z15	506632
Z16	267423
Z17	123889
Z18	328628
Z19	96200
Z20	91909
Z21	213208
Z22	118234

6.4.3 System Sustainability

The sub criteria associated with the System Sustainability were identified as Operation and Maintenance Cost, Salaries and Overtime Cost, and Transport Cost incurred by the project during operations.

1. Operation and Management Cost :

Operation and Management Costs for Piliyandala – Kesbewa WSS were not available for the study. Hence as an alternative, it was assumed that Operation and Management Costs are proportionate to the number of complaints recorded in the NWSDB Central database.

2. Salaries and Overtime Cost :

Salaries and Overtime Costs were also unavailable to use for study computations. The number of water connections in each zone is an indicator of the proportion of staff inputs required for the management of the water supply services. Hence the alternative weights computation used the number of water connections in lieu of the salaries and overtime costs.

3. Transport Cost

Transport Costs that could be attributed to each management zone were unavailable. Transport Costs that should be spent is taken as the routine inspections for monitoring of services. In the absence of details this research assumed that the Transport Cost to manage the water supply system is proportionate to the distance from a central office to the centre of each management zone. Hence distance from Area Engineer's Office to the centre of each management zone was used to determine the alternative weights for the Sub criterion Transport Cost. The parameters to assign System Sustainability weights are in the Table 6.10.

Table 6.10 : Water Supply System Management Costs

Management Zone ID	O & M Cost in Rs.(`000)	Salaries and Overtime Cost in Rs. (`000)	Transport Cost in Rs. (`000)
Z1	457.96	44.39	50.72
Z2	271.07	58.07	20.58
Z3	446.55	310.22	18.89
Z4	1.43	67.88	10.95
Z5	41.37	69.53	16.15
Z6	116.99	43.22	48.36
Z7	553.55	72.71	8.28
Z8	293.89	130.14	30.21
Z9	102.72	126.02	42.57
Z10	483.64	204.55	47.08
Z11	271.07	123.08	44.78
Z12	192.60	70.03	45.84
Z13	209.72	65.89	18.18
Z14	228.27	50.08	34.16
Z15	768.97	301.82	74.31
Z16	162.64	176.47	42.34
Z17	2.85	86.80	80.11
Z18	308.16	199.12	48.50
Z19	312.44	62.98	46.37
Z20	124.12	58.07	28.74
Z21	166.92	134.83	48.98
Z22	81.32	80.60	17.87

6.4.4 System Losses

System loss computations in NWSDB is carried out on the basis of schemes. In case of identifying the NRW for each zone the formula of NWSDB (Mallithi, 2016) was used. The water into the scheme was apportioned according to the number of connections in each zone. Percentage of water loss per connection was calculated for each management zone. NRW % for each zone computed as described above are in Table 6.11.

Table 6.11 : Zonal Distribution of NRW

Management Zone ID	NRW %	Weights
Z1	19.4	0.030731
Z2	29.2	0.046286
Z3	26.7	0.042280
Z4	32.7	0.051907
Z5	27.2	0.043074
Z6	32.4	0.051292
Z7	31.7	0.050263
Z8	13.2	0.020926
Z9	24.9	0.039487
Z10	27.5	0.043638
Z11	19.2	0.030421
Z12	31.7	0.050178
Z13	30.0	0.047482
Z14	38.8	0.061483
Z15	23.6	0.037473
Z16	35.2	0.055744
Z17	36.3	0.057601
Z18	27.8	0.044029
Z19	32.5	0.051449
Z20	29.7	0.047025
Z21	28.7	0.045466
Z22	32.7	0.051764

6.4.5 System Reliability

As it was identified (Table 6.4a & 6.4b) Consumer Complaints Database of NWSDB provided details corresponding to a characteristic groups. Complaints corresponding to each zone was totalled over the period from 2010 – 2014 and these values were taken to capture the pairwise comparison among management zones.The values are as shown in Table 6.12. Variation of Complaints corresponding to Sub Criteria are plotted in Figue 6.5.

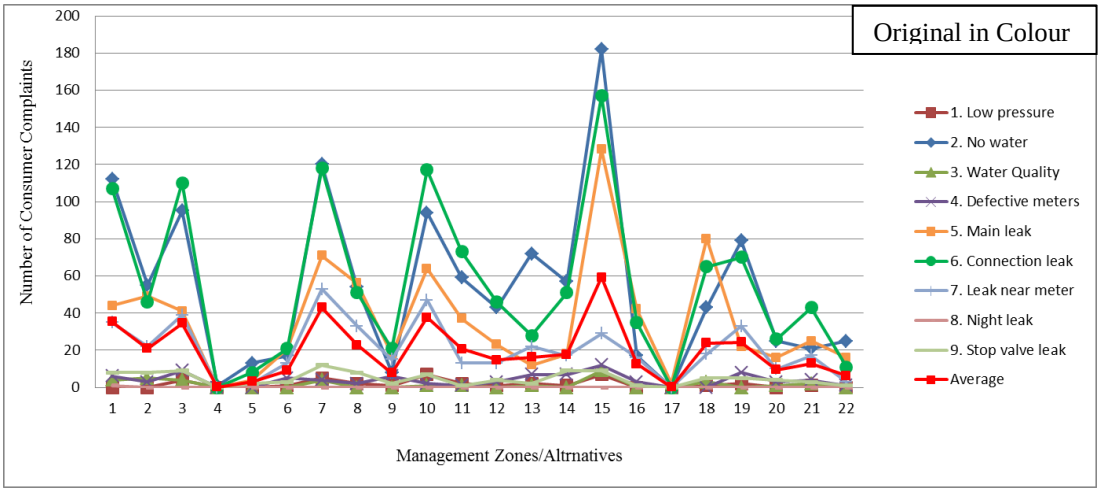


Figure 6. 5: Variation of Sub Criteria for System Reliability

Table 6.12 : Complaints Distribution in the Online Database of NWSDB

Management Zone ID	Number of Consumer Complaints								
	1. Low pressure	2. No water	3. Water Quality	4. Defective meters	5. Main leak	6. Connection leak	7. Leak near meter	8. Night time leak	9. Stop valve leak
Z1	0	112	4	6	44	107	35	1	8
Z2	0	55	5	3	49	46	22	0	8
Z3	4	95	4	9	41	110	39	0	9
Z4	0	1	0	0	0	0	0	0	0
Z5	0	13	0	0	4	8	2	0	2
Z6	1	17	0	5	21	21	13	0	3
Z7	5	120	4	4	71	118	53	0	12
Z8	2	54	0	2	56	51	33	0	8
Z9	1	8	0	6	18	21	15	0	2
Z10	7	94	1	2	64	117	47	0	7
Z11	2	59	1	1	37	73	13	0	1
Z12	1	43	0	3	23	46	13	0	4
Z13	2	72	1	7	12	28	22	0	2
Z14	1	57	0	7	18	51	17	0	9
Z15	7	182	9	12	128	157	29	0	9
Z16	0	17	0	3	42	35	16	0	1
Z17	0	0	0	0	2	0	0	0	0
Z18	1	43	3	0	80	65	18	0	5
Z19	2	79	0	8	22	70	33	0	5
Z20	0	25	1	3	16	26	10	0	4
Z21	1	21	2	4	25	43	17	0	3
Z22	0	25	0	1	16	11	3	0	1

6.4.6 Sub Criteria Normalized

The Sub Criteria indicators for each zone were normalized for ease of comparison and shown in Table 6.13. These were used as the relative weights for the MCDA model. Values of each Sub Criteria are plotted to demonstrate the probability of exceedance and shown in the Figures C.1 to C.15.

Table 6.13: Alternative Weights for Sub Criteria

Zone ID	New connection	Bill collection	O & M	Salaries & Overtime	Transport	NRW	Low Pressure	No Water	Water Quality	Defective Meters	Leak Mains	Leak Connections	Leak near meter	Leak night time	Leak stop valve
Z1	0.12	0.02	0.08	0.02	0.06	0.03	0.00	0.09	0.11	0.07	0.06	0.09	0.08	1.00	0.08
Z2	0.10	0.02	0.05	0.02	0.02	0.05	0.00	0.05	0.14	0.03	0.06	0.04	0.05	0.00	0.08
Z3	0.02	0.12	0.08	0.12	0.02	0.04	0.11	0.08	0.11	0.10	0.05	0.09	0.09	0.00	0.09
Z4	0.03	0.03	0.00	0.03	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z5	0.05	0.03	0.01	0.03	0.02	0.04	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.02
Z6	0.07	0.02	0.02	0.02	0.06	0.05	0.03	0.01	0.00	0.06	0.03	0.02	0.03	0.00	0.03
Z7	0.07	0.03	0.10	0.03	0.01	0.05	0.14	0.10	0.11	0.05	0.09	0.10	0.12	0.00	0.12
Z8	0.04	0.06	0.05	0.05	0.04	0.02	0.05	0.05	0.00	0.02	0.07	0.04	0.07	0.00	0.08
Z9	0.02	0.05	0.02	0.05	0.05	0.04	0.03	0.01	0.00	0.07	0.02	0.02	0.03	0.00	0.02
Z10	0.04	0.08	0.09	0.08	0.06	0.04	0.19	0.08	0.03	0.02	0.08	0.10	0.10	0.00	0.07
Z11	0.04	0.06	0.05	0.05	0.05	0.03	0.05	0.05	0.03	0.01	0.05	0.06	0.03	0.00	0.01
Z12	0.06	0.03	0.03	0.03	0.06	0.05	0.03	0.04	0.00	0.03	0.03	0.04	0.03	0.00	0.04
Z13	0.02	0.03	0.04	0.03	0.02	0.05	0.05	0.06	0.03	0.08	0.02	0.02	0.05	0.00	0.02
Z14	0.07	0.02	0.04	0.02	0.04	0.06	0.03	0.05	0.00	0.08	0.02	0.04	0.04	0.00	0.09
Z15	0.02	0.12	0.14	0.12	0.09	0.04	0.19	0.15	0.26	0.14	0.16	0.13	0.06	0.00	0.09
Z16	0.04	0.06	0.03	0.07	0.05	0.06	0.00	0.01	0.00	0.03	0.05	0.03	0.04	0.00	0.01
Z17	0.07	0.03	0.00	0.03	0.10	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Z18	0.02	0.08	0.06	0.08	0.06	0.04	0.03	0.04	0.09	0.00	0.10	0.05	0.04	0.00	0.05
Z19	0.04	0.02	0.06	0.02	0.06	0.05	0.05	0.07	0.00	0.09	0.03	0.06	0.07	0.00	0.05
Z20	0.02	0.02	0.02	0.02	0.03	0.05	0.00	0.02	0.03	0.03	0.02	0.02	0.02	0.00	0.04
Z21	0.03	0.05	0.03	0.05	0.06	0.05	0.03	0.02	0.06	0.05	0.03	0.04	0.04	0.00	0.03
Z22	0.04	0.03	0.01	0.03	0.02	0.05	0.00	0.02	0.00	0.01	0.02	0.01	0.01	0.00	0.01

6.5 Model Development

6.5.1 Main criteria peferences

The stakeholder opinions emphasising main criteria varied widely. This was critically evaluated in order capture the views of water supply system managers. Four combinations (Figure 6.6) were selected to use as initial values for the construction of pairwise matrices.

6.5.1.1 Main criteria – stakeholder scale

Resultant pairwise comparisons for main criteria corresponding to each combination is in Table 6.14.

Table 6.14 : Pairwise Comparison of Main criteria with respect to Stakeholder Views

Pairs of Main Criteria	Combination 1	Combination 2	Combination 3	Combination 4
Income Generation/System Sustainability	1.30	0.92	0.97	1.23
Income Generation/System Losses	2.16	0.93	1.49	1.55
Income Generation/System Reliability	2.37	1.21	0.56	1.24
System Sustainability/System Losses	1.66	1.02	1.54	1.27
System Sustainability/System Reliability	1.82	1.31	0.58	1.01
System Losses/System Reliability	1.10	1.29	0.38	0.80

Numerical values of each combination were then converted to a 1 to 9 numerical scale by assuming that the stakeholder options pertaining to each combination varied linearly between the minimum and maximum values. The pairwise combinations converted in this manner are in Table 6.15.

Table 6.15: Pairwise Comparison of Main Criteria Combinations in Saaty Scale of 1-9

Main Criteria	Combination 1	Combination 2	Combination 3	Combination 4
Income Generation/System Sustainability	3	1	1	5
Income Generation/System Losses	8	1	9	9
Income Generation/System Reliability	9	7	1	5
System Sustainability/System Losses	5	2	9	5
System Sustainability/System Reliability	6	9	1	2
System Losses/System Reliability	2	9	1	1

6.5.1.2 Pairwise matrices - Relative importance of main criteria

As described above pairwise matrices were constructed as part of the MCDA development (Table 6.16, 6.17, 6.18 & 6.19).

Table 6.16 : Pairwise Preferences of Main Criteria for Combination 1

Main Criteria	Income Generation	System Sustainability	System Losses	System Reliability
Income Generation	1	3	8	9
System Sustainability	1/3	1	5	6
System Losses	1/8	1/5	1	2
System Reliability	1/9	1/6	1/2	1

Table 6.17 : Pairwise Preferences of Main Criteria for Combination 2

Main Criteria	Income Generation	System Sustainability	System Losses	System Reliability
Income generation	1	1	1	7
System sustainability	1	1	2	9
System Losses	1	1/2	1	9
System Reliability	1/7	1/9	1/9	1

Table 6.18 : Pairwise Preferences of Main Criteria for Combination 3

Main Criteria	Income Generation	System Sustainability	System Losses	System Reliability
Income generation	1	1	9	1
System sustainability	1	1	9	1
System Losses	1/9	1/9	1	1
System Reliability	1	1	1	1

Table 6.19 : Pairwise Preferences of Main Criteria for Combination 4

Main Criteria	Income generation	System sustainability	System Losses	System Reliability
Income generation	1	5	9	5
System sustainability	1/5	1	5	2
System Losses	1/9	1/5	1	1
System Reliability	1/5	1/2	1	1

6.5.1.3 Ranking of main criteria

Ranking of Main Criteria was carried out by following the recommended Eigen Vector construction process for AHP (Saaty, 1990). Fractions in Tables 6.16 – 6.19 were converted to decimals. The 4x4 matrices of each combination were squared, row – summed and normalized by the row totals, to obtain the Eigen Vector. Verification of the Eigen Vector computed in this manner was carried out by performing several iterative computations to an accuracy of 6 decimal places. Relative ranking of each Main Criteria (Eigen Vectors) for each combination are shown in Table 6.20.

Table 6.20 : Relative Importance of Main Criteria

Main Criteria	Combination 1	Combination 2	Combination 3	Combination 4
Income Generation	0.600455	0.301764	0.352527	0.643293
System sustainability	0.277579	0.387475	0.352527	0.200086
System Losses	0.073541	0.272804	0.080172	0.064264
System Reliability	0.048425	0.037957	0.214775	0.092357

Comparison of Priority order of Main Criteria as per Stakeholder preferences is illustrated in Table 6.21.

Table 6.21: AHP Priority for each Main Criteria Combinations

Importance of Criterion	Stakeholder View Combinations			
	C1	C2	C3	C4
Most Important	Income Generation (0.6)	System Sustainability (0.4)	Income Generation (0.35) System Sustainability (0.35)	Income Generation (0..6)
Second Most Important	System Sustainability (0.3)	Income Generation (0.3)	System Reliability (0.2)	System Sustainability (0.2)
Third Most Important	System Losses (0.1)	System Losses (0.3)		System Reliability (0.1)
Least Important	System Reliability (0)	System Reliability (0)	System Losses (0.1)	System Losses (0.1)

These combinations though appeared as significantly different to each other (Figure 6.4) indicated a very similar vision except in Combination C3 where the AHP weights reflected a mismatch with the other three. Values of Table 6.21 showed that use of the average of all Stakeholder targets made a rational preferential representation.

6.5.2 Sub criteria preferences

In case of rating the sub criteria preferences of NWSDB System Management Stakeholders, many variations could be observed (Table B.4.1 – B.4.5) . Capturing the relative importance to Stakeholders was carried out by evaluating the entire set as a whole, because of the simplicity required when addressing the stakeholders for data collection through a simple questionnaire.

Determination of pairwise preferences of Sub criteria resorted to an averaging method (Table 6.4a and 6.4b) without evaluating combinations as in the case of Main criteria. This was also because averaging technique is the simplest and the most prudent application when relationships between many parameters are not established through systematic studies. After observing the values in Table 6.21, the appropriateness of using average values appeared as a strong option.

6.5.2.1 Sub criteria – Stakeholder scale

Pairwise comparison of Sub criteria using Stakeholder preferences are shown in Table 6.22. The scale of stakeholder averages were obtained by using the base values computed in Table 6.4a and 6.4b.

Converted pairwise values from base data are also in Table 6.22. It is important to note that the conversion of values within a main criteria varied due to the differences in the range of values obtained from observed data.

Table 6.22 : Pairwise Preferences of Sub Criteria – Conversion to Saaty Scale

			Sub Criteria Pair and Scale			
#	Main Criteria	#	Sub Criteria (Pairwise)	Stakeholder Scale		Saaty Scale (1-9)
				Value	Range	
1	Income Generation	1.1	New Connections/ Bill Collection	0.97		1
2	System Sustainability	2.1	Operation & Maintenance/ Salaries and Overtime	1.40	↑ 1.40 – 2.17 ↓	4
		2.2	Operation & Maintenance/ Transport	2.17		9
		2.3	Salaries and Overtime/ Transport	1.55		5
3	System Losses	3.1	Non Revenue Water (NRW)	1	1	1
4	System Reliability	4.1	Low Pressure/ No Water	0.86	↑ 0.67 – 1.45 ↓	1
		4.2	Low Pressure/ Water Quality	0.67		1
		4.3	Low Pressure/ Defective Meters	1.21		2
		4.4	Low Pressure/ Leak - mains	0.93		1
		4.5	Low Pressure/ Leak - connections	1.68		4
		4.6	Low Pressure/ Leak - near meter	2.19		5
		4.7	Low Pressure/ Leak - night time	1.61		3
		4.8	Low Pressure/ Leak - stop valve	2.33		6
		4.9	No water/ Water Quality	0.79		1
		4.10	No water/ Defective Meters	1.41		3
		4.11	No water/ Leak - mains	1.08		2
		4.12	No water/ Leak - connections	1.96		5
		4.13	No water/ Leak - near meter	2.55		7
		4.14	No water/ Leak - night time	1.87		4
		4.15	No water/ Leak - stop valve	2.71		7
		4.16	Water Quality/ Defective Meters	1.79		4
		4.17	Water Quality/ Leak - mains	1.37		3
		4.18	Water Quality/ Leak - connections	2.50		6
		4.19	Water Quality/ Leak - near meter	3.24		9
		4.20	Water Quality/ Leak - night time	2.38		6
		4.21	Water Quality/ Leak - stop valve	3.45		9
		4.22	Defective Meters/ Leak - mains	0.76		1
		4.23	Defective Meters/ Leak - connections	1.39		3
		4.24	Defective Meters/ Leak - near meter	1.81		4
		4.25	Defective Meters/ Leak - night time	1.33		3
		4.26	Defective Meters/ Leak - stop valve	1.92		5
		4.27	Leak - mains/ Leak - connections	1.82		4
		4.28	Leak - mains/ Leak - near meter	2.36		6
		4.29	Leak - mains/ Leak - night time	1.74		4
		4.30	Leak - mains/ Leak - stop valve	2.52		6
		4.31	Leak - connections/ Leak - near meter	1.30		2
		4.32	Leak - connections/ Leak - night time	0.95		1
		4.33	Leak - connections/ Leak - stop valve	1.38		3
		4.34	Leak - near meter/ Leak - night time	0.73		1
		4.35	Leak - near meter/ Leak - stop valve	1.07		2
		4.36	Leak - night time/ Leak - stop valve	1.45		3

6.5.2.2 Pairwise matrices – Relative importance of sub criteria

The pairwise matrices for sub criteria were developed in a similar manner described with the development of main criteria weights .

Pairwise matrices of subcriteria for each main criteria are in Table 6.23, 6.24, 6.25. In case of System Sustainability the only indicator is NRW sub criteria. Therefore a pairwise matrix is not required.

Table 6.23 : Pairwise Preferences for Sub Criteria under Main Criteria – Income Generation

	New connection	Bill collection
New connection	1	1
Bill collection	1	1

Table 6.24 : Pairwise Preferences for Sub Criteria under Main Criteria – System Sustainability

	Operation & Maintenance	Salaries and Overtime	Transport
Operation & Maintenance	1	4	9
Salaries and Overtime	1/4	1	5
Transport	1/9	1/5	1

Table 6.25 : Pairwise Preferences for Sub Criteria under Main Criteria – System Reliability

	Low Pressure	No water	Water Quality	Defective meters	Leak - mains	Leak - connections	Leak - near meter	Leak - night time	Leak - Stop valve
Low Pressure	1	1	1	2	1	4	5	3	6
No water	1	1	1	3	2	5	7	4	7
Water Quality	1	1	1	4	3	6	9	6	9
Defective meters	1/2	1/3	1/4	1	1	3	4	3	5
Leak - mains	1	1/2	1/3	1	1	4	6	4	6
Leak - connections	1/4	1/5	1/6	1/3	1/4	1	2	1	3
Leak - near meter	1/5	1/7	1/9	1/4	1/6	1/2	1	1	2
Leak - night time	1/3	1/4	1/6	1/3	1/4	1	1	1	3
Leak -Stop valve	1/6	1/7	1/9	1/5	1/6	1/3	1/2	1/3	1

6.5.2.3 Ranking of sub criteiria

Relative ranking of Sub Criteria obtained with the construction of Eigen Vectors are in Tables 6.23a, 6.24a and 6.25a.

Table 6.23a : Relative Importance of Sub Criteria – Income Generation

6.23 a	1	New connection	0.49315
	2	Bill collection	0.50685

Table 6.24a : Relative Importance of Sub Criteria –System Sustainability

6.24a	1	Operation & Maintenance	0.70852
	2	Salaries and Overtime	0.23115
	3	Transport	0.06033

Table 6.25a : Relative Importance of Sub Criteria – System Reliability

6.25 a	1	Low Pressure	0.168340
	2	No water	0.210897
	3	Water Quality	0.260453
	4	Defective meters	0.101169
	5	Leak - mains	0.121131
	6	Leak - connections	0.043796
	7	Leak - near meter	0.030018
	8	Leak - night time	0.043202
	9	Leak -Stop valve	0.020993

6.5.2.4 Sub crteria priority

Sub criteria priority from AHP method and associated weights are shown in the decending order (Table 6.22b)

Table 6.22 b: Sub Criteria in the Order of Priority

#	Main Criteria	#	Sub Criteria	Priority
1	Income Generation	1.1	Bill Collection	0.50685
		1.2	New Connections	0.49315
2	System Sustainability	2.1	Operation & Maintenance	0.70852
		2.2	Salaries and Overtime	0.23115
		2.3	Transport	0.06033
3	System Losses	3.1	Non Revenue Water (NRW)	1
4	System Reliability	4.1	Water Quality	0.260453
		4.2	No water	0.210897
		4.3	Low Pressure	0.168340
		4.4	Leak - Mains	0.121131
		4.5	Defective Meters	0.101169
		4.6	Leak - Connections	0.043796
		4.7	Leak - Night time	0.043202
		4.8	Leak - Near meter	0.030018
		4.9	Leak -Stop valve	0.020993

6.5.3 Preference of alternatives

In this research, ranking of organizational, managerial and employee preferences with respect to management alternatives (Management zones) was based on measurable quantities related to water supply system performance. Hence the ranking of each alternative against each other was based on the parameters computed from field data. Normalised Priority Vectors are in Figures 6.6, 6.7, 6.8 and 6.9.

Table 6.26.1: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion - New Connections

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	2	7	6	4	2	3	4	8	4	4	3	8	3	7	5	2	9	4	9	5	4
2	1/2	**1**	6	5	3	2	2	4	7	3	4	3	7	2	6	4	2	8	4	8	4	4
3	1/7	1/6	**1**	1/2	1/3	1/4	1/4	1/2	2	1/3	1/2	1/3	2	1/4	2	1/2	1/4	2	1/2	2	1/2	1/2
4	1/6	1/5	2	**1**	1/3	1/4	1/4	1/2	2	1/2	1/2	1/3	2	1/4	2	1/2	1/4	2	1/2	2	1/2	1/2
5	1/4	1/3	3	3	**1**	1/2	1/2	2	3	2	2	1/2	3	1/2	3	2	1/2	4	2	4	2	2
6	1/2	1/2	4	4	2	**1**	2	3	5	3	3	2	5	2	5	3	2	6	3	6	3	3
7	1/3	1/2	4	4	2	1/2	**1**	3	5	2	2	2	4	1/2	4	3	1/2	5	2	5	3	3
8	1/4	1/4	2	2	1/2	1/3	1/3	**1**	3	1/2	1/2	1/2	2	1/3	2	2	1/3	3	1/2	3	2	1/2
9	1/8	1/7	1/2	1/2	1/3	1/5	1/5	1/3	**1**	1/3	1/3	1/4	1/2	1/5	1/2	1/2	1/5	2	1/3	2	1/2	1/3
10	1/4	1/3	3	2	1/2	1/3	1/2	2	3	**1**	2	1/2	3	1/2	3	2	1/2	3	2	3	2	2
11	1/4	1/4	2	2	1/2	1/3	1/2	2	3	1/2	**1**	1/2	3	1/2	3	2	1/3	3	2	3	2	2
12	1/3	1/3	3	3	2	1/2	1/2	2	4	2	2	**1**	4	1/2	4	2	1/2	5	2	4	3	2
13	1/8	1/7	1/2	1/2	1/3	1/5	1/4	1/2	2	1/3	1/3	1/4	**1**	1/4	1/2	1/2	1/5	2	1/3	2	1/2	1/3
14	1/3	1/2	4	4	2	1/2	2	3	5	2	2	2	4	**1**	4	3	1/2	5	2	5	3	3
15	1/7	1/6	1/2	1/2	1/3	1/5	1/4	1/2	2	1/3	1/3	1/4	2	1/4	**1**	1/2	1/4	2	1/3	2	1/2	1/3
16	1/5	1/4	2	2	1/2	1/3	1/3	1/2	2	1/2	1/2	1/2	2	1/3	2	**1**	1/3	3	1/2	3	2	1/2
17	1/2	1/2	4	4	2	1/2	2	3	5	2	3	2	5	2	4	3	**1**	6	3	6	3	3
18	1/9	1/8	1/2	1/2	1/4	1/6	1/5	1/3	1/2	1/3	1/3	1/5	1/2	1/5	1/2	1/3	1/6	**1**	1/3	1/2	1/3	1/3
19	1/4	1/4	2	2	1/2	1/3	1/2	2	3	1/2	1/2	1/2	3	1/2	3	2	1/3	3	**1**	3	2	2
20	1/9	1/8	1/2	1/2	1/4	1/6	1/5	1/3	1/2	1/3	1/3	1/4	1/2	1/5	1/2	1/3	1/6	2	1/3	**1**	1/3	1/3
21	1/5	1/4	2	2	1/2	1/3	1/3	1/2	2	1/2	1/2	1/3	2	1/3	2	1/2	1/3	3	1/2	3	**1**	1/2
22	1/4	1/4	2	2	1/2	1/3	1/3	2	3	1/2	1/2	1/2	3	1/3	3	2	1/3	3	1/2	3	2	**1**

Table 6.26.2: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Bill Collection

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	1/2	1/2	1/2	1/2	2	1/2	1/5	1/4	1/6	1/4	1/2	1/2	1/2	1/9	1/5	1/2	1/6	1/2	1/2	1/4	1/2
2	2	**1**	1/2	1/2	1/2	2	1/2	1/4	1/3	1/5	1/3	1/2	1/2	2	1/7	1/4	1/2	1/5	1/2	2	1/3	1/2
3	2	2	**1**	2	2	9	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2
4	2	2	1/2	**1**	1/2	2	1/2	1/3	1/3	1/4	1/3	1/2	2	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
5	2	2	1/2	2	**1**	2	1/2	1/3	1/3	1/4	1/3	2	2	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
6	1/2	1/2	1/9	1/2	1/2	**1**	1/2	1/5	1/4	1/6	1/4	1/2	1/2	1/2	1/9	1/5	1/3	1/6	1/2	1/2	1/4	1/2
7	2	2	1/2	2	2	2	**1**	1/3	1/3	1/4	1/3	2	2	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
8	5	4	1/2	3	3	5	3	**1**	2	1/2	2	3	3	4	1/3	1/2	3	1/2	3	4	2	3
9	4	3	1/2	3	3	4	3	1/2	**1**	1/2	1/2	3	3	4	1/3	1/2	2	1/2	3	3	1/2	2
10	6	5	1/2	4	4	6	4	2	2	**1**	2	4	4	6	1/2	2	4	2	5	5	2	4
11	4	3	1/2	3	3	4	3	1/2	2	1/2	**1**	3	3	4	1/3	1/2	3	1/2	3	3	2	3
12	2	2	1/2	2	1/2	2	1/2	1/3	1/3	1/4	1/3	**1**	2	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
13	2	2	1/2	1/2	1/2	2	1/2	1/3	1/3	1/4	1/3	1/2	**1**	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
14	2	1/2	1/2	1/2	1/2	2	1/2	1/4	1/4	1/6	1/4	1/2	1/2	**1**	1/9	1/5	1/2	1/6	1/2	1/2	1/4	1/2
15	9	7	1	6	6	9	6	3	3	2	3	6	6	9	**1**	3	5	2	7	7	3	6
16	5	4	1/2	3	3	5	3	2	2	1/2	2	3	3	5	1/3	**1**	3	1/2	4	4	2	3
17	2	2	1/2	2	2	3	2	1/3	1/2	1/4	1/3	2	2	2	1/5	1/3	**1**	1/4	2	2	1/2	2
18	6	5	1/2	4	4	6	4	2	2	1/2	2	4	4	6	1/2	2	4	**1**	5	5	2	4
19	2	2	1/2	1/2	1/2	2	1/2	1/3	1/3	1/5	1/3	1/2	1/2	2	1/7	1/4	1/2	1/5	**1**	2	1/3	1/2
20	2	1/2	1/2	1/2	1/2	2	1/2	1/4	1/3	1/5	1/3	1/2	1/2	2	1/7	1/4	1/2	1/5	1/2	**1**	1/3	1/2
21	4	3	1/2	3	3	4	3	1/2	2	1/2	1/2	3	3	4	1/3	1/2	2	1/2	3	3	**1**	3
22	2	2	1/2	2	2	2	2	1/3	1/2	1/4	1/3	2	2	2	1/6	1/3	1/2	1/4	2	2	1/3	**1**

Table 6.26.3: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Operation & Maintenance Cost

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	2	2	6	2	2	1/2	2	2	1/2	2	2	2	2	1/2	2	4	2	2	2	2	2
2	1/2	**1**	1/2	4	2	2	1/2	1/2	2	1/2	1	2	2	2	1/2	2	3	1/2	1/2	2	2	2
3	1/2	2	**1**	6	2	2	1/2	2	2	1/2	2	2	2	2	1/2	2	4	2	2	2	2	2
4	1/6	1/4	1/6	**1**	1/2	1/3	1/7	1/5	1/3	1/7	1/4	1/3	1/4	1/4	1/9	1/3	1/2	1/5	1/5	1/3	1/3	1/2
5	1/2	1/2	1/2	2	**1**	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2
6	1/2	1/2	1/2	3	2	**1**	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	2
7	2	2	2	7	2	2	**1**	2	2	2	2	2	2	2	1/2	2	4	2	2	2	2	2
8	1/2	2	1/2	5	2	2	1/2	**1**	2	1/2	2	2	2	2	1/2	2	3	1/2	1/2	2	2	2
9	1/2	1/2	1/2	3	2	1/2	1/2	1/2	**1**	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	2
10	2	2	2	7	2	2	1/2	2	2	**1**	2	2	2	2	1/2	2	4	2	2	2	2	2
11	1/2	1	1/2	4	2	2	1/2	1/2	2	1/2	**1**	2	2	2	1/2	2	3	1/2	1/2	2	2	2
12	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	**1**	1/2	1/2	1/2	2	2	1/2	1/2	2	2	2
13	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	1/2	2	**1**	1/2	1/2	2	3	1/2	1/2	2	2	2
14	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	1/2	2	2	**1**	1/2	2	3	1/2	1/2	2	2	2
15	2	2	2	9	2	2	2	2	2	2	2	2	2	2	**1**	2	5	2	2	2	2	2
16	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	**1**	2	1/2	1/2	2	1/2	2
17	1/4	1/3	1/4	2	1/2	1/2	1/4	1/3	1/2	1/4	1/3	1/2	1/3	1/3	1/5	1/2	**1**	1/3	1/3	1/2	1/2	1/2
18	1/2	2	1/2	5	2	2	1/2	2	2	1/2	2	2	2	2	1/2	2	3	**1**	1/2	2	2	2
19	1/2	2	1/2	5	2	2	1/2	2	2	1/2	2	2	2	2	1/2	2	3	2	**1**	2	2	2
20	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	**1**	1/2	2
21	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	2	2	1/2	1/2	2	**1**	2
22	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	**1**

Table 6.26.4: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Salaries & Overtime Cost

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	1/2	1/2	1/2	1/2	2	1/3	1/4	1/4	1/6	1/4	1/2	1/2	1/2	1/9	1/5	1/3	1/6	1/2	1/2	1/4	1/3
2	2	**1**	1/2	1/2	1/2	2	1/2	1/3	1/3	1/5	1/3	1/2	1/2	2	1/7	1/4	1/2	1/5	1/2	1	1/3	1/2
3	2	2	**1**	2	2	9	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2
4	2	2	1/2	**1**	1/2	2	1/2	1/3	1/3	1/4	1/3	1/2	2	2	1/6	1/4	1/2	1/4	2	2	1/3	1/2
5	2	2	1/2	2	**1**	2	1/2	1/3	1/3	1/4	1/2	1/2	2	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
6	1/2	1/2	1/9	1/2	1/2	**1**	1/3	1/4	1/4	1/6	1/4	1/2	1/2	1/2	1/9	1/5	1/3	1/6	1/2	1/2	1/4	1/3
7	3	2	1/2	2	2	3	**1**	1/3	1/2	1/4	1/2	2	2	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
8	4	3	1/2	3	3	4	3	**1**	2	1/2	2	3	3	4	1/3	1/2	2	1/2	3	3	1/2	2
9	4	3	1/2	3	3	4	2	1/2	**1**	1/2	2	3	3	3	1/3	1/2	2	1/2	3	3	1/2	2
10	6	5	1/2	4	4	6	4	2	2	**1**	2	4	4	5	1/2	2	3	2	4	5	2	3
11	4	3	1/2	3	2	4	2	1/2	1/2	1/2	**1**	2	3	3	1/3	1/2	2	1/2	3	3	1/2	2
12	2	2	1/2	2	2	2	1/2	1/3	1/3	1/4	1/2	**1**	2	2	1/6	1/3	1/2	1/4	2	2	1/3	1/2
13	2	2	1/2	1/2	1/2	2	1/2	1/3	1/3	1/4	1/3	1/2	**1**	2	1/6	1/4	1/2	1/4	2	2	1/3	1/2
14	2	1/2	1/2	1/2	1/2	2	1/2	1/4	1/3	1/5	1/3	1/2	1/2	**1**	1/8	1/5	1/2	1/5	1/2	1/2	1/4	1/2
15	9	7	1	6	6	9	6	3	3	2	3	6	6	8	**1**	2	5	2	6	7	3	5
16	5	4	1/2	4	3	5	3	2	2	1/2	2	3	4	5	1/2	**1**	3	1/2	4	4	2	3
17	3	2	1/2	2	2	3	2	1/2	1/2	1/3	1/2	2	2	2	1/5	1/3	**1**	1/3	2	2	1/2	2
18	6	5	1/2	4	4	6	4	2	2	1/2	2	4	4	5	1/2	2	3	**1**	4	5	2	3
19	2	2	1/2	1/2	1/2	2	1/2	1/3	1/3	1/4	1/3	1/2	1/2	2	1/6	1/4	1/2	1/4	**1**	2	1/3	1/2
20	2	1	1/2	1/2	1/2	2	1/2	1/3	1/3	1/5	1/3	1/2	1/2	2	1/7	1/4	1/2	1/5	1/2	**1**	1/3	1/2
21	4	3	1/2	3	3	4	3	2	2	1/2	2	3	3	4	1/3	1/2	2	1/2	3	3	**1**	2
22	3	2	1/2	2	2	3	2	1/2	1/2	1/3	1/2	2	2	2	1/5	1/3	1/2	1/3	2	2	1/2	**1**

Table 6.26.5: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Transport Cost

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	3	3	5	3	2	6	2	2	2	2	2	3	2	1/2	2	1/2	2	2	2	2	3
2	1/3	**1**	2	2	2	1/3	3	1/2	1/2	1/3	1/3	1/3	2	1/2	1/4	1/2	1/2	1/3	1/3	1/2	1/3	2
3	1/3	1/2	**1**	2	2	1/3	3	1/2	1/3	1/3	1/3	1/3	2	1/2	1/4	1/3	1/2	1/3	1/3	1/2	1/3	2
4	1/5	1/2	1/2	**1**	1/2	1/5	2	1/3	1/4	1/5	1/4	1/4	1/2	1/3	1/7	1/4	1/2	1/5	1/4	1/3	1/5	1/2
5	1/3	1/2	1/2	2	**1**	1/3	2	1/2	1/3	1/3	1/3	1/3	1/2	1/3	1/5	1/3	1/2	1/3	1/3	1/2	1/3	1/2
6	1/2	3	3	5	3	**1**	6	2	2	2	2	2	3	2	1/2	2	1/2	1/2	2	2	1/2	3
7	1/6	1/3	1/3	1/2	1/2	1/6	**1**	1/4	1/5	1/6	1/6	1/6	1/3	1/4	1/9	1/5	1/9	1/6	1/6	1/4	1/6	1/3
8	1/2	2	2	3	2	1/2	4	**1**	1/2	1/2	1/2	1/2	2	1/2	1/3	1/2	1/2	1/2	1/2	2	1/2	2
9	1/2	2	3	4	3	1/2	5	2	**1**	1/2	1/2	1/2	3	2	1/2	2	1/2	1/2	1/2	2	1/2	3
10	1/2	3	3	5	3	1/2	6	2	2	**1**	2	2	3	2	1/2	2	1/2	1/2	2	2	1/2	3
11	1/2	3	3	4	3	1/2	6	2	2	1/2	**1**	1/2	3	2	1/2	2	1/2	1/2	1/2	2	1/2	3
12	1/2	3	3	4	3	1/2	6	2	2	1/2	2	**1**	3	2	1/2	2	1/2	1/2	1/2	2	1/2	3
13	1/3	1/2	1/2	2	2	1/3	3	1/2	1/3	1/3	1/3	1/3	**1**	1/2	1/4	1/3	1/2	1/3	1/3	1/2	1/3	2
14	1/2	2	2	3	3	1/2	4	2	1/2	1/2	1/2	1/2	2	**1**	1/3	1/2	1/2	1/2	1/2	2	1/2	2
15	2	4	4	7	5	2	9	3	2	2	2	2	4	3	**1**	2	1	2	2	3	2	4
16	1/2	2	3	4	3	1/2	5	2	1/2	1/2	1/2	1/2	3	2	1/2	**1**	1/2	1/2	1/2	2	1/2	3
17	2	2	2	2	2	2	9	2	2	2	2	2	2	2	1	2	**1**	2	2	2	2	2
18	1/2	3	3	5	3	2	6	2	2	2	2	2	3	2	1/2	2	1/2	**1**	2	2	1/2	3
19	1/2	3	3	4	3	1/2	6	2	2	1/2	2	2	3	2	1/2	2	1/2	1/2	**1**	2	1/2	3
20	1/2	2	2	3	2	1/2	4	1/2	1/2	1/2	1/2	1/2	2	1/2	1/3	1/2	1/2	1/2	1/2	**1**	1/2	2
21	1/2	3	3	5	3	2	6	2	2	2	2	2	3	2	1/2	2	1/2	2	2	2	**1**	3
22	1/3	1/2	1/2	2	2	1/3	3	1/2	1/3	1/3	1/3	1/3	1/2	1/2	1/4	1/3	1/2	1/3	1/3	1/2	1/3	**1**

Table 6.26.6 : Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – NRW

Zone No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	**1**	1/4	1/3	1/4	1/3	1/4	1/4	3	1/3	1/3	2	1/4	1/4	1/6	1/2	1/5	1/5	1/3	1/4	1/4	1/3	1/4
2	4	**1**	2	1/2	2	1/2	1/2	7	2	2	4	1/2	1/2	1/3	3	1/2	1/3	2	1/2	1/2	2	1/2
3	3	1/2	**1**	1/2	1/2	1/2	1/2	6	2	1/2	3	1/2	1/2	1/3	2	1/3	1/3	1/2	1/2	1/2	1/2	1/2
4	4	2	2	**1**	2	2	2	8	3	2	4	2	2	1/2	3	1/2	1/2	2	2	2	2	2
5	3	1/2	2	1/2	**1**	1/2	1/2	6	2	1/2	3	1/2	1/2	1/3	2	1/3	1/3	1/2	1/2	1/2	1/2	1/2
6	4	2	2	1/2	2	**1**	2	7	3	2	4	2	2	1/2	3	1/2	1/2	2	1/2	2	2	1/2
7	4	2	2	1/2	2	1/2	**1**	7	3	2	4	2	2	1/2	3	1/2	1/2	2	1/2	2	2	1/2
8	1/3	1/7	1/6	1/8	1/6	1/7	1/7	**1**	1/5	1/6	1/3	1/7	1/7	1/9	1/5	1/8	1/9	1/6	1/8	1/7	1/6	1/8
9	3	1/2	1/2	1/3	1/2	1/3	1/3	5	**1**	1/2	3	1/3	1/2	1/4	2	1/3	1/3	1/2	1/3	1/2	1/2	1/3
10	3	1/2	2	1/2	2	1/2	1/2	6	2	**1**	3	1/2	1/2	1/3	2	1/3	1/3	1/2	1/2	1/2	1/2	1/2
11	1/2	1/4	1/3	1/4	1/3	1/4	1/4	3	1/3	1/3	**1**	1/4	1/4	1/6	1/2	1/5	1/5	1/3	1/4	1/4	1/4	1/4
12	4	2	2	1/2	2	1/2	1/2	7	3	2	4	**1**	2	1/2	3	1/2	1/2	2	1/2	2	2	1/2
13	4	2	2	1/2	2	1/2	1/2	7	2	2	4	1/2	**1**	1/3	3	1/2	1/2	2	1/2	2	2	1/2
14	6	3	3	2	3	2	2	9	4	3	6	2	3	**1**	4	2	2	3	2	3	3	2
15	2	1/3	1/2	1/3	1/2	1/3	1/3	5	1/2	1/2	2	1/3	1/3	1/4	**1**	1/4	1/4	1/2	1/3	1/3	1/2	1/3
16	5	2	3	2	3	2	2	8	3	3	5	2	2	1/2	4	**1**	1/2	3	2	2	2	2
17	5	3	3	2	3	2	2	9	3	3	5	2	2	1/2	4	2	**1**	3	2	2	3	2
18	3	1/2	2	1/2	2	1/2	1/2	6	2	2	3	1/2	1/2	1/3	2	1/3	1/3	**1**	1/2	1/2	1/2	1/2
19	4	2	2	1/2	2	2	2	8	3	2	4	2	2	1/2	3	1/2	1/2	2	**1**	2	2	1/2
20	4	2	2	1/2	2	1/2	1/2	7	2	2	4	1/2	1/2	1/3	3	1/2	1/2	2	1/2	**1**	2	1/2
21	3	1/2	2	1/2	2	1/2	1/2	6	2	2	4	1/2	1/2	1/3	2	1/2	1/3	2	1/2	1/2	**1**	1/2
22	4	2	2	1/2	2	2	2	8	3	2	4	2	2	1/2	3	1/2	1/2	2	2	2	2	**1**

Table 6.26.7.: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Low Pressure

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	1	1/6	1	1	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	1	1	1/3	1/4	1	1/3	1
2	1	**1**	1/6	1	1	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	1	1	1/3	1/4	1	1/3	1
3	6	6	**1**	6	6	2	1/2	2	2	1/2	2	2	2	2	1/2	6	6	2	2	6	2	6
4	1	1	1/6	**1**	1	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	1	1	1/3	1/4	1	1/3	1
5	1	1	1/6	1	**1**	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	1	1	1/3	1/4	1	1/3	1
6	3	3	1/2	3	3	**1**	1/2	1/2	1	1/2	1/2	1	1/2	1	1/2	3	3	1	1/2	3	1	3
7	7	7	2	7	7	2	**1**	2	2	1/2	2	2	2	2	1/2	7	7	2	2	7	2	7
8	4	4	1/2	4	4	2	1/2	**1**	2	1/2	1	2	1	2	1/2	4	4	2	1	4	2	4
9	3	3	1/2	3	3	1	1/2	1/2	**1**	1/2	1/2	1	1/2	1	1/2	3	3	1	1/2	3	1	3
10	9	9	2	9	9	2	2	2	2	**1**	2	2	2	2	1	9	9	2	2	9	2	9
11	4	4	1/2	4	4	2	1/2	1	2	1/2	**1**	2	1	2	1/2	4	4	2	1	4	2	4
12	3	3	1/2	3	3	1	1/2	1/2	1	1/2	1/2	**1**	1/2	1	1/2	3	3	1	1/2	3	1	3
13	4	4	1/2	4	4	2	1/2	1	2	1/2	1	2	**1**	2	1/2	4	4	2	1	4	2	4
14	3	3	1/2	3	3	1	1/2	1/2	1	1/2	1/2	1	1/2	**1**	1/2	3	3	1	1/2	3	1	3
15	9	9	2	9	9	2	2	2	2	1	2	2	2	2	**1**	9	9	2	2	9	2	9
16	1	1	1/6	1	1	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	**1**	1	1/3	1/4	1	1/3	1
17	1	1	1/6	1	1	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	1	**1**	1/3	1/4	1	1/3	1
18	3	3	1/2	3	3	1	1/2	1/2	1	1/2	1/2	1	1/2	1	1/2	3	3	**1**	1/2	3	1	3
19	4	4	1/2	4	4	2	1/2	1	2	1/2	1	2	1	2	1/2	4	4	2	**1**	4	2	4
20	1	1	1/6	1	1	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	1	1	1/3	1/4	**1**	1/3	1
21	3	3	1/2	3	3	1	1/2	1/2	1	1/2	1/2	1	1/2	1	1/2	3	3	1	1/2	3	1	3
22	1	1	1/6	1	1	1/3	1/7	1/4	1/3	1/9	1/4	1/3	1/4	1/3	1/9	1	1	1/3	1/4	1	1/3	1

Table 6.26.8: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – No Water

Zone No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	**1**	2	2	6	6	6	1/2	2	6	2	2	2	2	2	1/2	6	6	2	2	2	6	6
2	1/2	**1**	1/2	4	4	4	1/2	2	4	1/2	1/2	2	1/2	1/2	1/2	4	4	2	1/2	2	4	4
3	1/2	2	**1**	6	6	6	1/2	2	6	2	2	2	2	2	1/2	6	6	2	2	2	6	6
4	1/6	1/4	1/6	**1**	1	1	1/7	1/4	1	1/6	1/4	1/4	1/5	1/4	1/2	1	1	1/3	1/5	1/3	1	1
5	1/6	1/4	1/6	1	**1**	1	1/7	1/4	1	1/6	1/4	1/4	1/5	1/4	1/2	1	1	1/3	1/5	1/3	1	1
6	1/6	1/4	1/6	1	1	**1**	1/7	1/4	1	1/6	1/4	1/4	1/5	1/4	1/2	1	1	1/3	1/5	1/3	1	1
7	2	2	2	7	7	7	**1**	2	7	2	2	2	2	2	1	7	7	2	2	2	7	7
8	1/2	1/2	1/2	4	4	4	1/2	**1**	4	1/2	1/2	2	1/2	1/2	1/2	4	4	2	1/2	2	4	4
9	1/6	1/4	1/6	1	1	1	1/7	1/4	**1**	1/6	1/4	1/4	1/5	1/4	1/2	1	1	1/3	1/5	1/3	1	1
10	1/2	2	1/2	6	6	6	1/2	2	6	**1**	2	2	2	2	1/2	6	6	2	2	2	6	6
11	1/2	2	1/2	4	4	4	1/2	2	4	1/2	**1**	2	1/2	2	1/2	4	4	2	1/2	2	4	4
12	1/2	1/2	1/2	4	4	4	1/2	1/2	4	1/2	1/2	**1**	1/2	1/2	1/2	4	4	1	1/2	2	4	3
13	1/2	2	1/2	5	5	5	1/2	2	5	1/2	2	2	**1**	2	1/2	5	5	2	1/2	2	5	5
14	1/2	2	1/2	4	4	4	1/2	2	4	1/2	1/2	2	1/2	**1**	1/2	4	4	2	1/2	2	4	4
15	2	2	2	2	2	2	1	2	2	2	2	2	2	2	**1**	2	9	2	2	2	2	2
16	1/6	1/4	1/6	1	1	1	1/7	1/4	1	1/6	1/4	1/4	1/5	1/4	1/2	**1**	1	1/3	1/5	1/3	1	1
17	1/6	1/4	1/6	1	1	1	1/7	1/4	1	1/6	1/4	1/4	1/5	1/4	1/9	1	**1**	1/3	1/5	1/3	1	1
18	1/2	1/2	1/2	3	3	3	1/2	1/2	3	1/2	1/2	1	1/2	1/2	1/2	3	3	**1**	1/2	2	3	3
19	1/2	2	1/2	5	5	5	1/2	2	5	1/2	2	2	2	2	1/2	5	5	2	**1**	2	5	5
20	1/2	1/2	1/2	3	3	3	1/2	1/2	3	1/2	1/2	1/2	1/2	1/2	1/2	3	3	1/2	1/2	**1**	3	3
21	1/6	1/4	1/6	1	1	1	1/7	1/4	1	1/6	1/4	1/4	1/5	1/4	1/2	1	1	1/3	1/5	1/3	**1**	1
22	1/6	1/4	1/6	1	1	1	1/7	1/4	1	1/6	1/4	1/3	1/5	1/4	1/2	1	1	1/3	1/5	1/3	1	**1**

Table 6.26.9: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Water Quality

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	1/2	1	5	5	5	1	5	5	2	2	5	2	5	1/2	5	5	2	5	2	2	5
2	2	**1**	2	6	6	6	2	6	6	2	2	6	2	6	1	6	6	2	6	2	2	6
3	1	1/2	**1**	5	5	5	1	5	5	2	2	5	2	5	1/2	5	5	2	5	2	2	5
4	1/5	1/6	1/5	**1**	1	1	1/5	1	2	1/2	1/2	2	1/2	2	1/2	2	2	1/4	2	1/2	1/3	2
5	1/5	1/6	1/5	1	**1**	1	1/5	1	1	1/2	1/2	1	1/2	1	1/2	1	1	1/4	1	1/2	1/3	1
6	1/5	1/6	1/5	1	1	**1**	1/5	1	1	1/2	1/2	1	1/2	1	1/2	1	1	1/4	1	1/2	1/3	1
7	1	1/2	1	5	5	5	**1**	5	5	2	2	5	2	5	1/2	5	5	2	5	2	2	5
8	1/5	1/6	1/5	1	1	1	1/5	**1**	1	1/2	1/2	1	1/2	1	1/2	1	1	1/4	1	1/2	1/3	1
9	1/5	1/6	1/5	1/2	1	1	1/5	1	**1**	1/2	1/2	1	1/2	1	1/2	1	1	1/4	1	1/2	1/3	1
10	1/2	1/2	1/2	2	2	2	1/2	2	2	**1**	1	2	1	2	1/2	2	2	1/2	2	1	1/2	2
11	1/2	1/2	1/2	2	2	2	1/2	2	2	1	**1**	2	1	2	1/2	2	2	1/2	2	1	1/2	2
12	1/5	1/6	1/5	1/2	1	1	1/5	1	1	1/2	1/2	**1**	1/2	1	1/2	1	1	1/4	1	1/2	1/3	1
13	1/2	1/2	1/2	2	2	2	1/2	2	2	1	1	2	**1**	2	1/2	2	2	1/2	2	1	1/2	2
14	1/5	1/6	1/5	1/2	1	1	1/5	1	1	1/2	1/2	1	1/2	**1**	1/2	1	1	1/4	1	1/2	1/3	1
15	2	1	2	2	2	2	2	2	2	2	2	2	2	2	**1**	2	2	2	2	2	2	9
16	1/5	1/6	1/5	1/2	1	1	1/5	1	1	1/2	1/2	1	1/2	1	1/2	**1**	1	1/4	1	1/2	1/3	1
17	1/5	1/6	1/5	1/2	1	1	1/5	1	1	1/2	1/2	1	1/2	1	1/2	1	**1**	1/4	1	1/2	1/3	1
18	1/2	1/2	1/2	4	4	4	1/2	4	4	2	2	4	2	4	1/2	4	4	**1**	4	2	2	4
19	1/5	1/6	1/5	1/2	1	1	1/5	1	1	1/2	1/2	1	1/2	1	1/2	1	1	1/4	**1**	1/2	1/3	1
20	1/2	1/2	1/2	2	2	2	1/2	2	2	1	1	2	1	2	1/2	2	2	1/2	2	**1**	1/2	2
21	1/2	1/2	1/2	3	3	3	1/2	3	3	2	2	3	2	3	1/2	3	3	1/2	3	2	**1**	3
22	1/5	1/6	1/5	1/2	1	1	1/5	1	1	1/2	1/2	1	1/2	1	1/9	1	1	1/4	1	1/2	1/3	**1**

Table 6.26.10: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Defective Meters

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	2	1/2	5	5	2	2	2	1	2	2	2	1/2	1/2	1/2	2	5	5	1/2	2	2	2
2	1/2	**1**	1/2	3	3	1/2	1/2	2	1/2	2	2	1	1/2	1/2	1/2	1	3	3	1/2	1	1/2	2
3	2	2	**1**	7	7	2	2	2	2	2	2	2	2	2	1	2	7	7	2	2	2	2
4	1/5	1/3	1/7	**1**	1	1/5	1/4	1/3	1/5	1/3	1/2	1/3	1/6	1/6	1/2	1/3	1	1	1/7	1/3	1/4	1/2
5	1/5	1/3	1/7	1	**1**	1/5	1/4	1/3	1/5	1/3	1/2	1/3	1/6	1/6	1/2	1/3	1	1	1/7	1/3	1/4	1/2
6	1/2	2	1/2	5	5	**1**	2	2	1/2	2	2	2	1/2	1/2	1/2	2	5	5	1/2	2	2	2
7	1/2	2	1/2	4	4	1/2	**1**	2	1/2	2	2	2	1/2	1/2	1/2	2	4	4	1/2	2	1	2
8	1/2	1/2	1/2	3	3	1/2	1/2	**1**	1/2	1	2	1/2	1/2	1/2	1/2	1/2	3	3	1/2	1/2	1/2	2
9	1	2	1/2	5	5	2	2	2	**1**	2	2	2	1/2	1/2	1/2	2	5	5	1/2	2	2	2
10	1/2	1/2	1/2	3	3	1/2	1/2	1	1/2	**1**	2	1/2	1/2	1/2	1/2	1/2	3	3	1/2	1/2	1/2	2
11	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	**1**	1/2	1/2	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1
12	1/2	1	1/2	3	3	1/2	1/2	2	1/2	2	2	**1**	1/2	1/2	1/2	1	3	3	1/2	1	1/2	2
13	2	2	1/2	6	6	2	2	2	2	2	2	2	**1**	1	1/2	2	6	6	1/2	2	2	2
14	2	2	1/2	6	6	2	2	2	2	2	2	2	1	**1**	1/2	2	6	6	1/2	2	2	2
15	2	2	1	2	2	2	2	2	2	2	2	2	2	2	**1**	2	2	9	2	2	2	2
16	1/2	1	1/2	3	3	1/2	1/2	2	1/2	2	2	1	1/2	1/2	1/2	**1**	3	3	1/2	1	1/2	2
17	1/5	1/3	1/7	1	1	1/5	1/4	1/3	1/5	1/3	1/2	1/3	1/6	1/6	1/2	1/3	**1**	1	1/7	1/3	1/4	1/2
18	1/5	1/3	1/7	1	1	1/5	1/4	1/3	1/5	1/3	1/2	1/3	1/6	1/6	1/9	1/3	1	**1**	1/7	1/3	1/4	1/2
19	2	2	1/2	7	7	2	2	2	2	2	2	2	2	2	1/2	2	7	7	**1**	2	2	2
20	1/2	1	1/2	3	3	1/2	1/2	2	1/2	2	2	1	1/2	1/2	1/2	1	3	3	1/2	**1**	1/2	2
21	1/2	2	1/2	4	4	1/2	1	2	1/2	2	2	2	1/2	1/2	1/2	2	4	4	1/2	2	**1**	2
22	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	1	1/2	1/2	1/2	1/2	1/2	2	2	1/2	1/2	1/2	**1**

Table 6.26.11: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Leak of Mains

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	1/2	2	4	2	2	1/2	1/2	2	1/2	2	2	2	2	1/2	2	2	1/2	2	2	2	2
2	2	**1**	2	5	2	2	1/2	1/2	2	1/2	2	2	2	2	1/2	2	2	1/2	2	2	2	2
3	1/2	1/2	**1**	4	2	2	1/2	1/2	2	1/2	2	2	2	2	1/2	1/2	2	1/2	2	2	2	2
4	1/4	1/5	1/4	**1**	1/2	1/3	1/6	1/5	1/3	1/5	1/4	1/	1/2	1/3	1/9	1/4	1/2	1/6	1/3	1/2	1/3	1/2
5	1/2	1/2	1/2	2	**1**	1/2	1/2	1/2	1/2	1/2	1/2	1/	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2
6	1/2	1/2	1/2	3	2	**1**	1/2	1/2	2	1/2	1/2	1/	2	2	1/2	1/2	2	1/2	1/2	2	1/2	2
7	2	2	2	6	2	2	**1**	2	2	2	2	2	2	2	1/2	2	2	1/2	2	2	2	2
8	2	2	2	5	2	2	1/2	**1**	2	1/2	2	2	2	2	1/2	2	2	1/2	2	2	2	2
9	1/2	1/2	1/2	3	2	1/2	1/2	1/2	**1**	1/2	1/2	1/	2	1	1/2	1/2	2	1/2	1/2	2	1/2	2
10	2	2	2	5	2	2	1/2	2	2	**1**	2	2	2	2	1/2	2	2	1/2	2	2	2	2
11	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	**1**	2	2	2	1/2	1/2	2	1/2	2	2	2	2
12	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	**1**	2	2	1/2	1/2	2	1/2	2	2	1/2	2
13	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/	**1**	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2
14	1/2	1/2	1/2	3	2	1/2	1/2	1/2	1	1/2	1/2	1/	2	**1**	1/2	1/2	2	1/2	1/2	2	1/2	2
15	2	2	2	9	2	2	2	2	2	2	2	2	2	2	**1**	2	2	2	2	2	2	2
16	1/2	1/2	2	4	2	2	1/2	1/2	2	1/2	2	2	2	2	1/2	**1**	2	1/2	2	2	2	2
17	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/	1/2	1/2	1/2	1/2	**1**	1/2	1/2	1/2	1/2	1/2
18	2	2	2	6	2	2	2	2	2	2	2	2	2	2	1/2	2	2	**1**	2	2	2	2
19	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	1/	2	2	1/2	1/2	2	1/2	**1**	2	1/2	2
20	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/	2	1/2	1/2	1/2	2	1/2	1/2	**1**	1/2	1
21	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	2	2	2	1/2	1/2	2	1/2	2	2	**1**	2
22	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/	2	1/2	1/2	1/2	2	1/2	1/2	1	1/2	**1**

Table 6.26.12: Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Leaks of Water Connections

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	2	1/2	7	2	2	1/2	2	2	1/2	2	2	2	2	1/2	2	7	2	2	2	2	2
2	1/2	**1**	1/2	4	2	2	1/2	1/2	2	1/2	1/2	1	2	1/2	1/2	2	4	1/2	1/2	2	2	2
3	2	2	**1**	7	2	2	1/2	2	2	1/2	2	2	2	2	1/2	2	7	2	2	2	2	2
4	1/7	1/4	1/7	**1**	1/2	1/3	1/8	1/4	1/3	1/7	1/5	1/4	1/3	1/4	1/9	1/3	1	1/5	1/5	1/3	1/4	1/2
5	1/2	1/2	1/2	2	**1**	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2
6	1/2	1/2	1/2	3	2	**1**	1/2	1/2	1	1/2	1/2	1/2	1/2	1/2	1/2	1/2	3	1/2	1/2	1/2	1/2	2
7	2	2	2	8	2	2	**1**	2	2	2	2	2	2	2	1/2	2	8	2	2	2	2	2
8	1/2	2	1/2	4	2	2	1/2	**1**	2	1/2	1/2	2	2	1	1/2	2	4	1/2	1/2	2	2	2
9	1/2	1/2	1/2	3	2	1	1/2	1/2	**1**	1/2	1/2	1/2	1/2	1/2	1/2	1/2	3	1/2	1/2	1/2	1/2	2
10	2	2	2	7	2	2	1/2	2	2	**1**	2	2	2	2	1/2	2	7	2	2	2	2	2
11	1/2	2	1/2	5	2	2	1/2	2	2	1/2	**1**	2	2	2	1/2	2	5	2	2	2	2	2
12	1/2	1	1/2	4	2	2	1/2	1/2	2	1/2	1/2	**1**	2	1/2	1/2	2	4	1/2	1/2	2	2	2
13	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	1/2	**1**	1/2	1/2	1/2	3	1/2	1/2	2	1/2	2
14	1/2	2	1/2	4	2	2	1/2	1	2	1/2	1/2	2	2	**1**	1/2	2	4	1/2	1/2	2	2	2
15	2	2	2	9	2	2	2	2	2	2	2	2	2	2	**1**	2	9	2	2	2	2	2
16	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	1/2	2	1/2	1/2	**1**	3	1/2	1/2	2	1/2	2
17	1/7	1/4	1/7	1	1/2	1/3	1/8	1/4	1/3	1/7	1/5	1/4	1/3	1/4	1/9	1/3	**1**	1/5	1/5	1/3	1/4	1/2
18	1/2	2	1/2	5	2	2	1/2	2	2	1/2	1/2	2	2	2	1/2	2	5	**1**	1/2	2	2	2
19	1/2	2	1/2	5	2	2	1/2	2	2	1/2	1/2	2	2	2	1/2	2	5	2	**1**	2	2	2
20	1/2	1/2	1/2	3	2	2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	3	1/2	1/2	**1**	1/2	2
21	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	1/2	1/2	2	1/2	1/2	2	4	1/2	1/2	2	**1**	2
22	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	**1**

Table 6.26.13 : Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Leaks near Water Meter

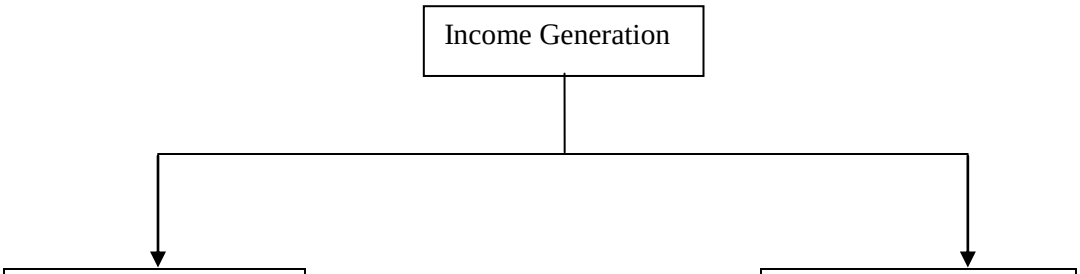
Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	2	1/2	7	2	2	1/2	2	2	1/2	2	2	2	2	2	2	7	2	2	2	2	2
2	1/2	**1**	1/2	5	2	2	1/2	1/2	2	1/2	2	2	1	2	1/2	2	5	2	1/2	2	2	2
3	2	2	**1**	7	2	2	1/2	2	2	1/2	2	2	2	2	2	2	7	2	2	2	2	2
4	1/7	1/5	1/7	**1**	1/2	1/3	1/9	1/6	1/4	1/9	1/3	1/3	1/5	1/4	1/6	1/4	1	1/4	1/6	1/3	1/4	1/2
5	1/2	1/2	1/2	2	**1**	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2
6	1/2	1/2	1/2	3	2	**1**	1/2	1/2	1/2	1/2	1	1	1/2	1/2	1/2	1/2	3	1/2	1/2	2	1/2	2
7	2	2	2	9	2	2	**1**	2	2	2	2	2	2	2	2	2	9	2	2	2	2	2
8	1/2	2	1/2	6	2	2	1/2	**1**	2	1/2	2	2	2	2	2	2	6	2	1	2	2	2
9	1/2	1/2	1/2	4	2	2	1/2	1/2	**1**	1/2	2	2	1/2	1/2	1/2	1/2	4	1/2	1/2	2	1/2	2
10	2	2	2	9	2	2	1/2	2	2	**1**	2	2	2	2	2	2	9	2	2	2	2	2
11	1/2	1/2	1/2	3	2	1	1/2	1/2	1/2	1/2	**1**	1	1/2	1/2	1/2	1/2	3	1/2	1/2	2	1/2	2
12	1/2	1/2	1/2	3	2	1	1/2	1/2	1/2	1/2	1	**1**	1/2	1/2	1/2	1/2	3	1/2	1/2	2	1/2	2
13	1/2	1	1/2	5	2	2	1/2	1/2	2	1/2	2	2	**1**	2	1/2	2	5	2	1/2	2	2	2
14	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	2	2	1/2	**1**	1/2	2	4	1/2	1/2	2	1	2
15	1/2	2	1/2	6	2	2	1/2	1/2	2	1/2	2	2	2	2	**1**	2	6	2	1/2	2	2	2
16	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	2	2	1/2	1/2	1/2	**1**	4	1/2	1/2	2	1/2	2
17	1/7	1/5	1/7	1	1/2	1/3	1/9	1/6	1/4	1/9	1/3	1/3	1/5	1/4	1/6	1/4	**1**	1/4	1/6	1/3	1/4	1/2
18	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	2	2	1/2	2	1/2	2	4	**1**	1/2	2	2	2
19	1/2	2	1/2	6	2	2	1/2	1	2	1/2	2	2	2	2	2	2	6	2	**1**	2	2	2
20	1/2	1/2	1/2	3	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	3	1/2	1/2	**1**	1/2	2
21	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	2	2	1/2	1	1/2	2	4	1/2	1/2	2	**1**	2
22	1/2	1/2	1/2	2	2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	**1**

Table 6.26.14 : Pairwise Preferences Converted to Saaty's Scale for Alternatives for Sub Criterion – Night Time Leaks

Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
2	1/9	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1/9	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1/9	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1/9	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1/9	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1/9	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1/9	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1/9	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1/9	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1	1
11	1/9	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1	1
12	1/9	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
13	1/9	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1
14	1/9	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1
15	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1
16	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1
17	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1
18	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1
19	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1
20	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1	1
21	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**	1
22	1/9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**

Table 6.26.15: Pairwise Preferences converted to Saaty's Scale for Alternatives for Sub Criterion – Stop Valve Leaks

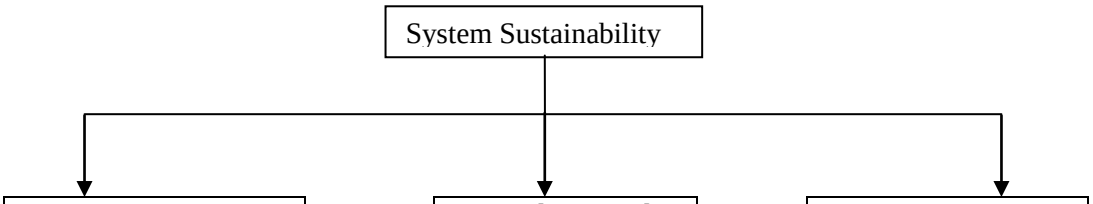
Zone No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	**1**	1	1/2	7	2	2	1/2	1	2	2	2	2	2	1/2	1/2	2	7	2	2	2	2	2
2	1	**1**	1/2	7	2	2	1/2	1	2	2	2	2	2	1/2	1/2	2	7	2	2	2	2	2
3	2	2	**1**	7	2	2	1/2	2	2	2	2	2	2	1	1	2	7	2	2	2	2	2
4	1/7	1/7	1/7	**1**	1/3	1/3	1/9	1/7	1/3	1/6	1/2	1/4	1/3	1/7	1/7	1/2	1	1/5	1/5	1/4	1/3	1/2
5	1/2	1/2	1/2	3	**1**	1/2	1/2	1/2	1	1/2	2	1/2	1	1/2	1/2	2	3	1/2	1/2	1/2	1/2	2
6	1/2	1/2	1/2	3	2	**1**	1/2	1/2	2	1/2	2	1/2	2	1/2	1/2	2	3	1/2	1/2	1/2	1	2
7	2	2	2	9	2	2	**1**	2	2	2	2	2	2	2	2	2	9	2	2	2	2	2
8	1	1	1/2	7	2	2	1/2	**1**	2	2	2	2	2	1/2	1/2	2	7	2	2	2	2	2
9	1/2	1/2	1/2	3	1	1/2	1/2	1/2	**1**	1/2	2	1/2	1	1/2	1/2	2	3	1/2	1/2	1/2	1/2	2
10	1/2	1/2	1/2	6	2	2	1/2	1/2	2	**1**	2	2	2	1/2	1/2	2	6	2	2	2	2	2
11	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	**1**	1/2	1/2	1/2	1/2	1	2	1/2	1/2	1/2	1/2	1
12	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	2	**1**	2	1/2	1/2	2	4	1/2	1/2	1	2	2
13	1/2	1/2	1/2	3	1	1/2	1/2	1/2	1	1/2	2	1/2	**1**	1/2	1/2	2	3	1/2	1/2	1/2	1/2	2
14	2	2	1	7	2	2	1/2	2	2	2	2	2	2	**1**	1	2	7	2	2	2	2	2
15	2	2	1	7	2	2	1/2	2	2	2	2	2	2	1	**1**	2	7	2	2	2	2	2
16	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	1	1/2	1/2	1/2	1/2	**1**	2	1/2	1/2	1/2	1/2	1
17	1/7	1/7	1/7	1	1/3	1/3	1/9	1/7	1/3	1/6	1/2	1/4	1/3	1/7	1/7	1/2	**1**	1/5	1/5	1/4	1/3	1/2
18	1/2	1/2	1/2	5	2	2	1/2	1/2	2	1/2	2	2	2	1/2	1/2	2	5	**1**	1	2	2	2
19	1/2	1/2	1/2	5	2	2	1/2	1/2	2	1/2	2	2	2	1/2	1/2	2	5	1	**1**	2	2	2
20	1/2	1/2	1/2	4	2	2	1/2	1/2	2	1/2	2	1	2	1/2	1/2	2	4	1/2	1/2	**1**	2	2
21	1/2	1/2	1/2	3	2	1	1/2	1/2	2	1/2	2	1/2	2	1/2	1/2	2	3	1/2	1/2	1/2	**1**	2
22	1/2	1/2	1/2	2	1/2	1/2	1/2	1/2	1/2	1/2	1	1/2	1/2	1/2	1/2	1	2	1/2	1/2	1/2	1/2	**1**



1. New Connections	
Zone 1	0.1409
Zone 2	0.1161
Zone 3	0.0182
Zone 4	0.0201
Zone 5	0.0478
Zone 6	0.0814
Zone 7	0.0707
Zone 8	0.0291
Zone 9	0.0146
Zone 10	0.0424
Zone 11	0.0356
Zone 12	0.0550
Zone 13	0.0132
Zone 14	0.0663
Zone 15	0.0160
Zone 16	0.0264
Zone 17	0.0895
Zone 18	0.0106
Zone 19	0.0380
Zone 20	0.0114
Zone 21	0.0244
Zone 22	0.0324
Total	1.0000

2. Bill collection	
Zone 1	0.0148
Zone 2	0.0182
Zone 3	0.1436
Zone 4	0.0217
Zone 5	0.0302
Zone 6	0.0114
Zone 7	0.0263
Zone 8	0.0729
Zone 9	0.0507
Zone 10	0.0971
Zone 11	0.0553
Zone 12	0.0247
Zone 13	0.0231
Zone 14	0.0138
Zone 15	0.0795
Zone 16	0.0670
Zone 17	0.0333
Zone 18	0.0911
Zone 19	0.0170
Zone 20	0.0196
Zone 21	0.0604
Zone 22	0.0280
Total	1.0000

Figure 6.6 : Preference of Alternatives – New Connections and Bill Collection



1. Operation & Maintenance	
Zone 1	0.0703
Zone 2	0.0478
Zone 3	0.0660
Zone 4	0.0104
Zone 5	0.0237
Zone 6	0.0291
Zone 7	0.0804
Zone 8	0.0536
Zone 9	0.0273
Zone 10	0.0754
Zone 11	0.0478
Zone 12	0.0376
Zone 13	0.0412
Zone 14	0.0439
Zone 15	0.0873
Zone 16	0.0331
Zone 17	0.0157
Zone 18	0.0571
Zone 19	0.0608
Zone 20	0.0310
Zone 21	0.0353
Zone 22	0.0252
	1.0000

2. Salaries and Overtime	
Zone 1	0.0113
Zone 2	0.0180
Zone 3	0.0801
Zone 4	0.0255
Zone 5	0.0233
Zone 6	0.0134
Zone 7	0.0304
Zone 8	0.0589
Zone 9	0.0479
Zone 10	0.0946
Zone 11	0.0533
Zone 12	0.0272
Zone 13	0.0219
Zone 14	0.0158
Zone 15	0.1403
Zone 16	0.0773
Zone 17	0.0365
Zone 18	0.0888
Zone 19	0.0205
Zone 20	0.0180
Zone 21	0.0628
Zone 22	0.0342
	1.0000

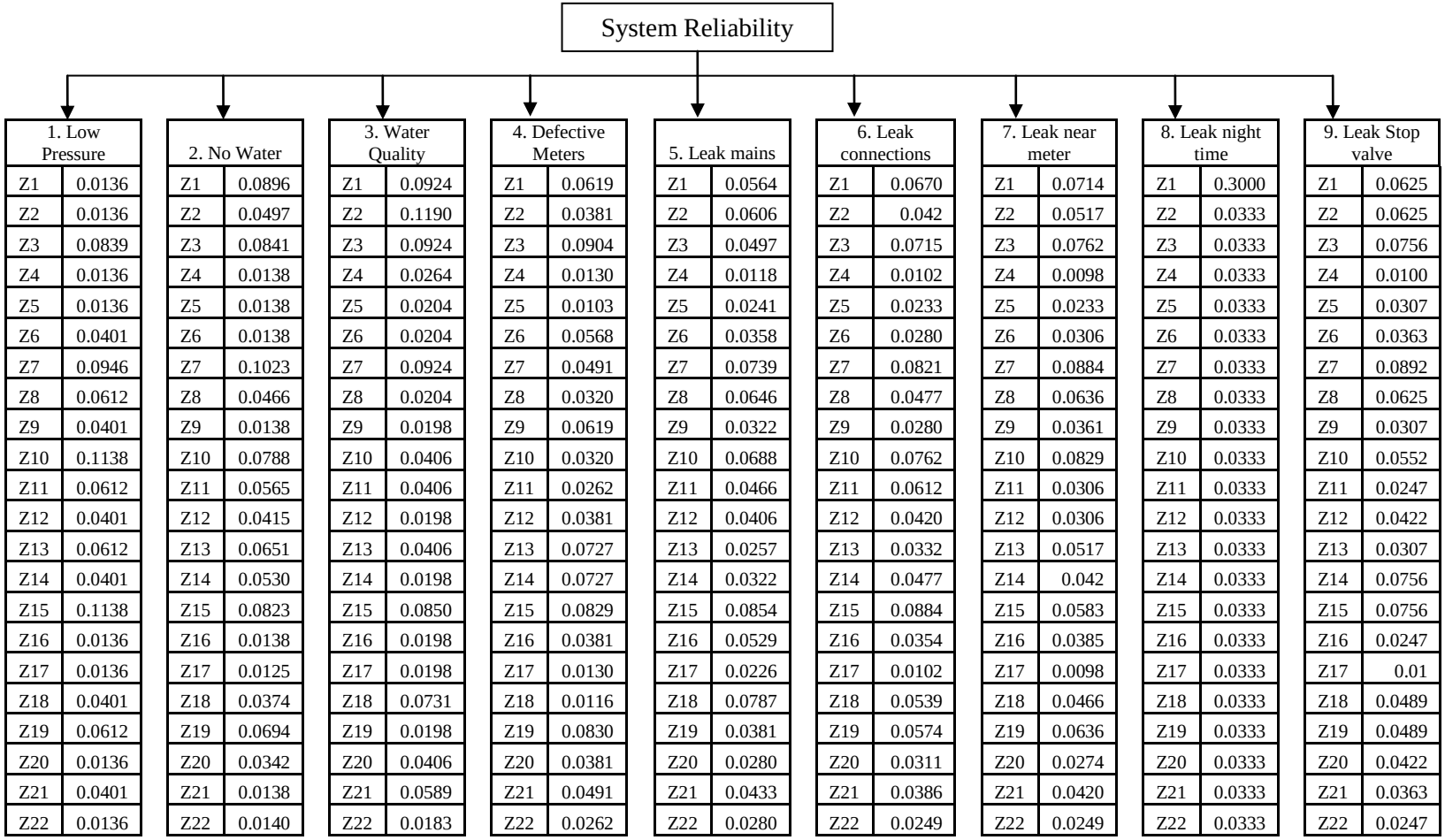
3. Transport	
Zone 1	0.0788
Zone 2	0.0243
Zone 3	0.0222
Zone 4	0.0130
Zone 5	0.0175
Zone 6	0.0650
Zone 7	0.0086
Zone 8	0.0329
Zone 9	0.0455
Zone 10	0.0610
Zone 11	0.0499
Zone 12	0.0532
Zone 13	0.0208
Zone 14	0.0359
Zone 15	0.0978
Zone 16	0.0426
Zone 17	0.0810
Zone 18	0.0693
Zone 19	0.0567
Zone 20	0.0309
Zone 21	0.0739
Zone 22	0.0195
	1.0000

Figure 6.7 : Preference of Alternatives – Operation and Maintenance, Salaries and Overtime, Transport

System Losses

NRW	
Zone 1	0.0514
Zone 2	0.0475
Zone 3	0.0375
Zone 4	0.0502
Zone 5	0.0463
Zone 6	0.0431
Zone 7	0.0436
Zone 8	0.0304
Zone 9	0.0307
Zone 10	0.0395
Zone 11	0.0209
Zone 12	0.0503
Zone 13	0.0470
Zone 14	0.0557
Zone 15	0.0440
Zone 16	0.0518
Zone 17	0.0615
Zone 18	0.0455
Zone 19	0.0519
Zone 20	0.0513
Zone 21	0.0423
Zone 22	0.0576
Total	1.0000

Figure 6.8 : Preference of Alternatives – Non Revenue Water



1. Low Pressure		2. No Water		3. Water Quality		4. Defective Meters		5. Leak mains		6. Leak connections		7. Leak near meter		8. Leak night time		9. Leak Stop valve	
Z1	0.0136	Z1	0.0896	Z1	0.0924	Z1	0.0619	Z1	0.0564	Z1	0.0670	Z1	0.0714	Z1	0.3000	Z1	0.0625
Z2	0.0136	Z2	0.0497	Z2	0.1190	Z2	0.0381	Z2	0.0606	Z2	0.042	Z2	0.0517	Z2	0.0333	Z2	0.0625
Z3	0.0839	Z3	0.0841	Z3	0.0924	Z3	0.0904	Z3	0.0497	Z3	0.0715	Z3	0.0762	Z3	0.0333	Z3	0.0756
Z4	0.0136	Z4	0.0138	Z4	0.0264	Z4	0.0130	Z4	0.0118	Z4	0.0102	Z4	0.0098	Z4	0.0333	Z4	0.0100
Z5	0.0136	Z5	0.0138	Z5	0.0204	Z5	0.0103	Z5	0.0241	Z5	0.0233	Z5	0.0233	Z5	0.0333	Z5	0.0307
Z6	0.0401	Z6	0.0138	Z6	0.0204	Z6	0.0568	Z6	0.0358	Z6	0.0280	Z6	0.0306	Z6	0.0333	Z6	0.0363
Z7	0.0946	Z7	0.1023	Z7	0.0924	Z7	0.0491	Z7	0.0739	Z7	0.0821	Z7	0.0884	Z7	0.0333	Z7	0.0892
Z8	0.0612	Z8	0.0466	Z8	0.0204	Z8	0.0320	Z8	0.0646	Z8	0.0477	Z8	0.0636	Z8	0.0333	Z8	0.0625
Z9	0.0401	Z9	0.0138	Z9	0.0198	Z9	0.0619	Z9	0.0322	Z9	0.0280	Z9	0.0361	Z9	0.0333	Z9	0.0307
Z10	0.1138	Z10	0.0788	Z10	0.0406	Z10	0.0320	Z10	0.0688	Z10	0.0762	Z10	0.0829	Z10	0.0333	Z10	0.0552
Z11	0.0612	Z11	0.0565	Z11	0.0406	Z11	0.0262	Z11	0.0466	Z11	0.0612	Z11	0.0306	Z11	0.0333	Z11	0.0247
Z12	0.0401	Z12	0.0415	Z12	0.0198	Z12	0.0381	Z12	0.0406	Z12	0.0420	Z12	0.0306	Z12	0.0333	Z12	0.0422
Z13	0.0612	Z13	0.0651	Z13	0.0406	Z13	0.0727	Z13	0.0257	Z13	0.0332	Z13	0.0517	Z13	0.0333	Z13	0.0307
Z14	0.0401	Z14	0.0530	Z14	0.0198	Z14	0.0727	Z14	0.0322	Z14	0.0477	Z14	0.042	Z14	0.0333	Z14	0.0756
Z15	0.1138	Z15	0.0823	Z15	0.0850	Z15	0.0829	Z15	0.0854	Z15	0.0884	Z15	0.0583	Z15	0.0333	Z15	0.0756
Z16	0.0136	Z16	0.0138	Z16	0.0198	Z16	0.0381	Z16	0.0529	Z16	0.0354	Z16	0.0385	Z16	0.0333	Z16	0.0247
Z17	0.0136	Z17	0.0125	Z17	0.0198	Z17	0.0130	Z17	0.0226	Z17	0.0102	Z17	0.0098	Z17	0.0333	Z17	0.01
Z18	0.0401	Z18	0.0374	Z18	0.0731	Z18	0.0116	Z18	0.0787	Z18	0.0539	Z18	0.0466	Z18	0.0333	Z18	0.0489
Z19	0.0612	Z19	0.0694	Z19	0.0198	Z19	0.0830	Z19	0.0381	Z19	0.0574	Z19	0.0636	Z19	0.0333	Z19	0.0489
Z20	0.0136	Z20	0.0342	Z20	0.0406	Z20	0.0381	Z20	0.0280	Z20	0.0311	Z20	0.0274	Z20	0.0333	Z20	0.0422
Z21	0.0401	Z21	0.0138	Z21	0.0589	Z21	0.0491	Z21	0.0433	Z21	0.0386	Z21	0.0420	Z21	0.0333	Z21	0.0363
Z22	0.0136	Z22	0.0140	Z22	0.0183	Z22	0.0262	Z22	0.0280	Z22	0.0249	Z22	0.0249	Z22	0.0333	Z22	0.0247

Figure 6.9 : Preference of Alternatives for Sub Criteria of System Reliability

6.6 Consistency Estimations

Weights of MCDA model corresponding to main and sub criteria along with management alternatives were checked for consistency. Consistency indices and consistency ratio were computed according to the method (Saaty, 1977) and Parameters (Donegan & Dodd, 1991) indicated in literature. MCDA model was calibrated by checking the consistency for Main criteria, Sub criteria and Alternatives. Using the above data prioritization of the management zones were obtained and verified with the field data.

6.6.1 Main criteria

Consistency ratio and associated parameters corresponding to Main Criteria are in Table 6.27.

Table 6.27: Consistency Ratios – Main Criteria

	Number of alternatives (n)	λ max	Consistency Ratio, CR	Inconsistent/ Consistent
C 1	4	4.0935	0.035	Consistent
C 2		4.0685	0.025	Consistent
C 3		4.7418	0.275	Inconsistent
C 4		4.1771	0.066	Consistent

6.6.2 Sub criteria

Consistancy ratio for subcriteria alternatives are as in Table 6.28, 6.29 and 6.30 .

1. Income Generation

Table 6.28: Consistency Ratio – Sub Criteria

Number of alternatives (n)	λ max	Consistency Ratio	Consistent/ Inconsistent
2	2	0	Consistent

2. System Sustainability

Table 6.29: Consistency Ratio – Sub Criteria

Number of alternatives (n)	ƛ max	Consistency Ratio	Consistent/ Inconsistent
3	3.0723	0.062	Consistent

3. System Reliability

Table 6.30: Consistency Ratio – Sub Criteria

Number of alternatives (n)	ƛ max	Consistency Ratio	Consistent/ Inconsistent
9	9.1783	0.015	Consistent

6.6.3 Alternatives

Table 6.31: Consistency Ratios for Alternatives

#	Sub Criteria	Number of alternatives (n)	ƛ max	Consistency Ratio	Consistent/ Inconsistent
1	New Connections	22	22.9046	0.028	Consistent
2	Bill collection		23.3577	0.042	Consistent
3	Operation & Maintenance Cost		23.2933	0.040	Consistent
4	Salaries and Overtime		23.2203	0.038	Consistent
5	Transport Cost		23.2429	0.038	Consistent
6	Non Revenue Water (NRW)		23.1353	0.035	Consistent
7	Low Pressure		22.2741	0.008	Consistent
8	No water		23.0982	0.034	Consistent
9	Water Quality		22.6346	0.020	Consistent
10	Defective Meters		23.0204	0.031	Consistent
11	Leak - Mains		23.3898	0.043	Consistent
12	Leak - Connections		23.2351	0.038	Consistent
13	Leak - Near meter		23.1726	0.036	Consistent
14	Leak - Night time		22	0.000	Consistent
15	Leak -Stop valve		23.0055	0.031	Consistent

6.7 Model Calibration Results – MCDA Weights

6.7.1 Introdution

Computation of weights corresponding to each management zone required the evaluation of combinations of main criteria identified as consistant (Figure 6.10). The alternative weights for the three consistant combinations are in Table 6.32 and Figure 6.10.

Table 6.32 Alternative weights of MCDA Model

Management Zones	Combination 1	Combination 2	Combination 4
Z1	0.070393	0.065119	0.072102
Z2	0.058062	0.053397	0.059996
Z3	0.075547	0.068711	0.076865
Z4	0.021100	0.026555	0.021186
Z5	0.034487	0.035547	0.034690
Z6	0.040478	0.039738	0.041116
Z7	0.054735	0.056759	0.055061
Z8	0.051468	0.051587	0.050951
Z9	0.034061	0.037577	0.033724
Z10	0.070736	0.067239	0.070092
Z11	0.046767	0.047440	0.046516
Z12	0.038893	0.039888	0.038880
Z13	0.026569	0.033560	0.026380
Z14	0.039281	0.039837	0.039499
Z15	0.064116	0.068525	0.061793
Z16	0.044802	0.043903	0.044126
Z17	0.047330	0.040041	0.048384
Z18	0.054302	0.053446	0.053313
Z19	0.035843	0.040243	0.034892
Z20	0.020924	0.025143	0.020533
Z21	0.042003	0.039734	0.041915
Z22	0.028102	0.026011	0.027985

Efficient and Effective Management of a Pipe Borne Water Supply System

	Income Generation	System Sustainability	System Losses	System Reliability
Combination 1	0.600455	0.277579	0.073541	0.048425
Combination 2	0.301764	0.387475	0.272804	0.037957
Combination 4	0.643293	0.200086	0.064264	0.092357

New Connections	Bill Collection	Operation & Maintenance	Salaries and Overtime	Transport	NRW	Low Pressure	No Water	Water Quality	Defective Meters	Leak - Mains	Leak - Connections	Leak – near meter	Night time - Leaks	Leak – Stop Valve
0.49315	0.50685	0.70852	0.23115	0.06033	1	0.16834	0.21090	0.26045	0.10117	0.12113	0.04380	0.03002	0.04320	0.02099
0.1409	0.0148	0.0703	0.0113	0.0788	0.0514	0.0136	0.0896	0.0924	0.0619	0.0564	0.0670	0.0714	0.3000	0.0625
0.1161	0.0182	0.0478	0.0180	0.0243	0.0475	0.0136	0.0497	0.1190	0.0381	0.0606	0.0420	0.0517	0.0333	0.0625
0.0182	0.1436	0.0660	0.0801	0.0222	0.0375	0.0839	0.0841	0.0924	0.0904	0.0497	0.0715	0.0762	0.0333	0.0756
0.0201	0.0217	0.0104	0.0255	0.0130	0.0502	0.0136	0.0138	0.0264	0.0130	0.0118	0.0102	0.0098	0.0333	0.0100
0.0478	0.0302	0.0237	0.0233	0.0175	0.0463	0.0136	0.0138	0.0204	0.0130	0.0241	0.0233	0.0233	0.0333	0.0307
0.0814	0.0114	0.0291	0.0134	0.0650	0.0431	0.0401	0.0138	0.0204	0.0568	0.0358	0.0280	0.0306	0.0333	0.0363
0.0707	0.0263	0.0804	0.0304	0.0086	0.0436	0.0946	0.1023	0.0924	0.0491	0.0739	0.0821	0.0884	0.0333	0.0892
0.0291	0.0729	0.0536	0.0589	0.0329	0.0304	0.0612	0.0466	0.0204	0.0320	0.0646	0.0477	0.0636	0.0333	0.0625
0.0146	0.0507	0.0273	0.0479	0.0455	0.0307	0.0401	0.0138	0.0198	0.0619	0.0322	0.0280	0.0361	0.0333	0.0307
0.0424	0.0971	0.0754	0.0946	0.0610	0.0395	0.1138	0.0788	0.0406	0.0320	0.0688	0.0762	0.0829	0.0333	0.0552
0.0356	0.0553	0.0478	0.0533	0.0499	0.0209	0.0612	0.0565	0.0406	0.0262	0.0466	0.0612	0.0306	0.0333	0.0247
0.0550	0.0247	0.0376	0.0272	0.0532	0.0503	0.0401	0.0415	0.0198	0.0381	0.0406	0.0420	0.0306	0.0333	0.0422
0.0132	0.0231	0.0412	0.0219	0.0208	0.0470	0.0612	0.0651	0.0406	0.0727	0.0257	0.0332	0.0517	0.0333	0.0307
0.0663	0.0138	0.0439	0.0158	0.0359	0.0557	0.0401	0.0530	0.0198	0.0727	0.0322	0.0477	0.0420	0.0333	0.0756
0.0160	0.0795	0.0873	0.1403	0.0978	0.0440	0.1138	0.0823	0.0850	0.0829	0.0854	0.0884	0.0583	0.0333	0.0756
0.0264	0.0670	0.0331	0.0773	0.0426	0.0518	0.0136	0.0138	0.0198	0.0381	0.0529	0.0354	0.0385	0.0333	0.0247
0.0895	0.0333	0.0157	0.0365	0.0810	0.0615	0.0136	0.0125	0.0198	0.0130	0.0226	0.0102	0.0098	0.0333	0.0100
0.0106	0.0911	0.0571	0.0888	0.0693	0.0455	0.0401	0.0374	0.0731	0.0116	0.0787	0.0539	0.0466	0.0333	0.0489
0.0380	0.0170	0.0608	0.0205	0.0567	0.0519	0.0612	0.0694	0.0198	0.0830	0.0381	0.0574	0.0636	0.0333	0.0489
0.0114	0.0196	0.0310	0.0180	0.0309	0.0513	0.0136	0.0342	0.0406	0.0381	0.0280	0.0311	0.0274	0.0333	0.0422
0.0244	0.0604	0.0353	0.0628	0.0739	0.0423	0.0401	0.0138	0.0589	0.0491	0.0433	0.0386	0.0420	0.0333	0.0363
0.0324	0.0280	0.0252	0.0342	0.0195	0.0576	0.0136	0.014	0.0183	0.0262	0.0280	0.0249	0.0249	0.0333	0.0247

ZI – Z22

Figure 6.10 : Combinations of MCDA Model Weights

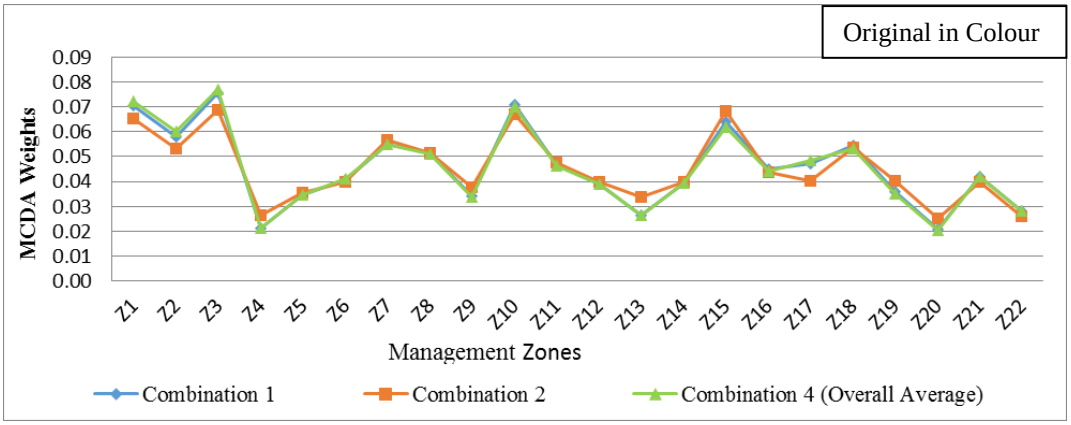


Figure 6.11 : Alternative weights for Combinationss

6.7.2 Comparison

Difference between the weights were compared by using the Combination C.4 (Average values) as the datum. The absolute errors of C.1 & C.2 with respect to C.4 were negligible when compared with the C4 Combination values at an order of second decimal (Table 6.33). Figure 6.11 also clearly demonstrates that all consistent combinations were leading to almost the same result. The result of this work indicated the suitability of using the average of similar stakeholder opinions.

Table 6.33 : Comparison of Consistent Weight Combinations

Management Zones	Combination 4 (C4)	Combination 1 (C1)	Combination 2 (C2)	Difference of C1 compared to C4	Difference of C2 compared to C4
Z1	0.072102	0.070393	0.065119	0.000	0.000
Z2	0.059996	0.058062	0.053397	0.000	0.010
Z3	0.076865	0.075547	0.068711	0.000	0.010
Z4	0.021186	0.021100	0.026555	0.000	0.010
Z5	0.034690	0.034487	0.035547	0.000	0.010
Z6	0.041116	0.040478	0.039738	0.000	0.000
Z7	0.055061	0.054735	0.056759	0.010	0.010
Z8	0.050951	0.051468	0.051587	0.000	0.000
Z9	0.033724	0.034061	0.037577	0.000	0.010
Z10	0.070092	0.070736	0.067239	0.000	0.000
Z11	0.046516	0.046767	0.047440	0.000	0.000
Z12	0.038880	0.038893	0.039888	0.000	0.000
Z13	0.026380	0.026569	0.033560	0.000	0.000
Z14	0.039499	0.039281	0.039837	0.000	0.000
Z15	0.061793	0.064116	0.068525	0.000	0.010
Z16	0.044126	0.044802	0.043903	0.000	0.000
Z17	0.048384	0.047330	0.040041	0.000	0.010
Z18	0.053313	0.054302	0.053446	0.000	0.000
Z19	0.034892	0.035843	0.040243	0.010	0.000
Z20	0.020533	0.020924	0.025143	0.000	0.010
Z21	0.041915	0.042003	0.039734	0.000	0.000
Z22	0.027985	0.028102	0.026011	0.000	0.000
Maximum Error				0.010	0.010
Minimum Error				0.000	0.000
Average Error				0.001	0.004

6.8 Model Verification

6.8.1 Priority order in practice

As described in the field data collection (section 5.13), though with difficiencies, the present work captured the feild level priority when managing the Piliyandala-Kesbewa Water Supply System. At field level, the priority indication for overall management was on a 1-10 scale (Figure 5.4, Table 5.2)

Table 6.34 Field level Priority for Overall Management

Field Priority	Zone Identity	Remarks
1	Z17	
2	Z6	Same Priority
	Z15	
	Z18	
3	Z1	Same Priority
	Z12	
	Z16	
	Z21	
4	Z9	Same Priority
	Z11	
5	Z10	Same Priority
	Z22	
6	Z8	
7	Z2	Same Priority
	Z7	
8	Z3	Same Priority
	Z14	
9	Z4	Same Priority
	Z19	
10	Z5	Same Priority
	Z13	
	Z20	

6.8.2 Verification of priority

Priority oder from MCDA weights were rescaled to 1-10 range and compared with field observations (Table 6.35). The conversion assumed a linear and an integer conversion from MCDA weights to observed range.

Table 6.35 : Priority Comparision – Model & Field.

Priority Order	Zones in Field Approach	Zones in MCDA Model
1	Z17	Z1, Z3, Z10
2	Z6, Z15, Z18	Z2, Z15
3	Z1, Z12, Z16, Z21	Z7, Z18
4	Z9, Z11	Z8, Z17
5	Z10, Z22	Z11, Z16
6	Z8	Z 6, Z21
7	Z2, Z7	Z12, Z14
8	Z3, Z14	Z5, Z9, Z19
9	Z4, Z19	Z13, Z22
10	Z5, Z13, Z20	Z4, Z20

Values in Table 6.35 were re-ordered to reflect the behaviour of the field level prioritization with respect to the MCDA model ranking. Values are shown in Table 6.36 & Figure 6.11 shows the plot of values and the trend in the behaviour of system management. In general, the overall system management demonstrated a similar trend in prioritization of management zones. However, there are two outlier clusters namely Z2, Z3, Z7 & Z10 in one cluster and, Z6, Z9, Z12, Z21 & Z22 in the other. Priority order of the management zones was compared and the trends of the graphs were shown in Figure 6.12.

Table 6.36 : Management Zone Priority Order Comparison (Re ordered).

Managemet Zone	Priority Order of MCDA	Priority Order of Field Application
Z3	1	8
Z1	1	3
Z10	1	5
Z15	2	2
Z2	2	7
Z7	3	7
Z18	3	2
Z8	4	6
Z17	4	1
Z11	5	4
Z16	5	3
Z21	6	3
Z 6	6	2
Z14	7	8
Z12	7	3
Z19	8	9
Z5	8	10
Z9	8	4
Z22	9	5
Z13	9	10
Z4	10	9
Z20	10	10

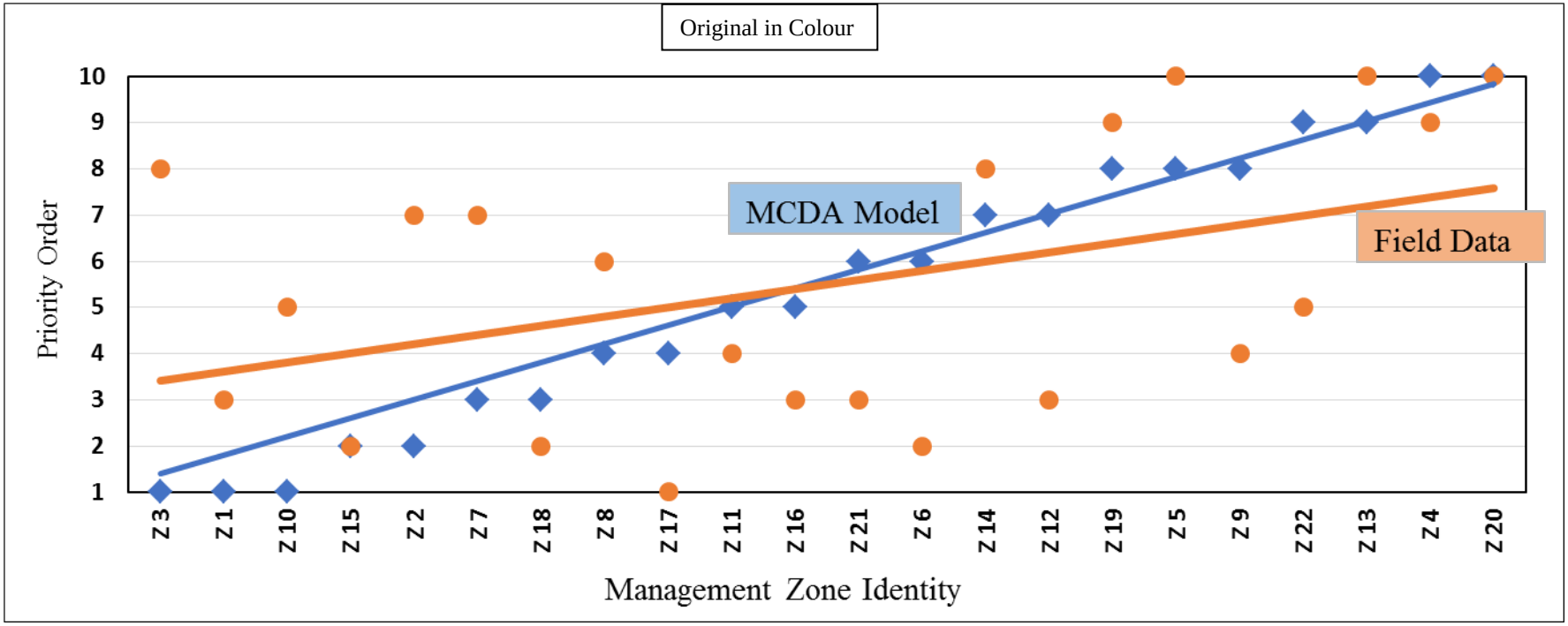


Figure 6.12: Comparison of Priority Order during Model Verification

7. DISCUSSION

7.1 Model Conceptualisation

Water Supply System management is a multicriteria problem. Development of a MCDA model for Water Supply System management posed many problems. Lack of System management guidelines to capture parameters targeting national and organisational objectives, lack of guidelines or documentation to identify field level management indicators to fullfill organizational aspirations and the lack of guidelines to embed sustainability considerations from the point of view of receipient stakeholders are the main problems.

Hence there is a difficulty to conceptualize the model criteria and associated sub criteria. This difficulty was overcome by an identification of details through a literature survey and discussions with senior water supply system managers. Through the model outputs reflected a satisfactory trend matching of model and field application, it is required to do fine tuning of model parameters and sub parameters after a critical stakeholder analysis for the assessment of system management objectives. In this study the stakeholder analysis was restricted to NWSDB Water System managers only. Hence it is important to strengthen the criteria identification aspect.

7.2 Main Criteria Prioritization

The present work resorted to a stakeholder survey to assess preferences and then carryout pairwise comparisons. A stakeholder survey for this activity is appropriate for verification of known responses. Therefore, NWSDB must perform area specific and objective specific studies as demonstrated by this research, inorder to make more quantified guidance available for the modellers. This research studied stakeholder responses in great detail to note varying stakeholder prioritization trends leading to several consistent Saaty combinations. However, it was noted that a simple average of stakeholder views was a suitable solution. When the data collected were carefully looked at, it was noted that this could have been possible because of the near uniform

nature of the stakeholder survey sample. In future studies, it is prudent to appropriately select the stakeholder sample and use a simple averaging method to determine the prioritization weights form MCDA models.

7.3 Sub Criteria Prioritization

In MCDA models, with the increase of number of sub parameters corresponding to a main parameter, the evaluation of priority combinations become significantly difficult unless organizational level study results are available. In this research a significant number, but a rational set of assumptions were required to evaluate the performance of sub criterion against the main criteria. These assumptions also would have led to the disparity of model results with the actual application values. The assumptions used in the research needs a critical evaluation prior to other model developments.

7.4 Project Management Alternatives

Objective of Water Supply System management is to identify the spatial distribution of priority among management zones. In this case the most important is to demarcate the spatial extents according to a management objective. Presently there is a lack of guidelines when demarcating spatial extents. Field survey done for this research revealed that the demarcations are mostly on Meter Reader convenience, and then by trial and error. A uniformity in decisions could not be identified. Hence the field work required many discussions with the Engineers, Engineering Assistants and Meter Readers to identify manageable clusters for MCDA model development.

As resources become competitive, it is very important to use models to manage systems. Therefore in such anticipation it is necessary for water supply managers to identify the actual parameters that govern the spatial management of WSS. Hence NWSDB planning and monitoring activities must focus on the determination of spatial boundaries and associate parameters.

7.5 Field Level Prioritization

Water Supply System management is mostly based on monitory indicators of the Water Supply and Drainage Board. Upon investigation it could be noted that there is a lack of guidelines to manage field level activities within a WSS to appropriately link with organizational objectives. This difficulty also causes a problem in the quantification of Sub parameter performance. This study attempted to identify management priority of spatial extents either dynamic or static. Though WSS employees possessed a sense of prioritization, there was no systematic approach that would enable a rational evaluation connecting organisational objectives and field level practices. The MCDA model validation required the conducting of several discussions with the Area Engineer to arrive at field level prioritisation map. Improvement of the MCDA model development could be done better with systematic organizational attention towards spatial planning and management at field level leading to field level execution maps.

7.6 Model Calibration and Verification

Model Calibration and Verfication required conversion of stakeholder responses and Area Engineer's priority order values to suit Saaty's AHP scale. In this study a linear behavioural approximation was condidered 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 modelling.

In case of field management levels the field office priority values were restricted to a scale of 1- 10. This was merely for convenience. This study emphasises the importance of establishing management practices clearly reflecting objectives at various levels of management hierarchy and the degree of detailing to embed in assessment scales. This would strengthen and improve field data collection accuracies.

The non uniformity in weight conversions, the gaps in criteria determination, field level constraints for obtaining verification data would have lead to the mismatch of

MCDA model out put and the actual situation. The clustering of zones also require detailed evaluation to improve the MCDA model.

7.7 MCDA Model for WSS Management

The MCDA model development undertaken by this study shows the success of applying simple multicriteria models for WSS management. This type of modelling attempts also points to the organisational gaps in guidance to employees through clear hierarchical objectives that start from the National level and then, moves through the organisational planning, monitoring and finally ends at receipient stakeholder level via field level operational management units. It is important to carry out many similar studies to evaluate the assumptions made both interms of criteria and interms of factors that enable 9 rational quantifications through tangible outputs.

In case of MCDA models for WSS management the most important factor other than criteria and their quantification is the identification of spatial units, their characteristics and quantifications. These factors would further strenghthen the management of WSS for the Sustainability of water resources while assuming National and recipient stakeholder targets.

7.8 Criteria Weights

The main criteria weights derived from stakeholder data demonstrated a heavy inclination on Income Generation and a very low attention on System Losses and System Sustainability. This significant importance requires a detailed investigation since it reflects the existence of a deficiency in management process.

Lower priority to these two criteria identified during modelling should be looked at from the point of view of Sub criteria linked to those Main criteria. The low weightage values given to NRW and System weakness can be easily noted from the MCDA management tree. This evaluation can be further extended to spatial extents to capture the preference given to specific areas.

8. CONCLUSIONS AND RECOMMENDATIONS

1. A MCDA model for the management of the water supply system for Piliyandala – Kesbewa was successfully developed.
2. The trend line showing the spatial variability of priority from MCDA model closely matched the area engineer's prioritisation exhibiting the satisfactory level of model verification.
3. The AHP model incorporating stakeholder pairwise combinations revealed that the average of stakeholder preferences would be a satisfactory starting indicator for model development.
4. Field identified priority indicators of each management zone differed from the AHP indicators demonstrating a lack of guidelines for the management at field level and a clear link of objectives at various levels of management.
5. The criteria weights for Income Generation, System Sustainability, System Losses and System Reliability were 0.64, 0.20, 0.07 and 0.09 respectively.
6. Very low priority for System Losses and System Reliability reflects a deficiency in System Management.
7. MCDA model hierarchy and weights provide a clear indication for water supply organisations to evaluate management objectives.
8. This study recommends to carryout other system studies in a similar manner while overcoming the current weakness with respect to the guidelines and stakeholder assessment.

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APPENDIX A – DATA CHECKING

Table A.1: Monthly Inflows to the Piliyandala Water Tower

Month	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
January	230280	185935	275260	319889	305625	321450	399050	462160	494235	548346
February	159390	159205	264597	297888	271160	310330	393543	433550	452810	456532
March	169410	169840	247914	414632	285949	348925	463715	497705	599500	505170
April	173630	165915	262145	318071	294185	329065	404555	450415	602015	541350
May	165555	170054	292134	328494	310548	341485	404698	483047	596760	561315
June	163066	162816	288917	307328	282710	336032	410070	466350	545360	581350
July	171455	165175	287940	329537	311875	351216	432705	486975	575070	634903
August	168885	168725	282855	342652	315235	379871	428265	477255	582098	557191
September	165673	160959	282154	294147	298295	362875	433595	476330	576530	622825
October	178580	219935	284800	272878	299788	376605	472175	468087	577428	583323
November	179305	247525	302731	271218	296986	400581	429855	476800	509600	576760
December	177181	243527	316967	296857	312562	396766	448885	520845	570044	592348
Average	175201	184968	282368	316133	298743	354600	426759	474960	556788	563451
Maximum	230280	247525	316967	414632	315235	400581	472175	520845	602015	634903
Minimum	159390	159205	247914	271218	271160	310330	393543	433550	452810	456532

Table A.2: Monthly Consumption Data

	January	February	March	April	May	June	July	August	September	October	November	December
2001						552	170	226	237	357	275	284
2002	74627	83786	93801	104169	117170	117586	94647	98492	110294	116644	137182	151591
2003	150450	154140	129354	142505	169597	146649	153318	161400	165691	161672	163901	158094
2004	174516	168639	154346	187598	195375	165694	171527	142107	152279	176165	175887	186818
2005	232291	174151	155999	145468	163100	171763	165621	164707	166104	170465	156109	163799
2006	162063	168526	155428	151757	160584	159098	161200	145271	154403	147524	177280	162063
2007	201119	206220	201788	205706	200365	216554	219091	233939	234150	230126	256248	182615
2008	241877	269346	276072	258080	239271	248043	192245	251188	260342	261565	259525	238999
2009	283056	287347	258398	264338	290708	241194	241553	258689	248153	261864	257364	236522
2010	273003	282110	264217	287948	300683	300855	319241	255608	281497	276421	306734	267472
2011	299896	291436	290798	330645	334566	290300	320166	331079	325845	347141	323092	323441
2012	340448	359292	342129	375409	424822	326387	329705	343215	351259	331009	385004	335866
2013	367039	357648	336569	401439	411227	345687	323674	368278	385368	361016	383826	360292
2014	397567	399234	391756	414300	416538	391277	383178	421794	415442	372322	376584	376616

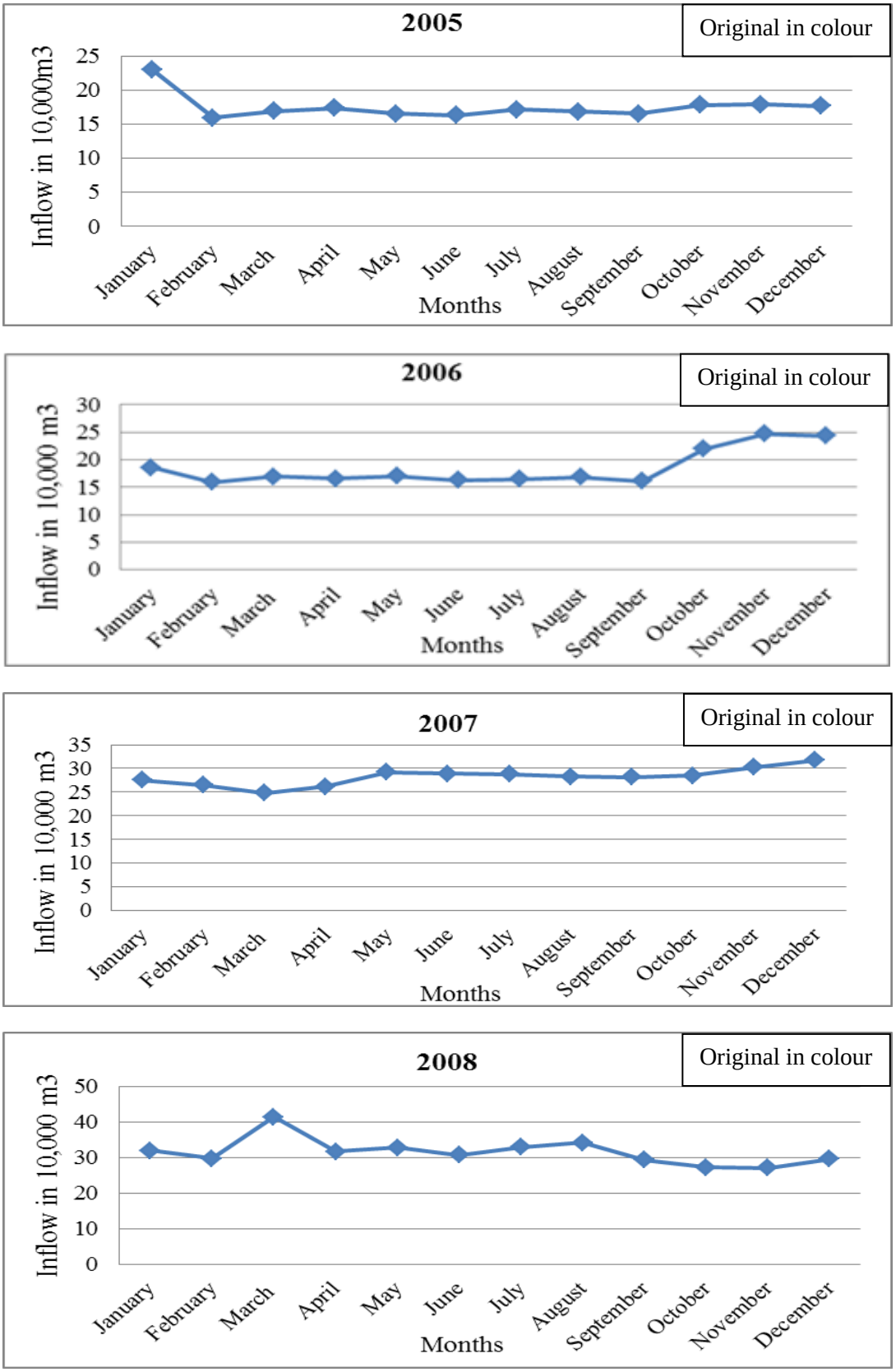

Figure A.1: Water Inflows to the Piliyandala Water Tower

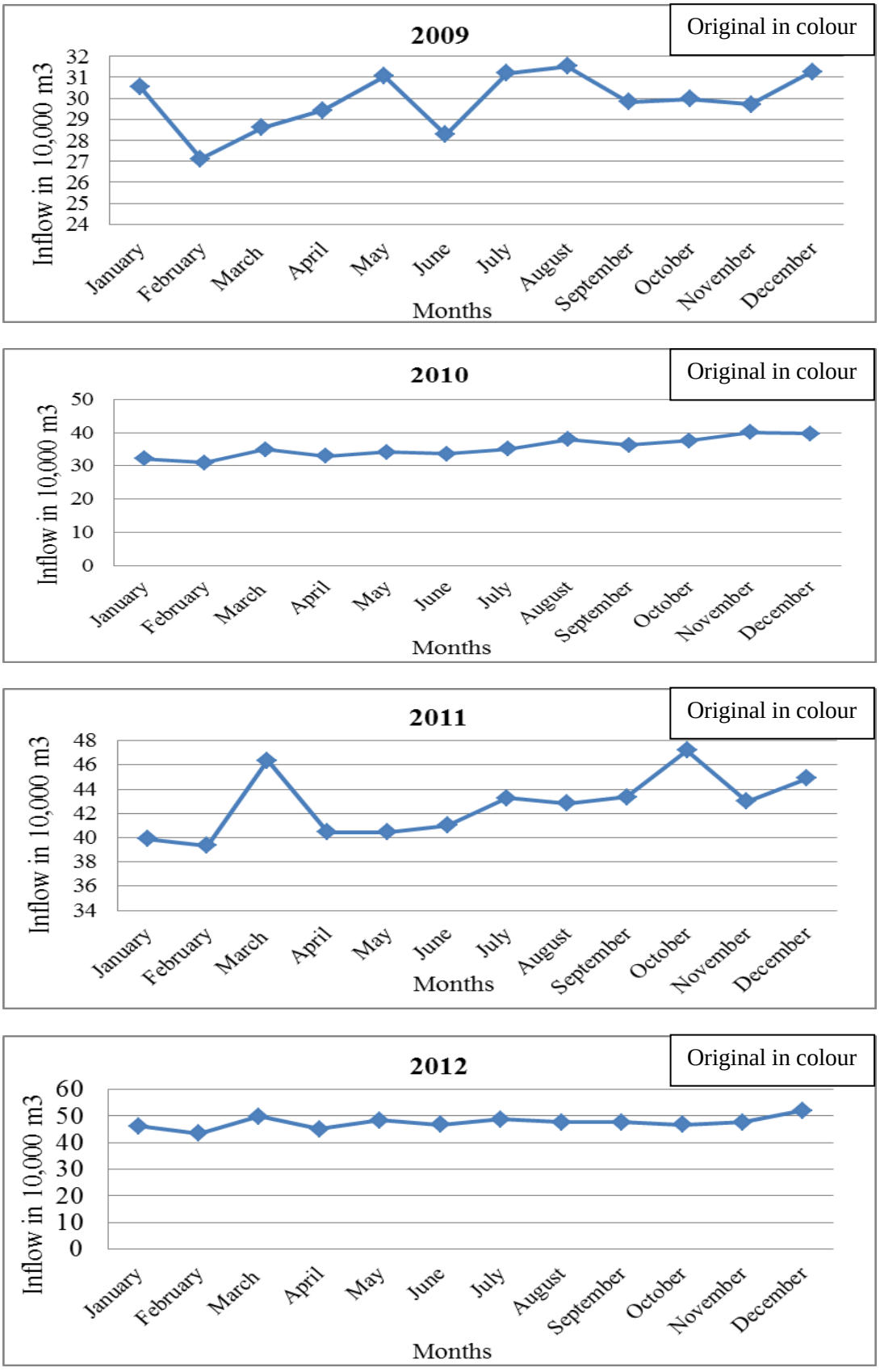

Figure A.2: Water Inflows to the Piliyandala Water Tower

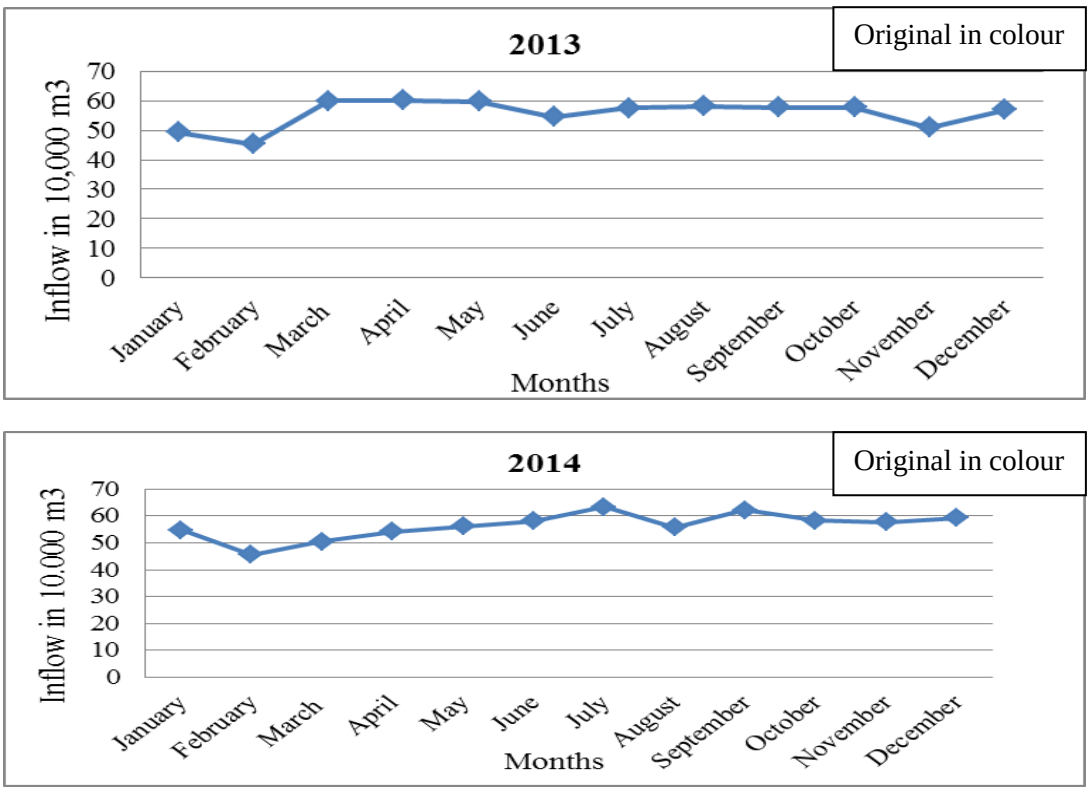

Figure A.3: Water Inflows to the Piliyandala Water Tower

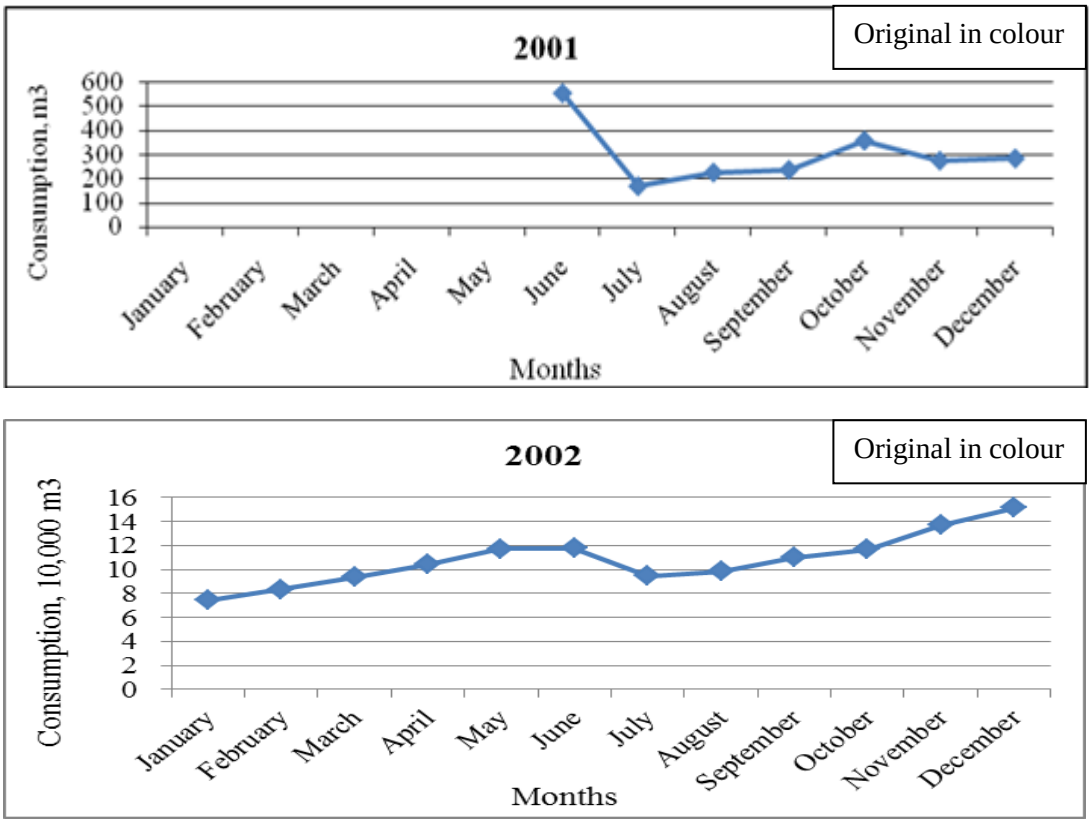

Figure A.3 : Water Consumption Data

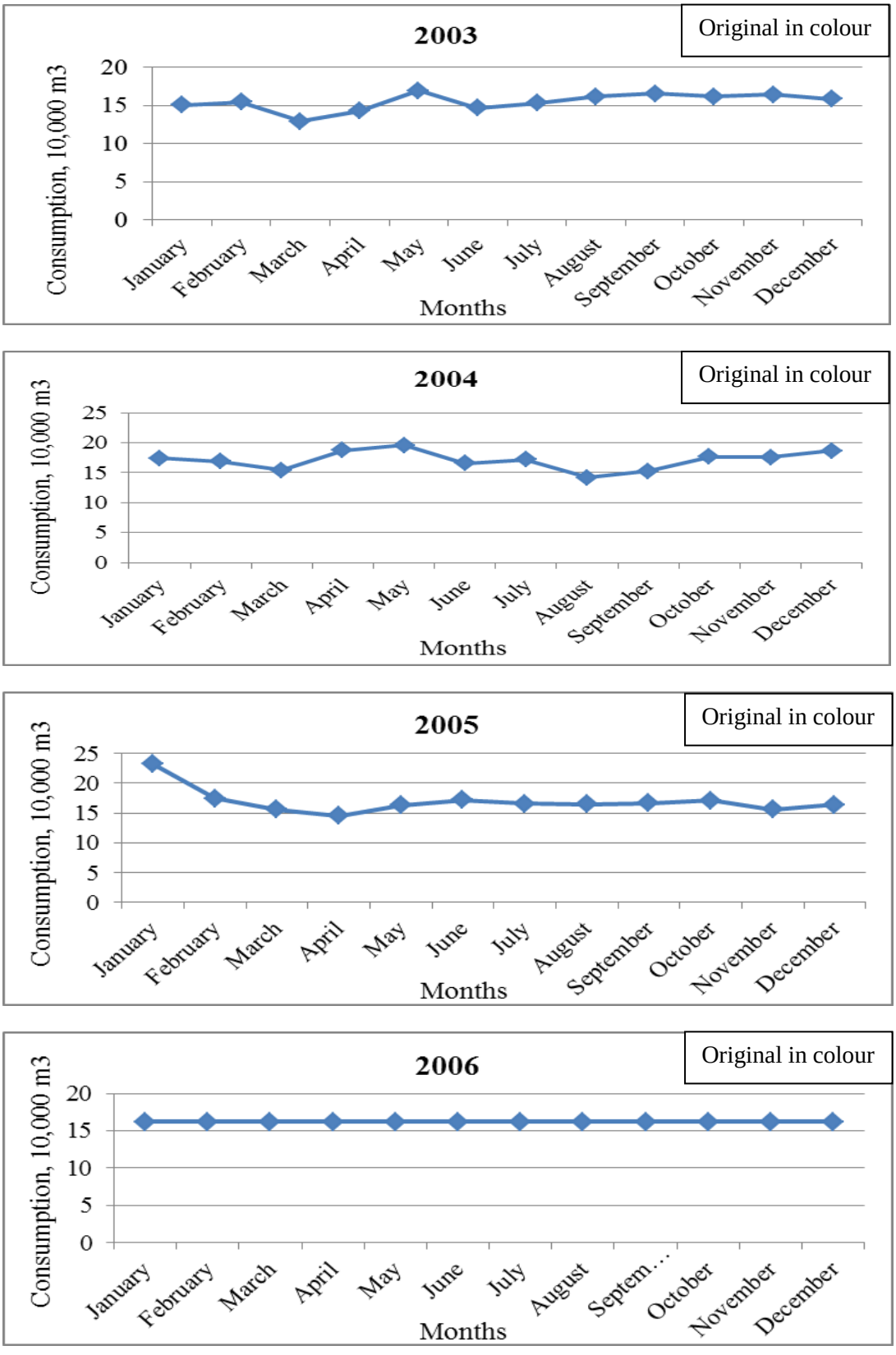

Figure A.4 : Water Consumption Data

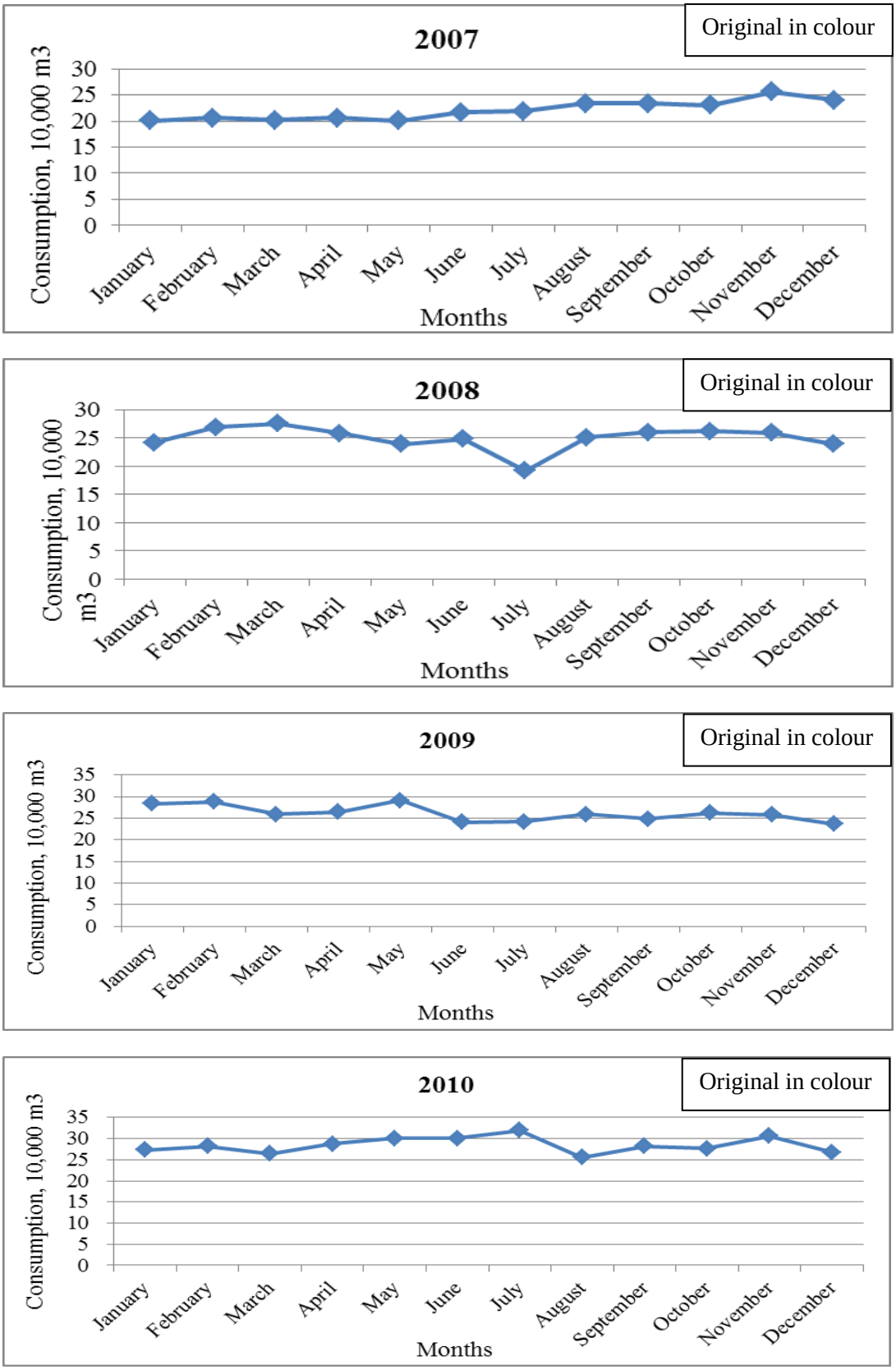

Figure A.5 : Water Consumption Data

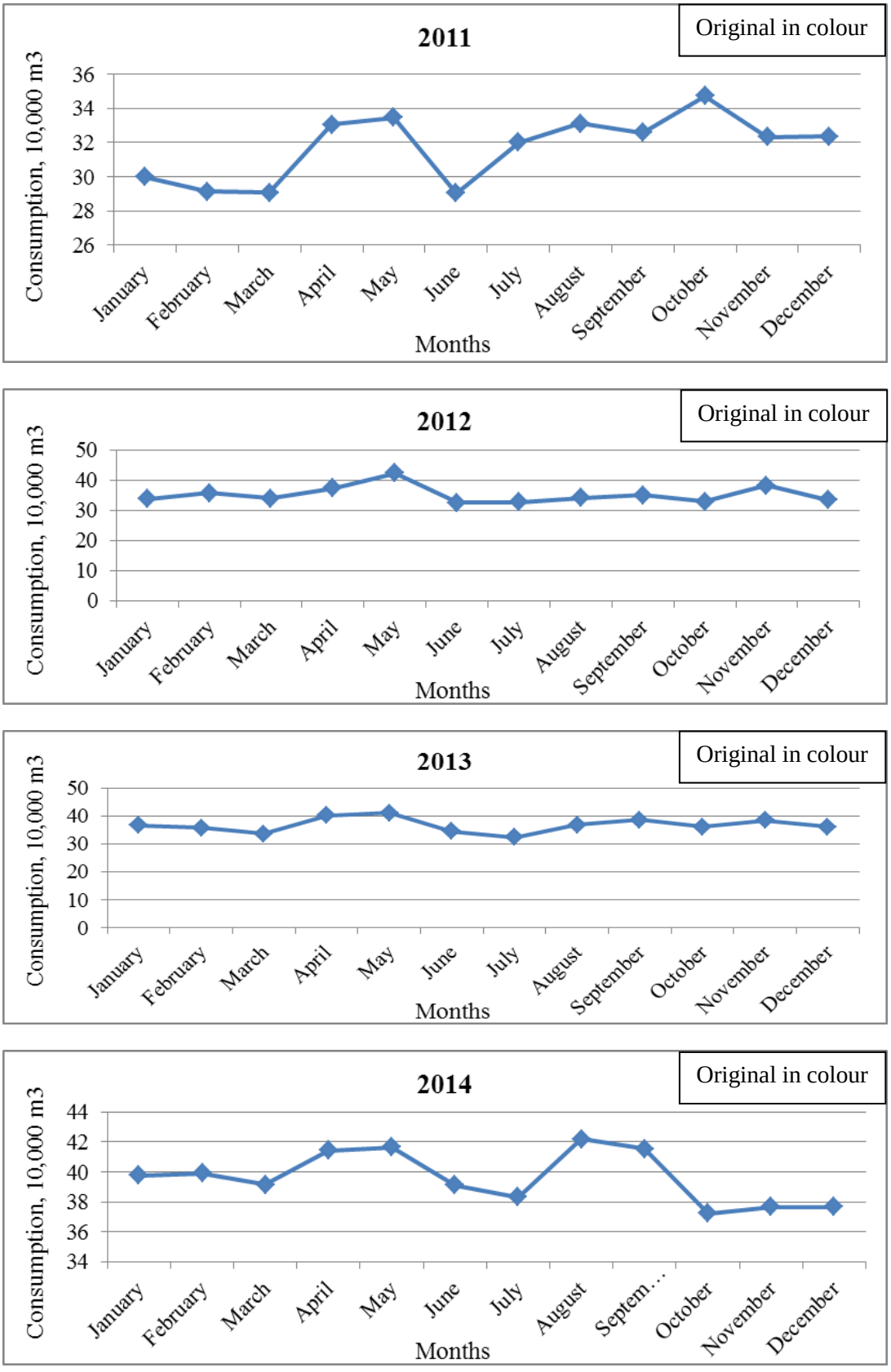

Figure A.6 : Water Consumption Data

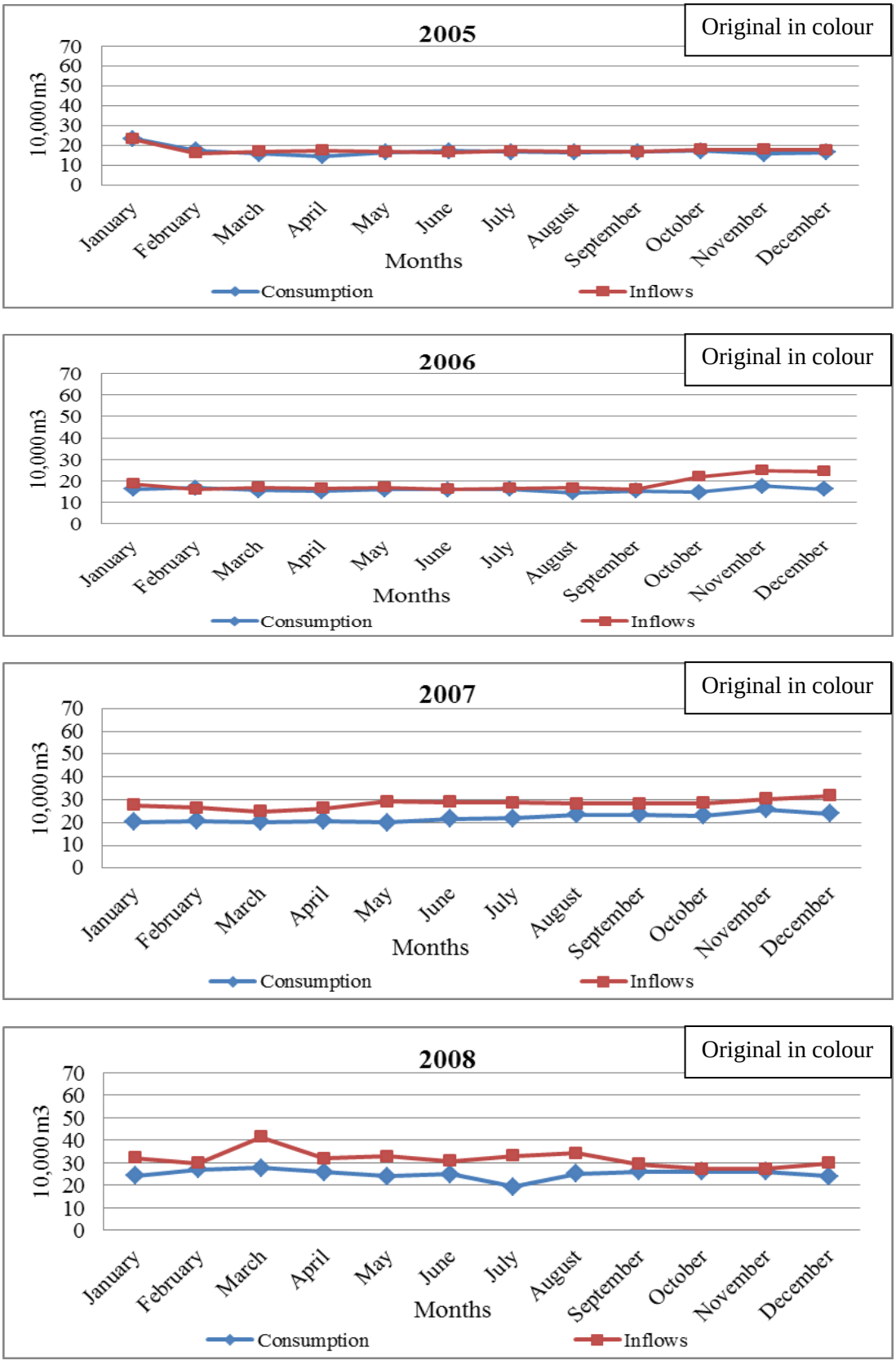

Figure A.7: Comparison of Water Inflows to Water Tower with the Consumption data

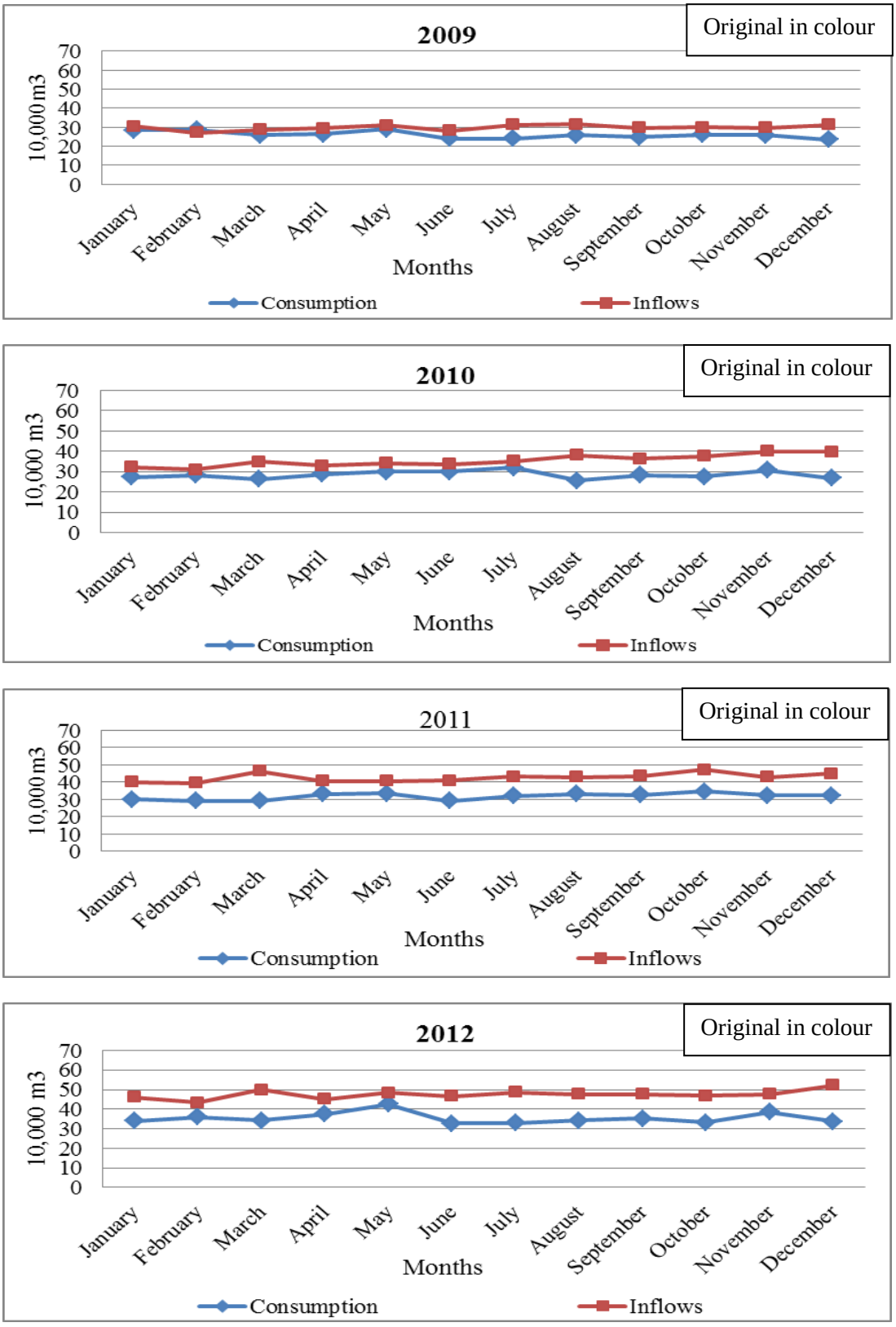

Figure A.8: Comparison of Inflows to the Water Tank with the Consumption data

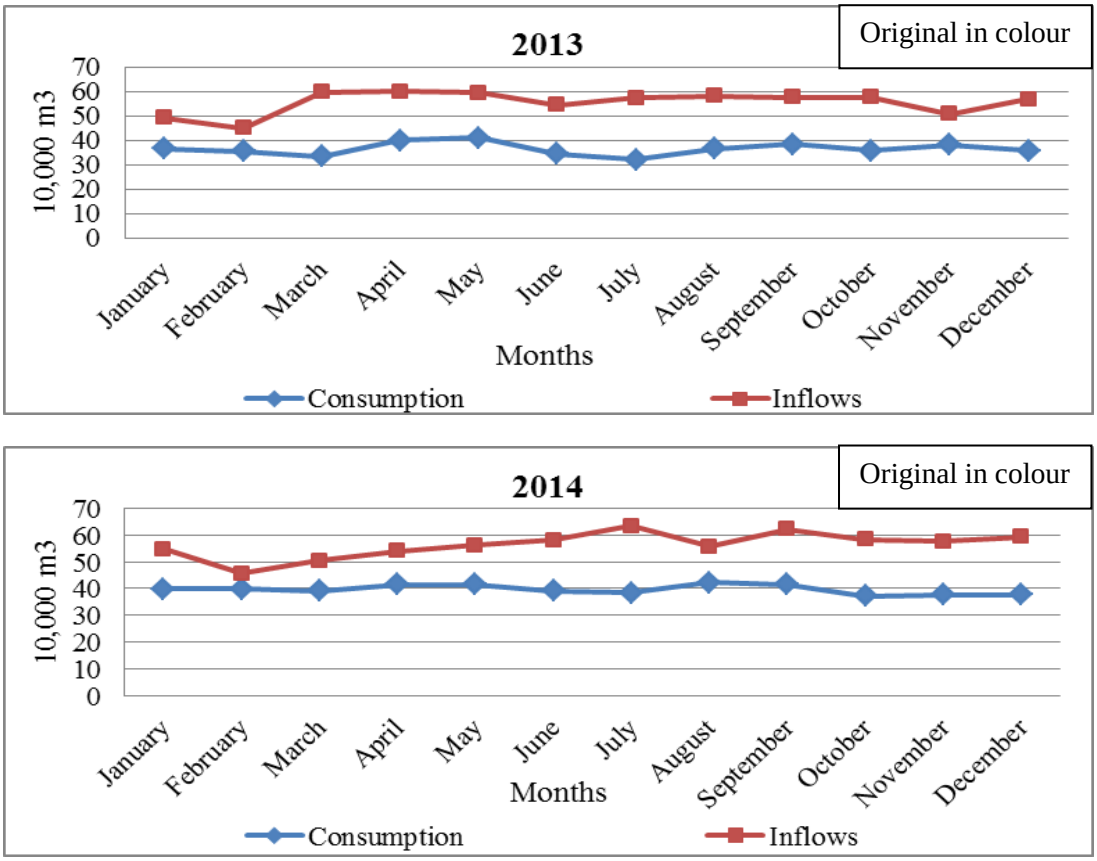

Figure A.9: Comparison of Inflows to the Water Tank with the Consumption data

APPENDIX B – STAKEHOLDER SURVEY

Master Degree Research 2014/2015 - University of Moratuwa Sri Lanka

Student: TKNK Kumari, Senior Engineer, Development Section,

NWSDB Head Office, Ratmalana, Sri Lanka

Dear Sir/Madam,

I am presently carrying out a masters degree research on the Management Prioritisation in Water Supply Systems in the National Water Supply & Drainage Board (NWSDB). This is an attempt to identify priority water supply sub divisions based on the key management parameters considered by a system manager.

.....
TKNK Kumari
...../...../.....

STAGE 1: Identification of 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, then the key management parameters that concerns a system manager would fall into the following groups. Please observe the groups and **comment on any other additional consideration** that requires to be included in the list.

Income Generation System Sustainability	1. Non Revenue Water(NRW) 2. Other (pl specify)……
System Reliability	2.
Problem Solving	1.
System Losses	1. New Connections 2. Bill collection 3. Other (pl specify) ……..

STAGE 2: Identification of Priorities for Main and Sub Parameters

Stage two is further divided for the ease of capturing the relative importance. This is to capture a decision maker's perspective of each an every individual item irrespective of the main parameter consideration. The sub divisions are, a) As a score for each of sub parameter irrespective of a main parameter. b) the priority for each Main Parameter as a standalone entity. The Main Parameter Weights are expected as a percentage.

STAGE 2a) Score for Each of Sub Parameter (Not considering the main parameter).

#	Sub Parameter	Score ?/1000	Remarks *(Sub Parameters are to be ranked in a scale of 1000 in total)*
1	New Connections		Key factor for income generation
2	Bill Collection		Reflects the transfer of connections to finances
3	Operation & Maintenance Cost		Covers routine maintenance and complain repair costs
4	Salaries and Overtime		Looks after expenses for functionality without interruption
5	Transport		Looks after expenses for functionality with inspections and repair
6	Non Revenue Water(NRW)		Minimisation of water income loss
7	Low pressure		A reasonable pressure should be maintained
8	No water		Adequate requirements as per norms must be supplied
9	Water Quality		Standards must be maintained
10	Defective meters		Security against income and also customer confidence in the organisation.
11	Leak - Mains		Leaking Mains lose a high quantity of treated water loss of income
12	Leak - Connections		Loss of treated water leading to reduced income
13	Leak – near meter		Loss of treated water leading to reduced income
14	Leak - Night time		Loss of treated water leading to reduced income
15	Leak - Stop valve		Loss of treated water leading to reduced income
16	Other (pl specify) ……		Pl indicate ……
17	Other (pl specify) ……		Pl indicate ……
18	Other (pl specify) ……		Pl indicate ……
19	Other (pl specify) ……		Pl indicate ……
20	Other (pl specify) ……		Pl indicate ……
	Total	1000	

STAGE 2b) Priority given for each Main Parameter

#	Main Parameter	Weight
1	**Income Generation**	
2	**System Sustainability** (Recurrent Expenditure)	
3	**System Losses**	
4	**System Reliability** (Problem Solving)	
	TOTAL	**100%**

Comments

(ifany)……..…….……

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Name of Respondent: …….

Designation: ……

Division: …….

Date: ……..

Table B.1.1 : Respondent Details of Stakeholder Survey

#	Name	Designation	NWSDB Division
Form 1	S.G.J Rajkumar	Deputy General Manager (Development)	Development
Form 2	B.A Fernando	Senior Engineer	Planning and Design
Form 3	D. Warapitiya	Engineer	Planning and Design
Form 4	G.W.D.P.De Silva	Engineer	Corporte Planing
Form 5	S. Sarankan	Engineer	Planning and Design
Form 6	G.M Mathuranesan	Chief Engineer	Planning and Design
Form 7	J.M.C.G Jayasinghe	Engineer	Additional General Manager (North/Central) office
Form 8	W.D.A.L Devapriya	Engineer	Additional General Manager (Southern/East) office
Form 9	R. S. Karunasena	Engineer	Development
Form 10	D.M.S.S Dissanayake	Area Engineer (Kolonnawa)	Regional Support Centre (Western Central)
Form 11	I.I Weerarathne	Engineer	Development
Form 12	D.A.H. Dissanayaka	Chief Engineer	Planning and Design
Form 13	W.W. Liyanage	Structural Specialist	Planning and Design
Form 14	D Jayawardane	Engineer	Planning and Design
Form 15	S Kalubowila	Senior Engineer	Planning and Design
Form 16	P.K.M Dissanayake	Engineer	Planning and Design
Form 17	H.T Perera	Engineer	Planning and Design
Form 18	R Gurusinghe	Engineer	Planning and Design
Form 19	T.D Peiris	Chief Engineer	Policy and Planning
Form 20	B. H. H Liyanage	Engineer	Planning and Design
Form 21	H.T.T Wimalaweera	Assistant General Manager	Additional General Manager (North/Central) Office
Form 22	S. Kandeepan	Engineer	Planning and Design
Form 23	S. Dharmasinghe	Engineer	Planning and Design
Form 24	A.P Ratnayake	Engineer	Policy & Planning
Form 25	A.K.M De Silva	Engineer	Planning and Design
Form 26	N.R.S Wickramasinghe	Chief Engineer	Planning and Design
Form 27	M.S.M Riswan	Chief Engineer	Development
Form 28	A. Kaluarachchi	Chief Engineer	Planning and Design
Form 29	N. Thilagarajah	Engineer	Corporate Planning
Form 30	G.G.S Lekha	Chief Engineer	Planning and Design
Form 31	U.A Upeksha	Senior Engineer	Planning and Design
Form 32	V. P. Thiranagama	Chief Engineer	Planning and Design
Form 33	Rajika Rajapakshe	Chief Engineer	Planning and Design
Form 34	H.T.N Jayathilake	Engineer	Planning and Design
Form 35	A Munasinghe	Assistant General Manager	Planning and Design
Form 36	S.S Devaraja	Assistant General Manager	General Manager Office
Form 37	A Mahathanthila	Assistant General Manager	Planning and Design
Form 38	D.S.P.R.D.Premachandra	Chief Engineer	Planning and Design
Form 39	H.M.C.P Herath	Chief Engineer	Sewerage Section

Table B.1.2 : Respondent Details of Stakeholder Survey

#	Name	Designation	Section
Form 40	D.M.L.C Pitawala	Assistant General Manager	Research and Development
Form 41	D.G.N. Kumari	Chief Engineer	Regional Support Centre (Western South)
Form 42	P.M.D.T.Pannila	Chief Engineer	Regional Support Centre (Western South)
Form 43	M. Wijesinghe	Assistant General Manager	Additional General Manager (Western) office
Form 44	W.B.G Fernando	Additional General Manager	Corporate Services
Form 45	W.A.S.M Gunasekara	Engineer	Planning and Design
Form 46	A.K Manori	Chief Engineer	Rural Water Supply
Form 47	D.A.D.U Nishantha	Area Engineer (Kotte)	Regional Support Centre (Western Central)
Form 48	G.A Pushpalatha	Area Engineer (Kesbewa)	Regional Support Centre (Western Central)
Form 49	L.G Wadanambi	Chief Engineer	Corporate Planning
Form 50	H.A.E.N Huladdoowaarachchi	Manager (Panadura)	Regional Support Centre (Western South)
Form 51	K.W.P.M Thilakaratne	Area Engineer (Panadura)	Regional Support Centre (Western South)
Form 52	D.S Jayasekara	Area Engineer (Bandaragama)	Regional Support Centre (Western South)
Form 53	B. Thavendrakumar	Chief Engineer	Regional Support Centre (Western South)
Form 54	R.S.C George	Additional General Manager	Policy and Planning
Form 55	T.B.Heenkenda	Manager	Non Revenue Water
Form 56	P. Fernando	Deputy General Manager	Water Supply Projects
Form 57	J.P.G Jayarathne	Deputy Project Director	Waste Water Disposal Project
Form 58	R.D.V.K Silva	Engineer	Japenese Project Unit
Form 59	J.A.K.K Senevirathne	Manager (Kalutara)	Regional Support Centre (Western South)
Form 60	A.G.B Pathmasiri	Project Engineer	Anuradhapura
Form 61	A.D.K.K Wijegunawardane	Manager (Maharagama)	Regional Support Centre (Western Central)
Form 62	H.P Erandika	Engineer	Policy and Strategy
Form 63	S. Jayasinghe	Engineer	Planning and Design
Form 64	I. Karunasena	Engineer	Research and Development
Form 65	N.P. Goonawardana	Chief Engineer	Planning and Design
Form 66	N.W.E.S Nirasha	Engineer	Planning and Design
Form 67	Geethanjali Gunathilake	Chief Engineer	Regional Support Centre (Western North)
Form 68	A.V.A.U. Karunathilaka	Engineer	Water Supply Project
Form 69	D.W.K.D Amaratunga	Chief Engineer	Procurement and Construction
Form 70	P.N.Herath	Chief Engineer	Mapping Section
Form 71	S.K.L.S Rupasinghe	Chief Engineer	Research and Development
Form 72	WRS Fernando	Civil Engineer	Regional Suppport Centre (Western South)
Form 73	C.S. Lokubarana	Chief Engineer	Regional Suppport Centre (North Central)
Form 74	W.C.A Gunarathna	Area Engineer (Maligawatta)	Regional Suppport Centre (Western Central)
Form 75	R.A.S.P Ranaweera	Chief Engineer	Regional Suppport Centre (North Western)
Form 76	J.S Aravindan	Chief Engineer	Regional Suppport Centre (North)
Form 77	A.D.A Ranjani	Chief Engineer	Regional Suppport Centre (Western Central)
Form 78	A.M.H.K Abeykoon	Engineer	Regional Suppport Centre (Western North)

Appendix B 3: Typical Respondent Data

56

Master Degree Research 2014/2015 - University of Moratuwa Sri Lanka

Student: TKNK Kumari, Senior Engineer, Development Section, NWSDB Head Office, Ratmalana, Sri Lanka

Dear Sir/Madam

I am presently carrying out a masters degree research on the Management Prioritisation in Water Supply Systems in the National Water Supply & Drainage Board (NWSDB). This is an attempt to identify priority water supply sub divisions based on the key management parameters considered by a system manager.

Nisansha

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TKNK Kumari

28/01/2016

STAGE 1: Identification of 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, then the key management parameters that concerns a system manager would fall into the following groups. Please observe the groups and **comment on any other additional consideration** that requires to be included in the list.

Income Generation	1. New Connections 2. Bill collection 3. Other (pl specify) ……..
System Sustainability	**Recurrent Expenditure** 1. Operation & Maintenance 2. Salaries and Overtime 3. Transport 4. Other (pl specify)……
System Losses	1. Non Revenue Water(NRW) 2. Other (pl specify)……
System Reliability	**Problem Solving** 1. Low pressure 2. No water 3. Water Quality 4. Defective meters 5. Leak - Mains 6. Leak - Connections 7. Leak – near meter 8. Leak - Night time 9. Leak - Stop valve 10. Other (pl specify)……

Appendix B 4.1: Typical Respondent Data

STAGE 2: Identification of Priorities for Main and Sub Parameters

Stage two is further divided for the ease of capturing the relative importance. This is to capture a decision maker's perspective of each an every individual item irrespective of the main parameter consideration. The sub divisions are, a) As a score for each of sub parameter irrespective of a main parameter. b) the priority for each Main Parameter as a stand alone entity. The Main Parameter Weights are expected as a percentage.

STAGE 2a) Score for Each of Sub Parameter (Not considering the main parameters).

#	Sub Parameter	Score ?/1000	Remarks *(Sub Parameters are to be ranked in a scale of 1000 in total)*
1	New Connections	160	Key factor for income generation
2	Bill Collection	100	Reflects the transfer of connections to finances
3	Operation & Maintenance Cost	25	Covers routine maintenance and complain repair costs
4	Salaries and Overtime	25	Looks after expenses for functionality without interruption
5	Transport	20	Looks after expenses for functionality with inspections and repair
6	Non Revenue Water(NRW)	150	Minimisation of water income loss
7	Low pressure	50	A reasonable pressure should be maintained
8	No water	70	Adequate requirements as per norms must be supplied
9	Water Quality	100	Standards must be maintained
10	Defective meters	50	Security against income and also customer confidence in the organisation.
11	Leak - Mains	50	Leaking Mains lose a high quantity of treated water loss of income
12	Leak - Connections	50	Loss of treated water leading to reduced income
13	Leak – near meter	50	Loss of treated water leading to reduced income
14	Leak - Night time	50	Loss of treated water leading to reduced income
15	Leak - Stop valve	50	Loss of treated water leading to reduced income
16	Other (pl specify)		Pl indicate .....
17	Other (pl specify)		Pl indicate .....
18	Other (pl specify)		Pl indicate .....
19	Other (pl specify)		Pl indicate .....
20	Other (pl specify)		Pl indicate .....
	Total	1000	

Appendix B 4.2: Typical Respondent Data

STAGE 2b) Priority given for each Main Parameter

#	Main Parameter	Weight
1	**Income Generation**	20
2	**System Sustainability** (Recurrent Expenditure)	10
3	**System Losses**	10
4	**System Reliability** (Problem Solving)	60.
	TOTAL	**100%**

Comments (if any).....

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Name of Respondent: ..... P. Fernando .....

Designation: ..... DGM (PC) .....

Division: ..... WSP Section .....

Date: ..... 28/01/2016. .....

Table B.2.1 :Stakeholder Confirmation of Main and Sub Parameters

	Parameter	Respondent (1 – 26)																								
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*
1	New Connections	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	Bill collection	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3	Operation & Maintenance	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4	Salaries and Overtime	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
5	Transport	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6	Non Revenue Water (NRW)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7	Low Pressure	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
8	No water	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
9	Water Quality	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
10	Defective Meters	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
11	Leak - Mains	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
12	Leak - Connections	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
13	Leak - near meter	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
14	Leak - Night time	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
15	Leak - stop valve	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
16	other							√	√								√	√	√			√			√		
17	other							√	√								√	√	√			√			√		
18	other								√									√	√						√		
19	other								√									√	√						√		
20	other																	√	√						√		

Table B.2.2 :Stakeholder Confirmation of Main and Sub Parameters

		Respondent (27 – 52)																								
	Parameter	***27***	***28***	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***	***38***	***39***	***40***	***41***	***42***	***43***	***44***	***45***	***46***	***47***	***48***	***49***	***50***	***51***	***52***
1	New Connections	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	Bill collection	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3	Operation & Maintenance	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4	Salaries and Overtime	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
5	Transport	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6	Non Revenue Water (NRW)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7	Low Pressure	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
8	No water	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
9	Water Quality	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
10	Defective Meters	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
11	Leak - Mains	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
12	Leak - Connections	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
13	Leak - near meter	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
14	Leak - Night time	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
15	Leak - stop valve	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
16	other		√	√	√		√		√			√			√	√	√	√	√	√	√				√		
17	other			√								√			√		√	√	√	√							
18	other											√			√				√	√							
19	other											√			√				√	√							
20	other											√			√												

Table B.2.3 :Stakeholder Confirmation of Main and Sub Parameters

	Parameter	Respondent (53 – 78)																									
		53	*54*	*55*	*56*	*57*	*58*	*59*	*60*	*61*	*62*	*63*	*64*	*65*	*66*	*67*	*68*	*69*	*70*	*71*	*72*	*73*	*74*	*75*	*76*	*77*	*78*
1	New Connections	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	Bill collection	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3	Operation & Maintenance	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4	Salaries and Overtime	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
5	Transport	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6	Non Revenue Water (NRW)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7	Low Pressure	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
8	No water	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
9	Water Quality	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
10	Defective Meters	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
11	Leak - Mains	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
12	Leak - Connections	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
13	Leak - near meter	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
14	Leak - Night time	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
15	Leak - stop valve	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
16	other		√	√				√		√		√						√	√							√	
17	other									√								√									
18	other																	√									
19	other																	√									
20	other																	√									

Table B.3.1 : Stakeholder Inputs as “Other” Parameters

#	Main Parameter			
	Income Generation	System Sustainability	System Losses	System Reliability
Form 1	Other services to rechargeable,	Electricity, Telephone, Chemical	Depreciation of Assets	
Form 2			Insufficient usage of resources, Usage of how quality materials and equipments	
Form 5	External design and consultancy		Energy losses	
Form 7	Water Quality Testing, Organisational standards	Electricity	Scaling of existing pipes, unability of operate source old valve and specials, Service linesdamages due to development works	
Form 8	Tube well construction, Investigation and pump testing, Laboratory testing	Energy		
Form 9	Disconnections, Ferrule/ Meter shifting		Defective meter	Unauthorised house connections
Form 12	Illegal Connections			Replace old lines
Form 13	Action for delay payment			Air release from domestic connections
Form 15		Training	Pipe scaling	Pipe bursting, unforeseen disasters
Form 16	Consultancy service	Capital investment for new projects		
Form 17	Auction of items which are not used, Charges for involving consultation work for external organization organisations	Awareness programs	Damages of plants, pipes, networks and other assets due to disasters	Lack of raw water quality
Form 18	Consultancy services	Training Programs	Material wastage minimize, minimize chemicals	Protect raw water source
Form 19	Quality increase		Increased labour	
Form 21	Laboratory services	Rehabilitation	Power	
Form 24	Consultancy services (outsourcing activities)	Head Office Overhead (Reduction of Overhead cost),		Protection of water sources, Consumer satisfaction, New technologies
Form 26		Plant efficiency, Bonus/ Leave encashment/medical payments , Over staff	Energy losses	Meter reader errors, new connection delays, delay in attending complaints
Form 28				Power facilities

Table B.3.2 : Stakeholder Inputs as “Other” Parameters

#	Main Parameter			
	Income Generation	System Sustainability	System Losses	System Reliability
Form 29	Consultancy Income, Bowser supply, Drilling tubewells	Depreciation of infrastructure, loan interest payment		Air entrap in the pipeline avoid hammer effect
Form 30				Less storage
Form 32		Loan repayment/ Interest payment		
Form 34		Improve Raw Water Quality		
Form 36		System Improvements	Energy loss	
Form 37	Bottling water plant	Public awareness to save water	Lack of raw water availabilty	
Form 38			Energy cost	
Form 39		Loan Repayment		
Form 40	Consultancy services, other possible and relavant services such as quality testing, bottle water		Due to mal practices in O&M, such as lack of assets mgt/ preventive maintenance, energy & chemical optimization	Productivity improvement
Form 41			Energy Loss	
Form 42		System Improvement	Energy Loss	
Form 43		Asset Management Rehabilitation		
Form 45	Consultancy	Training, Workers Safety plan	Illegal connections	
Form 46		Improve the System		
Form 50		System Improvement		
Form 52			Illegal connections	
Form 55			System Loss	
Form 61		Chemical cost	Overflow of Towers	
Form 63		Rehabilitation		
Form 65		Quality and Quantity of water, Defective meter	Poor O&M	NRW
Form 70	Meter shifting , fines for illegal connections, Laboratory service, Ground water activities	Chemicals, Electricity	Estimate bills, Billing errors, Illegal connections, System losses due to low efficiency operations	Bill estimates, Bill errors
Form 71	Bowser Supply		Energy losses	Billing errors, Meter shifting new charges

Table B.4.1 : Priority Scores from Stakeholder Responses – Main Parameter

Main Parameter		Form ID (1 – 15)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Income generation	40	20	25	10	40	50	15	30	30	25	50	10	30	18	35
2	System sustainability	30	35	30	15	15	30	40	30	25	30	30	5	15	15	20
3	System Losses	20	30	10	50	25	10	25	20	20	5	10	25	35	20	20
4	System Reliability	10	15	35	25	20	10	20	20	25	40	10	60	20	48	25
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table B.4.2 : Priority Scores from Stakeholder Responses – Main Parameter

Main Parameter		Form ID (16 – 30)														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	Income generation	36.5	23	10	50	35	30	15	20	50	20	30	30	20	30	20
2	System sustainability	34.5	23	30	30	25	40	20	50	25	20	25	40	20	20	25
3	System Losses	10	9	20	10	25	20	50	10	12.5	10	20	15	20	30	25
4	System Reliability	19	45	40	10	15	10	15	20	12.5	50	25	15	40	20	30
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table B.4.3 : Priority Scores from Stakeholder Responses – Main Parameter

Main Parameter		Form ID (31 – 45)														
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	Income generation	30	15	50	25	25	20	40	30	40	20	40	45	30	30	20
2	System sustainability	23	20	10	30	25	30	15	20	30	35	20	25	30	30	15
3	System Losses	22	25	30	25	25	20	20	30	20	15	20	15	20	15	20
4	System Reliability	25	40	10	20	25	30	25	20	10	30	20	15	20	25	45
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table B.4.4 : Priority Scores from Stakeholder Responses – Main Parameter

Main Parameter		Form ID (46 – 60)														
		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	Income generation	30	40	35	30	40	40	45	35	25	25	20	30	20	40	50
2	System sustainability	25	20	40	40	20	25	20	40	40	15	10	30	30	20	20
3	System Losses	15	15	10	10	15	10	15	10	25	40	10	20	30	20	10
4	System Reliability	30	25	15	20	25	25	20	15	10	20	60	20	20	20	20
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table B.4.5 : Priority Scores from Stakeholder Responses – Main Parameter

Main Parameter		Form ID (61 – 78)																	
		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
1	Income generation	40	40	50	35	30	13	20	25	35	50	30	23	30	25	25	30	35	40
2	System sustainability	30	25	30	10	25	25	20	30	30	15	10	23	30	25	20	20	25	10
3	System Losses	15	10	10	30	25	37	20	5	15	20	30	31	20	25	15	10	10	20
4	System Reliability	15	25	10	25	20	25	40	40	20	15	30	23	20	25	40	40	30	30
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table B.5.1 : Priority Scores from Stakeholder Responses – Sub Parameter

		Form ID (1 – 15)														
	Sub Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	New Connections	200	100	100	75	100	150	72	100	140	70	200	50	150	75	85
2	Bill collection	300	75	40	35	140	50	57	100	100	125	150	130	175	100	65
3	Operation & Maintenance	200	60	60	35	40	100	75	80	125	85	100	80	125	100	70
4	Salaries and Overtime	50	55	75	100	10	50	65	130	115	80	100	20	100	25	80
5	Transport	50	65	30	100	10	50	50	50	90	30	50	30	50	25	70
6	Non Revenue Water (NRW)	50	100	125	180	150	100	80	200	110	10	50	170	50	25	85
7	Low Pressure	30	60	100	100	120	50	68	40	35	65	20	100	75	25	60
8	No water	20	60	150	100	100	50	70	40	45	120	20	200	75	5	80
9	Water Quality	20	65	100	100	150	50	65	40	45	120	50	150	25	300	60
10	Defective Meters	20	50	40	50	50	100	55	40	40	90	50	20	25	150	65
11	Leak - Mains	20	90	60	25	50	100	50	8	45	115	50	10	50	150	80
12	Leak - Connections	10	60	30	25	20	50	45	8	20	30	40	10	25	5	70
13	Leak - near meter	10	40	30	25	10	30	40	8	15	35	40	10	25	5	35
14	Leak - Night time	10	80	30	25	40	50	57	8	55	15	40	10	25	5	65
15	Leak - stop valve	10	40	30	25	10	20	35	8	20	10	40	10	25	5	30
16	other							60	50							
17	other							56	25							
18	other								25							
19	other								40							
20	other															
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.5.2 : Priority Scores from Stakeholder Responses – Sub Parameter

		Form ID (16 – 30)														
	Sub Parameter	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	New Connections	175	110	5	100	150	150	100	100	25	150	150	70	25	150	30
2	Bill collection	175	90	5	200	100	80	50	150	50	100	200	70	50	130	50
3	Operation & Maintenance	120	100	30	100	75	100	100	50	50	50	100	80	125	80	120
4	Salaries and Overtime	125	70	5	70	75	100	100	50	50	50	75	100	50	60	80
5	Transport	75	40	5	60	50	30	50	50	50	50	50	50	25	40	20
6	Non Revenue Water (NRW)	100	60	50	150	100	30	100	100	50	100	75	80	100	90	120
7	Low Pressure	50	60	60	50	75	80	100	50	50	50	20	50	25	80	50
8	No water	25	70	100	20	30	80	50	25	100	50	50	70	50	100	100
9	Water Quality	25	80	100	100	50	80	10	125	150	100	100	100	175	80	50
10	Defective Meters	15	50	10	40	50	100	50	50	50	25	50	30	50	70	50
11	Leak - Mains	15	40	60	70	75	40	100	25	25	100	50	80	125	30	150
12	Leak - Connections	15	20	60	10	50	20	50	25	12.5	25	20	60	25	10	50
13	Leak - near meter	15	20	50	10	40	20	50	50	12.5	25	20	60	25	10	10
14	Leak - Night time	15	40	50	10	50	20	75	100	12.5	100	20	60	100	10	70
15	Leak - stop valve	15	20	50	10	30	20	15	50	12.5	25	20	40	25	10	10
16	other	15	10	60			30			50				25	25	40
17	other	25	20	50			20			50					25	
18	other		20	50						50						
19	other		30	100						100						
20	other		50	100						50						
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.5.3 : Priority Scores from Stakeholder Responses – Sub Parameter

		Form ID (31 – 45)														
	Sub Parameter	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	New Connections	100	170	180	60	100	50	90	80	200	65	100	150	50	50	90
2	Bill collection	100	90	120	50	100	150	90	160	150	60	140	120	100	75	100
3	Operation & Maintenance	100	100	50	75	50	100	70	80	100	65	80	70	150	75	90
4	Salaries and Overtime	80	40	100	50	50	95	70	40	90	60	60	40	50	50	60
5	Transport	50	80	50	25	30	50	40	40	80	60	60	30	25	25	20
6	Non Revenue Water (NRW)	90	90	80	90	150	40	50	138	75	60	100	70	75	50	30
7	Low Pressure	80	75	70	50	50	65	60	45	65	55	60	50	75	50	70
8	No water	80	80	80	75	80	65	70	40	30	50	60	50	50	100	70
9	Water Quality	80	100	80	100	150	100	80	120	30	65	70	50	100	100	60
10	Defective Meters	50	50	70	70	30	50	40	60	30	50	60	50	50	25	20
11	Leak - Mains	40	25	30	80	80	75	30	45	30	65	100	50	100	50	20
12	Leak - Connections	40	10	30	50	30	70	20	38	30	30	10	40	12.5	50	30
13	Leak - near meter	40	10	20	50	30	10	20	38	30	25	10	30	12.5	25	20
14	Leak - Night time	40	10	20	50	40	70	30	38	30	35	10	50	25	25	20
15	Leak - stop valve	30	10	20	50	30	10	20	38	30	25	10	30	25	25	20
16	other		60		75			50			35	70	80	50	50	75
17	other							30			25		40	50	50	65
18	other							20			50				50	70
19	other							50			55				75	70
20	other							70			65					
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.5.4 : Priority Scores from Stakeholder Responses – Sub Parameter

Water supply sytem management sub Parameters		Form ID (46 – 60)														
		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	New Connections	125	80	160	110	180	130	130	150	150	180	160	175	100	80	200
2	Bill collection	150	120	120	100	120	120	80	120	90	150	100	150	70	120	100
3	Operation & Maintenance	80	80	120	160	80	100	90	80	150	60	25	180	60	110	100
4	Salaries and Overtime	50	50	40	30	10	10	40	50	110	20	25	50	70	30	50
5	Transport	40	50	40	50	10	10	30	40	100	10	20	25	50	20	50
6	Non Revenue Water (NRW)	70	70	110	110	50	80	80	80	90	200	150	175	100	60	50
7	Low Pressure	40	60	70	50	60	60	70	60	50	20	50	25	60	70	25
8	No water	40	50	100	70	80	80	100	90	60	80	70	50	70	80	50
9	Water Quality	100	90	120	100	100	100	60	90	40	70	100	25	100	80	50
10	Defective Meters	40	90	40	40	20	30	60	60	40	10	50	25	50	60	25
11	Leak - Mains	80	100	30	120	100	120	100	80	20	100	50	50	70	80	50
12	Leak - Connections	50	70	20	15	50	80	40	40	10	60	50	30	50	50	50
13	Leak - near meter	20	30	10	15	30	10	40	20	10	10	50	20	50	30	50
14	Leak - Night time	20	30	10	15	30	60	40	20	10	10	50	20	50	30	100
15	Leak - stop valve	20	30	10	15	30	10	40	20	10	10	50	20	50	30	50
16	other	75				50				60	10				70	
17	other															
18	other															
19	other															
20	other															
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1020	1000	1000	1000

Table B.5.5 : Priority Scores from Stakeholder Responses – Sub Parameter

		Form ID (61 – 78)																	
	Sub Parameter	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
1	New Connections	120	100	25	100	80	25	50	80	150	100	130	50	150	100	125	150	120	125
2	Bill collection	300	50	300	50	90	50	40	100	200	100	100	100	150	150	100	100	150	200
3	Operation & Maintenance	110	80	100	80	100	50	50	90	150	100	200	50	150	100	150	100	100	100
4	Salaries and Overtime	200	60	250	70	60	25	50	80	80	50	70	50	90	70	80	50	40	75
5	Transport	15	50	10	50	30	15	30	40	70	50	50	40	60	60	40	40	20	50
6	Non Revenue Water (NRW)	100	80	100	60	150	100	90	25	140	50	100	150	200	100	125	120	70	100
7	Low Pressure	15	50	15	100	90	100	90	70	20	50	30	50	10	80	70	50	70	50
8	No water	15	50	35	80	80	25	90	125	35	50	30	50	40	90	75	80	100	50
9	Water Quality	10	150	50	80	150	10	90	120	25	50	40	200	50	100	100	110	100	50
10	Defective Meters	10	80	5	70	40	100	90	70	10	50	20	50	20	30	40	70	40	75
11	Leak - Mains	20	50	30	60	65	100	90	110	15	100	100	70	30	35	40	40	70	25
12	Leak - Connections	20	50	5	50	20	100	60	30	10	50	20	50	20	30	10	35	35	25
13	Leak - near meter	5	50	5	50	20	100	60	35	5	50	20	30	10	15	10	15	15	25
14	Leak - Night time	5	50	5	50	10	100	60	15	5	50	70	30	10	25	25	25	25	25
15	Leak - stop valve	5	50	5	50	15	100	60	10	5	50	20	30	10	15	10	15	15	25
16	other	25		60						15	50							30	
17	other	25								20									
18	other									20									
19	other									10									
20	other									15									
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.6.1 : Corrected Priority Scores from Stakeholder Responses – Sub Parameters

	Sub Parameter	Form ID (1 – 15)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	New Connections	200	100	100	75	100	150	81	116	140	70	200	50	150	75	85
2	Bill collection	300	75	40	35	140	50	64	116	100	125	150	130	175	100	65
3	Operation & Maintenance	200	60	60	35	40	100	85	93	125	85	100	80	125	100	70
4	Salaries and Overtime	50	55	75	100	10	50	74	151	115	80	100	20	100	25	80
5	Transport	50	65	30	100	10	50	57	58	90	30	50	30	50	25	70
6	Non Revenue Water (NRW)	50	100	125	180	150	100	90	233	110	10	50	170	50	25	85
7	Low Pressure	30	60	100	100	120	50	77	47	35	65	20	100	75	25	60
8	No water	20	60	150	100	100	50	79	47	45	120	20	200	75	5	80
9	Water Quality	20	65	100	100	150	50	74	47	45	120	50	150	25	300	60
10	Defective Meters	20	50	40	50	50	100	62	47	40	90	50	20	25	150	65
11	Leak - Mains	20	90	60	25	50	100	57	9	45	115	50	10	50	150	80
12	Leak - Connections	10	60	30	25	20	50	51	9	20	30	40	10	25	5	70
13	Leak - near meter	10	40	30	25	10	30	45	9	15	35	40	10	25	5	35
14	Leak - Night time	10	80	30	25	40	50	64	9	55	15	40	10	25	5	65
15	Leak - stop valve	10	40	30	25	10	20	40	9	20	10	40	10	25	5	30
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.6.2 : Corrected Priority Scores from Stakeholder Responses – Sub Parameters

Sub Parameter		Form ID (16 – 30)														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	New Connections	182	126	8	100	150	158	100	100	36	150	150	70	26	158	31
2	Bill collection	182	103	8	200	100	84	50	150	71	100	200	70	51	137	52
3	Operation & Maintenance	125	115	47	100	75	105	100	50	71	50	100	80	128	84	125
4	Salaries and Overtime	130	80	8	70	75	105	100	50	71	50	75	100	51	63	83
5	Transport	78	46	8	60	50	32	50	50	71	50	50	50	26	42	21
6	Non Revenue Water (NRW)	104	69	78	150	100	32	100	100	71	100	75	80	103	95	125
7	Low Pressure	52	69	94	50	75	84	100	50	71	50	20	50	26	84	52
8	No water	26	80	156	20	30	84	50	25	143	50	50	70	51	105	104
9	Water Quality	26	92	156	100	50	84	10	125	214	100	100	100	179	84	52
10	Defective Meters	16	57	16	40	50	105	50	50	71	25	50	30	51	74	52
11	Leak - Mains	16	46	94	70	75	42	100	25	36	100	50	80	128	32	156
12	Leak - Connections	16	23	94	10	50	21	50	25	18	25	20	60	26	11	52
13	Leak - near meter	16	23	78	10	40	21	50	50	18	25	20	60	26	11	10
14	Leak - Night time	16	46	78	10	50	21	75	100	18	100	20	60	103	11	73
15	Leak - stop valve	16	23	78	10	30	21	15	50	18	25	20	40	26	11	10
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.6.3 : Corrected Priority Scores from Stakeholder Responses – Sub Parameters

		Form ID (31 – 45)														
Sub Parameter		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	New Connections	100	181	180	65	100	50	115	80	200	84	108	170	56	65	125
2	Bill collection	100	96	120	54	100	150	115	160	150	78	151	136	111	97	139
3	Operation & Maintenance	100	106	50	81	50	100	90	80	100	84	86	80	167	97	125
4	Salaries and Overtime	80	43	100	54	50	95	90	40	90	78	65	45	56	65	83
5	Transport	50	85	50	27	30	50	51	40	80	78	65	34	28	32	28
6	Non Revenue Water (NRW)	90	96	80	97	150	40	64	138	75	78	108	80	83	65	42
7	Low Pressure	80	80	70	54	50	65	77	45	65	71	65	57	83	65	97
8	No water	80	85	80	81	80	65	90	40	30	65	65	57	56	129	97
9	Water Quality	80	106	80	108	150	100	103	120	30	84	75	57	111	129	83
10	Defective Meters	50	53	70	76	30	50	51	60	30	65	65	57	56	32	28
11	Leak - Mains	40	27	30	86	80	75	38	45	30	84	108	57	111	65	28
12	Leak - Connections	40	11	30	54	30	70	26	38	30	39	11	45	14	65	42
13	Leak - near meter	40	11	20	54	30	10	26	38	30	32	11	34	14	32	28
14	Leak - Night time	40	11	20	54	40	70	38	38	30	45	11	57	28	32	28
15	Leak - stop valve	30	11	20	54	30	10	26	38	30	32	11	34	28	32	28
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.6.4 : Corrected Priority Scores from Stakeholder Responses – Sub Parameters

Sub	Parameter	Form ID (46 – 60)														
		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	New Connections	135	80	160	110	189	130	130	150	160	182	160	172	100	86	200
2	Bill collection	162	120	120	100	126	120	80	120	96	152	100	147	70	129	100
3	Operation & Maintenance	86	80	120	160	84	100	90	80	160	61	25	176	60	118	100
4	Salaries and Overtime	54	50	40	30	11	10	40	50	117	20	25	49	70	32	50
5	Transport	43	50	40	50	11	10	30	40	106	10	20	25	50	22	50
6	Non Revenue Water (NRW)	76	70	110	110	53	80	80	80	96	202	150	172	100	65	50
7	Low Pressure	43	60	70	50	63	60	70	60	53	20	50	25	60	75	25
8	No water	43	50	100	70	84	80	100	90	64	81	70	49	70	86	50
9	Water Quality	108	90	120	100	105	100	60	90	43	71	100	25	100	86	50
10	Defective Meters	43	90	40	40	21	30	60	60	43	10	50	25	50	65	25
11	Leak - Mains	86	100	30	120	105	120	100	80	21	101	50	49	70	86	50
12	Leak - Connections	54	70	20	15	53	80	40	40	11	61	50	29	50	54	50
13	Leak - near meter	22	30	10	15	32	10	40	20	11	10	50	20	50	32	50
14	Leak - Night time	22	30	10	15	32	60	40	20	11	10	50	20	50	32	100
15	Leak - stop valve	22	30	10	15	32	10	40	20	11	10	50	20	50	32	50
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.6.5 : Corrected Priority Scores from Stakeholder Responses – Sub Parameters

Sub	Parameter	Form ID (61 – 78)																	
		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
1	New Connections	126	100	27	100	80	25	50	80	163	105	130	50	150	100	125	150	124	125
2	Bill collection	316	50	319	50	90	50	40	100	217	105	100	100	150	150	100	100	155	200
3	Operation & Maintenance	116	80	106	80	100	50	50	90	163	105	200	50	150	100	150	100	103	100
4	Salaries and Overtime	211	60	266	70	60	25	50	80	87	53	70	50	90	70	80	50	41	75
5	Transport	16	50	11	50	30	15	30	40	76	53	50	40	60	60	40	40	21	50
6	Non Revenue Water (NRW)	105	80	106	60	150	100	90	25	152	53	100	150	200	100	125	120	72	100
7	Low Pressure	16	50	16	100	90	100	90	70	22	53	30	50	10	80	70	50	72	50
8	No water	16	50	37	80	80	25	90	125	38	53	30	50	40	90	75	80	103	50
9	Water Quality	11	150	53	80	150	10	90	120	27	53	40	200	50	100	100	110	103	50
10	Defective Meters	11	80	5	70	40	100	90	70	11	53	20	50	20	30	40	70	41	75
11	Leak - Mains	21	50	32	60	65	100	90	110	16	105	100	70	30	35	40	40	72	25
12	Leak - Connections	21	50	5	50	20	100	60	30	11	53	20	50	20	30	10	35	36	25
13	Leak - near	5	50	5	50	20	100	60	35	5	53	20	30	10	15	10	15	15	25
14	Leak - Night time	5	50	5	50	10	100	60	15	5	53	70	30	10	25	25	25	26	25
15	Leak - stop valve	5	50	5	50	15	100	60	10	5	53	20	30	10	15	10	15	15	25
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

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

		Form ID (1 – 15)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Income Generation																
1	New Connections	200	100	100	75	100	150	81	116	140	70	200	50	150	75	85
2	Bill collection	300	75	40	35	140	50	64	116	100	125	150	130	175	100	65
	Sub Total	500	175	140	110	240	200	146	233	240	195	350	180	325	175	150
	Sub Total %	**50**	**18**	**14**	**11**	**24**	**20**	**15**	**23**	**24**	**20**	**35**	**18**	**33**	**18**	**15**
	System Sustainability															
3	Operation & Maintenance	200	60	60	35	40	100	85	93	125	85	100	80	125	100	70
4	Salaries and Overtime	50	55	75	100	10	50	74	151	115	80	100	20	100	25	80
5	Transport	50	65	30	100	10	50	57	58	90	30	50	30	50	25	70
	Sub Total	300	180	165	235	60	200	215	302	330	195	250	130	275	150	220
	Sub Total %	**30**	**18**	**17**	**24**	**6**	**20**	**21**	**30**	**33**	**20**	**25**	**13**	**28**	**15**	**22**
	System Losses															
6	Non Revenue Water (NRW)	50	100	125	180	150	100	90	233	110	10	50	170	50	25	85
	Sub Total	50	100	125	180	150	100	90	233	110	10	50	170	50	25	85
	Sub Total %	**5**	**10**	**13**	**18**	**15**	**10**	**9**	**23**	**11**	**1**	**5**	**17**	**5**	**3**	**9**
	System Reliability															
7	Low Pressure	30	60	100	100	120	50	77	47	35	65	20	100	75	25	60
8	No water	20	60	150	100	100	50	79	47	45	120	20	200	75	5	80
9	Water Quality	20	65	100	100	150	50	74	47	45	120	50	150	25	300	60
10	Defective Meters	20	50	40	50	50	100	62	47	40	90	50	20	25	150	65
11	Leak - Mains	20	90	60	25	50	100	57	9	45	115	50	10	50	150	80
12	Leak - Connections	10	60	30	25	20	50	51	9	20	30	40	10	25	5	70
13	Leak - near meter	10	40	30	25	10	30	45	9	15	35	40	10	25	5	35
14	Leak - Night time	10	80	30	25	40	50	64	9	55	15	40	10	25	5	65
15	Leak - stop valve	10	40	30	25	10	20	40	9	20	10	40	10	25	5	30
	Sub Total	150	545	570	475	550	500	549	233	320	600	350	520	350	650	545
	Sub Total %	**15**	**55**	**57**	**48**	**55**	**50**	**55**	**23**	**32**	**60**	**35**	**52**	**35**	**65**	**55**
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.7.2 : Aggregated Sub Criteria Responses Corresponding to each Main Criteria

		Form ID (16 – 30)														
		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Income Generation															
1	New Connections	182	126	8	100	150	158	100	100	36	150	150	70	26	158	31
2	Bill collection	182	103	8	200	100	84	50	150	71	100	200	70	51	137	52
	Sub Total	365	230	16	300	250	242	150	250	107	250	350	140	77	295	83
	Sub Total %	**36**	**23**	**2**	**30**	**25**	**24**	**15**	**25**	**11**	**25**	**35**	**14**	**8**	**29**	**8**
	System Sustainability															
3	Operation & Maintenance	125	115	47	100	75	105	100	50	71	50	100	80	128	84	125
4	Salaries and Overtime	130	80	8	70	75	105	100	50	71	50	75	100	51	63	83
5	Transport	78	46	8	60	50	32	50	50	71	50	50	50	26	42	21
	Sub Total	333	241	63	230	200	242	250	150	214	150	225	230	205	189	229
	Sub Total %	**33**	**24**	**6**	**23**	**20**	**24**	**25**	**15**	**21**	**15**	**23**	**23**	**21**	**19**	**23**
	System Losses															
6	Non Revenue Water (NRW)	104	69	78	150	100	32	100	100	71	100	75	80	103	95	125
	Sub Total	104	69	78	150	100	32	100	100	71	100	75	80	103	95	125
	Sub Total %	**10**	**7**	**8**	**15**	**10**	**3**	**10**	**10**	**7**	**10**	**8**	**8**	**10**	**9**	**13**
	System Reliability															
7	Low Pressure	52	69	94	50	75	84	100	50	71	50	20	50	26	84	52
8	No water	26	80	156	20	30	84	50	25	143	50	50	70	51	105	104
9	Water Quality	26	92	156	100	50	84	10	125	214	100	100	100	179	84	52
10	Defective Meters	16	57	16	40	50	105	50	50	71	25	50	30	51	74	52
11	Leak - Mains	16	46	94	70	75	42	100	25	36	100	50	80	128	32	156
12	Leak - Connections	16	23	94	10	50	21	50	25	18	25	20	60	26	11	52
13	Leak - near meter	16	23	78	10	40	21	50	50	18	25	20	60	26	11	10
14	Leak - Night time	16	46	78	10	50	21	75	100	18	100	20	60	103	11	73
15	Leak - stop valve	16	23	78	10	30	21	15	50	18	25	20	40	26	11	10
	Sub Total	198	460	844	320	450	484	500	500	607	500	350	550	615	421	563
	Sub Total %	**20**	**46**	**84**	**32**	**45**	**48**	**50**	**50**	**61**	**50**	**35**	**55**	**62**	**42**	**56**
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

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

		Form ID (31 – 45)														
		31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
	Income Generation															
1	New Connections	100	181	180	65	100	50	115	80	200	84	108	170	56	65	125
2	Bill collection	100	96	120	54	100	150	115	160	150	78	151	136	111	97	139
	Sub Total	200	277	300	119	200	200	231	240	350	162	258	307	167	161	264
	Sub Total %	**20**	**28**	**30**	**12**	**20**	**20**	**23**	**24**	**35**	**16**	**26**	**31**	**17**	**16**	**26**
	System Sustainability															
3	Operation & Maintenance	100	106	50	81	50	100	90	80	100	84	86	80	167	97	125
4	Salaries and Overtime	80	43	100	54	50	95	90	40	90	78	65	45	56	65	83
5	Transport	50	85	50	27	30	50	51	40	80	78	65	34	28	32	28
	Sub Total	230	234	200	162	130	245	231	160	270	240	215	159	250	194	236
	Sub Total %	**23**	**23**	**20**	**16**	**13**	**25**	**23**	**16**	**27**	**24**	**22**	**16**	**25**	**19**	**24**
	System Losses															
6	Non Revenue Water (NRW)	90	96	80	97	150	40	64	138	75	78	108	80	83	65	42
	Sub Total	90	96	80	97	150	40	64	138	75	78	108	80	83	65	42
	Sub Total %	**9**	**10**	**8**	**10**	**15**	**4**	**6**	**14**	**8**	**8**	**11**	**8**	**8**	**6**	**4**
	System Reliability															
7	Low Pressure	80	80	70	54	50	65	77	45	65	71	65	57	83	65	97
8	No water	80	85	80	81	80	65	90	40	30	65	65	57	56	129	97
9	Water Quality	80	106	80	108	150	100	103	120	30	84	75	57	111	129	83
10	Defective Meters	50	53	70	76	30	50	51	60	30	65	65	57	56	32	28
11	Leak - Mains	40	27	30	86	80	75	38	45	30	84	108	57	111	65	28
12	Leak - Connections	40	11	30	54	30	70	26	38	30	39	11	45	14	65	42
13	Leak - near meter	40	11	20	54	30	10	26	38	30	32	11	34	14	32	28
14	Leak - Night time	40	11	20	54	40	70	38	38	30	45	11	57	28	32	28
15	Leak - stop valve	30	11	20	54	30	10	26	38	30	32	11	34	28	32	28
	Sub Total	480	394	420	622	520	515	474	462	305	519	419	455	500	581	458
	Sub Total %	**48**	**39**	**42**	**62**	**52**	**52**	**47**	**46**	**31**	**52**	**42**	**45**	**50**	**58**	**46**
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

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

		Form ID (46 – 60)														
		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
	Income Generation															
1	New Connections	135	80	160	110	189	130	130	150	160	182	160	172	100	86	200
2	Bill collection	162	120	120	100	126	120	80	120	96	152	100	147	70	129	100
	Sub Total	297	200	280	210	316	250	210	270	255	333	260	319	170	215	300
	Sub Total %	**30**	**20**	**28**	**21**	**32**	**25**	**21**	**27**	**26**	**33**	**26**	**32**	**17**	**22**	**30**
	System Sustainability															
3	Operation & Maintenance	86	80	120	160	84	100	90	80	160	61	25	176	60	118	100
4	Salaries and Overtime	54	50	40	30	11	10	40	50	117	20	25	49	70	32	50
5	Transport	43	50	40	50	11	10	30	40	106	10	20	25	50	22	50
	Sub Total	184	180	200	240	105	120	160	170	383	91	70	250	180	172	200
	Sub Total %	**18**	**18**	**20**	**24**	**11**	**12**	**16**	**17**	**38**	**9**	**7**	**25**	**18**	**17**	**20**
	System Losses															
6	Non Revenue Water (NRW)	76	70	110	110	53	80	80	80	96	202	150	172	100	65	50
	Sub Total	76	70	110	110	53	80	80	80	96	202	150	172	100	65	50
	Sub Total %	**8**	**7**	**11**	**11**	**5**	**8**	**8**	**8**	**10**	**20**	**15**	**17**	**10**	**6**	**5**
	System Reliability															
7	Low Pressure	43	60	70	50	63	60	70	60	53	20	50	25	60	75	25
8	No water	43	50	100	70	84	80	100	90	64	81	70	49	70	86	50
9	Water Quality	108	90	120	100	105	100	60	90	43	71	100	25	100	86	50
10	Defective Meters	43	90	40	40	21	30	60	60	43	10	50	25	50	65	25
11	Leak - Mains	86	100	30	120	105	120	100	80	21	101	50	49	70	86	50
12	Leak - Connections	54	70	20	15	53	80	40	40	11	61	50	29	50	54	50
13	Leak - near meter	22	30	10	15	32	10	40	20	11	10	50	20	50	32	50
14	Leak - Night time	22	30	10	15	32	60	40	20	11	10	50	20	50	32	100
15	Leak - stop valve	22	30	10	15	32	10	40	20	11	10	50	20	50	32	50
	Sub Total	443	550	410	440	526	550	550	480	266	374	520	260	550	548	450
	Sub Total %	**44**	**55**	**41**	**44**	**53**	**55**	**55**	**48**	**27**	**37**	**52**	**26**	**55**	**55**	**45**
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

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

		Form ID (61 – 78)																	
		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Income Generation																			
1	New Connections	126	100	27	100	80	25	50	80	163	105	130	50	150	100	125	150	124	125
2	Bill collection	316	50	319	50	90	50	40	100	217	105	100	100	150	150	100	100	155	200
	Sub Total	442	150	346	150	170	75	90	180	380	211	230	150	300	250	225	250	278	325
	Sub Total %	**44**	**15**	**35**	**15**	**17**	**8**	**9**	**18**	**38**	**21**	**23**	**15**	**30**	**25**	**23**	**25**	**28**	**33**
System Sustainability																			
3	Operation &	116	80	106	80	100	50	50	90	163	105	200	50	150	100	150	100	103	100
4	Salaries and Overtime	211	60	266	70	60	25	50	80	87	53	70	50	90	70	80	50	41	75
5	Transport	16	50	11	50	30	15	30	40	76	53	50	40	60	60	40	40	21	50
	Sub Total	342	190	383	200	190	90	130	210	326	211	320	140	300	230	270	190	165	225
	Sub Total %	**34**	**19**	**38**	**20**	**19**	**9**	**13**	**21**	**33**	**21**	**32**	**14**	**30**	**23**	**27**	**19**	**16**	**23**
System Losses																			
6	Non Revenue Water	105	80	106	60	150	100	90	25	152	53	100	150	200	100	125	120	72	100
	Sub Total	105	80	106	60	150	100	90	25	152	53	100	150	200	100	125	120	72	100
	Sub Total %	**11**	**8**	**11**	**6**	**15**	**10**	**9**	**3**	**15**	**5**	**10**	**15**	**20**	**10**	**13**	**12**	**7**	**10**
System Reliability																			
7	Low Pressure	16	50	16	100	90	100	90	70	22	53	30	50	10	80	70	50	72	50
8	No water	16	50	37	80	80	25	90	125	38	53	30	50	40	90	75	80	103	50
9	Water Quality	11	150	53	80	150	10	90	120	27	53	40	200	50	100	100	110	103	50
10	Defective Meters	11	80	5	70	40	100	90	70	11	53	20	50	20	30	40	70	41	75
11	Leak - Mains	21	50	32	60	65	100	90	110	16	105	100	70	30	35	40	40	72	25
12	Leak - Connections	21	50	5	50	20	100	60	30	11	53	20	50	20	30	10	35	36	25
13	Leak - near meter	5	50	5	50	20	100	60	35	5	53	20	30	10	15	10	15	15	25
14	Leak - Night time	5	50	5	50	10	100	60	15	5	53	70	30	10	25	25	25	26	25
15	Leak - stop valve	5	50	5	50	15	100	60	10	5	53	20	30	10	15	10	15	15	25
	Sub Total	111	580	165	590	490	735	690	585	141	526	350	560	200	420	380	440	485	350
	Sub Total %	**11**	**58**	**16**	**59**	**49**	**74**	**69**	**59**	**14**	**53**	**35**	**56**	**20**	**42**	**38**	**44**	**48**	**35**
	Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Table B.8.1 : Comparison of Main Criteria from Direct Weights and from Summation of Sub Criteria

	Water supply sytem management main Criteria	Form ID (1 – 20)																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Income Generation																				
1	From sub Parameters	50	18	14	11	24	20	15	23	24	20	35	18	33	18	15	36	23	2	30	25
2	From main Parameters	40	20	25	10	40	50	15	30	30	25	50	10	30	18	35	37	23	10	50	35
	System Sustainability																				
1	From sub Parameters	30	18	17	24	6	20	21	30	33	20	25	13	28	15	22	33	24	6	23	20
2	From main Parameters	30	35	30	15	15	30	40	30	25	30	30	5	15	15	20	35	23	30	30	25
	System Losses																				
1	From sub Parameters	5	10	13	18	15	10	9	23	11	1	5	17	5	3	9	10	7	8	15	10
2	From main Parameters	20	30	10	50	25	10	25	20	20	5	10	25	35	20	20	10	9	20	10	25
	System Reliability																				
1	From sub Parameters	15	55	57	48	55	50	55	23	32	60	35	52	35	65	55	20	46	84	32	45
2	From main Parameters	10	15	35	25	20	10	20	20	25	40	10	60	20	48	25	19	45	40	10	15

Table B.8.2 : Comparison of Main Criteria from Direct Weights and from Summation of Sub Criteria

	Water supply sytem management main Criteria	Form ID (21 – 40)																			
		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	Income Generation																				
1	From sub Parameters	24	15	25	11	25	35	14	8	29	8	20	28	30	12	20	20	23	24	35	16
2	From main Parameters	30	15	20	50	20	30	30	20	30	20	30	15	50	25	25	20	40	30	40	20
	System Sustainability																				
1	From sub Parameters	24	25	15	21	15	23	23	21	19	23	23	23	20	16	13	25	23	16	27	24
2	From main Parameters	40	20	50	25	20	25	40	20	20	25	23	20	10	30	25	30	15	20	30	35
	System Losses																				
1	From sub Parameters	3	10	10	7	10	8	8	10	9	13	9	10	8	10	15	4	6	14	8	8
2	From main Parameters	20	50	10	13	10	20	15	20	30	25	22	25	30	25	25	20	20	30	20	15
	System Reliability																				
1	From sub Parameters	48	50	50	61	50	35	55	62	42	56	48	39	42	62	52	52	47	46	31	52
2	From main Parameters	10	15	20	13	50	25	15	40	20	30	25	40	10	20	25	30	25	20	10	30

Table B.8.3 : Comparison of Main criteria from direct weights and from summation of sub criteria

	Water supply sytem management main Criteria	Form ID (41 – 60)																			
		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
	Income Generation																				
1	From sub Parameters	26	31	17	16	26	30	20	28	21	32	25	21	27	26	33	26	32	17	22	30
2	From main Parameters	40	45	30	30	20	30	40	35	30	40	40	45	35	25	25	20	30	20	40	50
	System Sustainability																				
1	From sub Parameters	22	16	25	19	24	18	18	20	24	11	12	16	17	38	9	7	25	18	17	20
2	From main Parameters	20	25	30	30	15	25	20	40	40	20	25	20	40	40	15	10	30	30	20	20
	System Losses																				
1	From sub Parameters	11	8	8	6	4	8	7	11	11	5	8	8	8	10	20	15	17	10	6	5
2	From main Parameters	20	15	20	15	20	15	15	10	10	15	10	15	10	25	40	10	20	30	20	10
	System Reliability																				
1	From sub Parameters	42	45	50	58	46	44	55	41	44	53	55	55	48	27	37	52	26	55	55	45
2	From main Parameters	20	15	20	25	45	30	25	15	20	25	25	20	15	10	20	60	20	20	20	20

Table B.8.4 : Comparison of Main Criteria from Direct Weights and from Summation of Sub Criteria

Water supply sytem management main Criteria		Form ID (61 – 78)																	
		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Income Generation																			
1	From sub Parameters	44	15	35	15	17	8	9	18	38	21	23	15	30	25	23	25	28	33
2	From main Parameters	40	40	50	35	30	13	20	25	35	50	30	23	30	25	25	30	35	40
	System Sustainability																		
1	From sub Parameters	34	19	38	20	19	9	13	21	33	21	32	14	30	23	27	19	16	23
2	From main Parameters	30	25	30	10	25	25	20	30	30	15	10	23	30	25	20	20	25	10
	System Losses																		
1	From sub Parameters	11	8	11	6	15	10	9	3	15	5	10	15	20	10	13	12	7	10
2	From main Parameters	15	10	10	30	25	37	20	5	15	20	30	31	20	25	15	10	10	20
	System Reliability																		
1	From sub Parameters	11	58	16	59	49	74	69	59	14	53	35	56	20	42	38	44	48	35
2	From main Parameters	15	25	10	25	20	25	40	40	20	15	30	23	20	25	40	40	30	30

APPENDIX C – ANALYSIS AND RESULTS

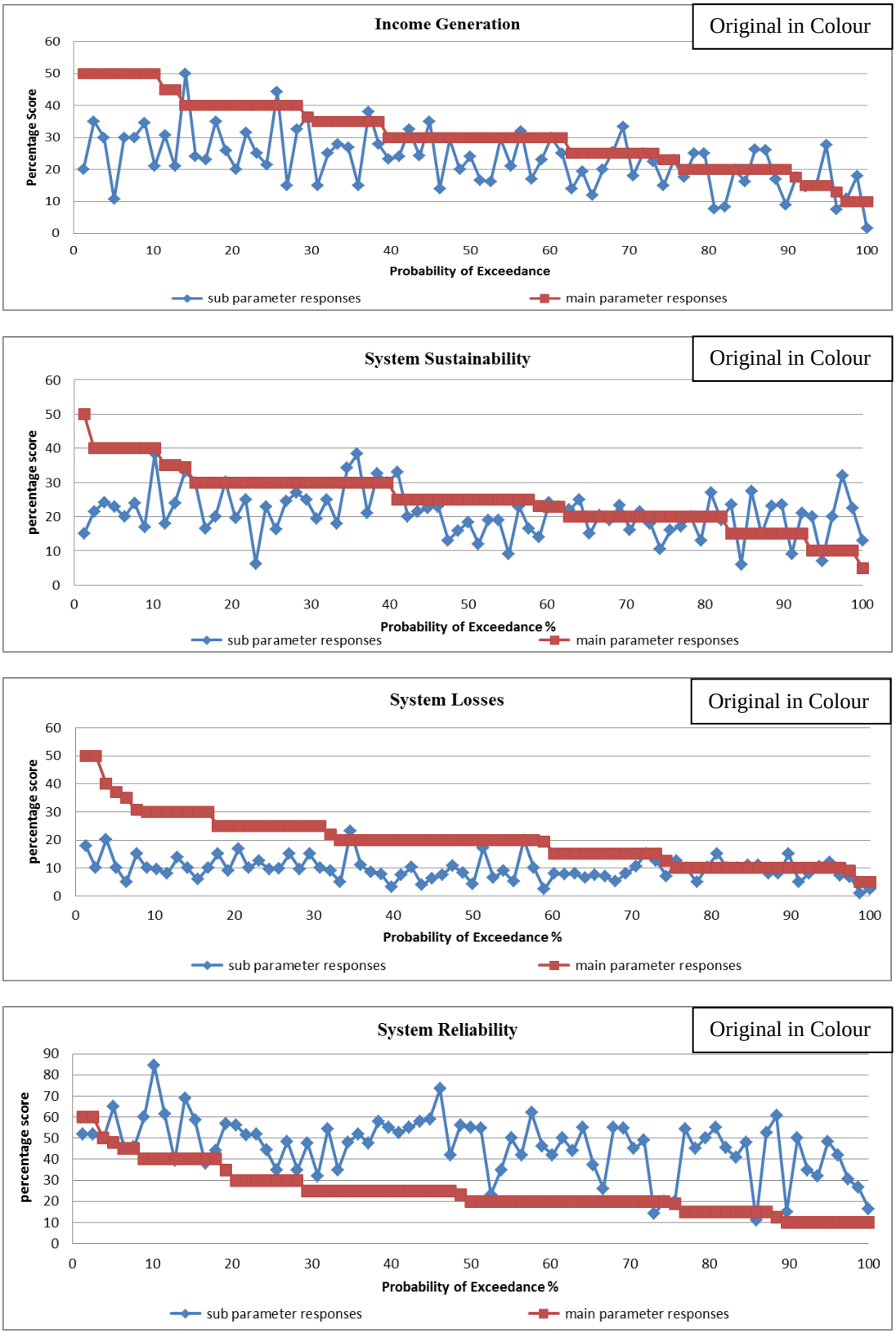

Figure C.1: Comparison of Responses of Main Criteria and Sub Criteria using Probability of Exceedance

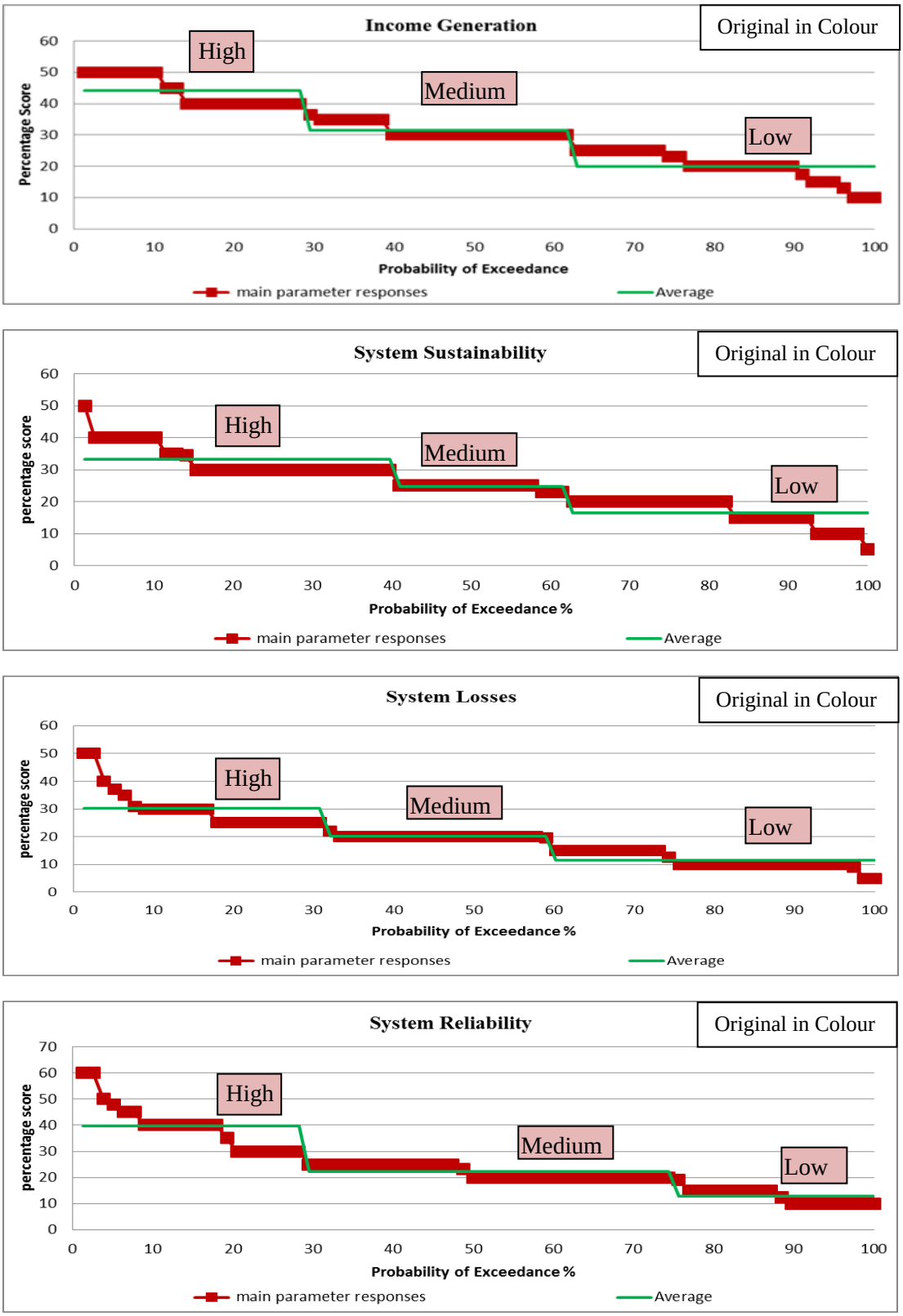

Figure C.2: Probability of Exceedance Curves for Main Criteria

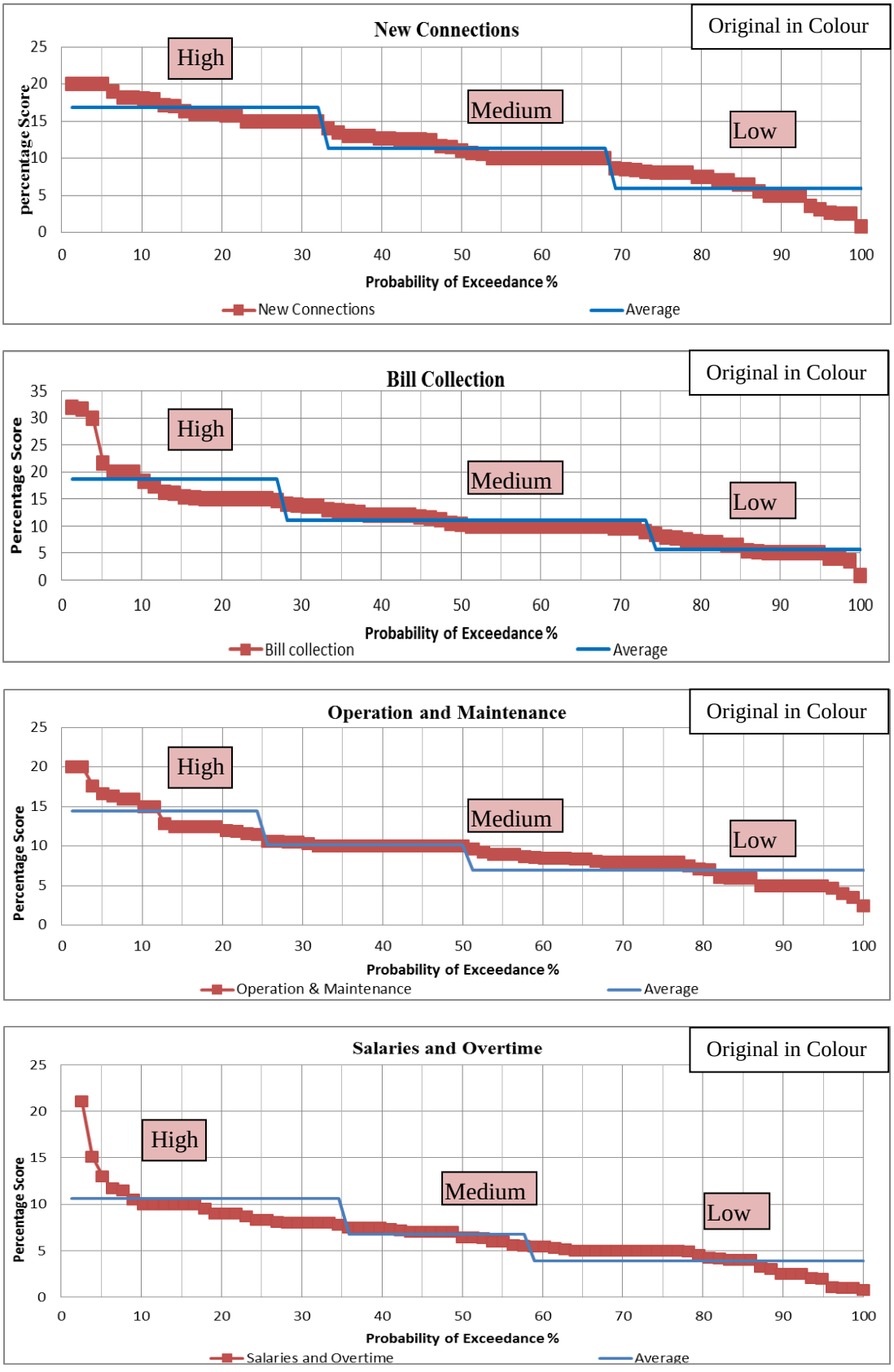

Figure C.3: Probability of Exceedance Curves for Sub Criteria

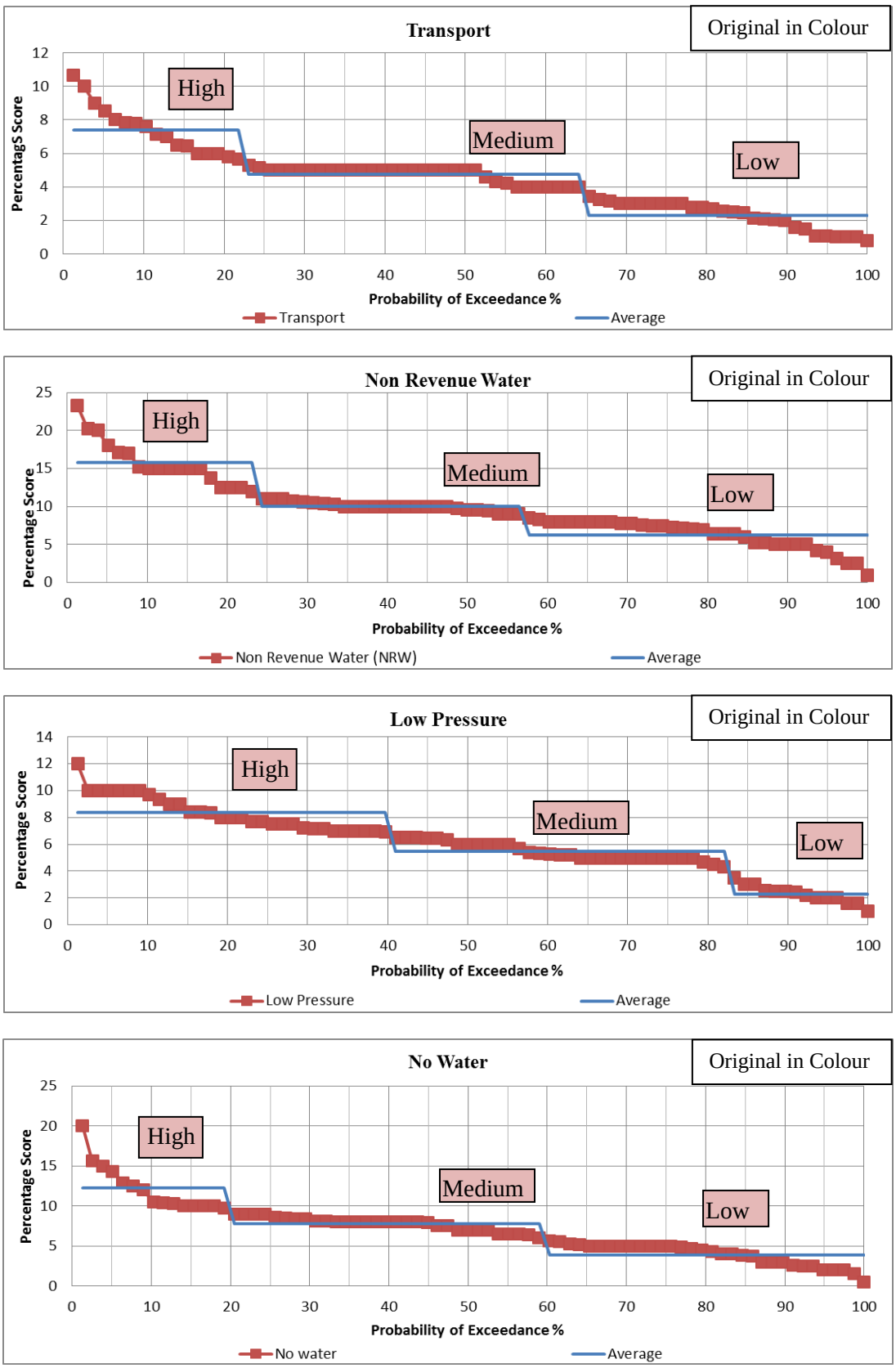

Figure C.4: Probability of Exceedance Curves for Sub Criteria

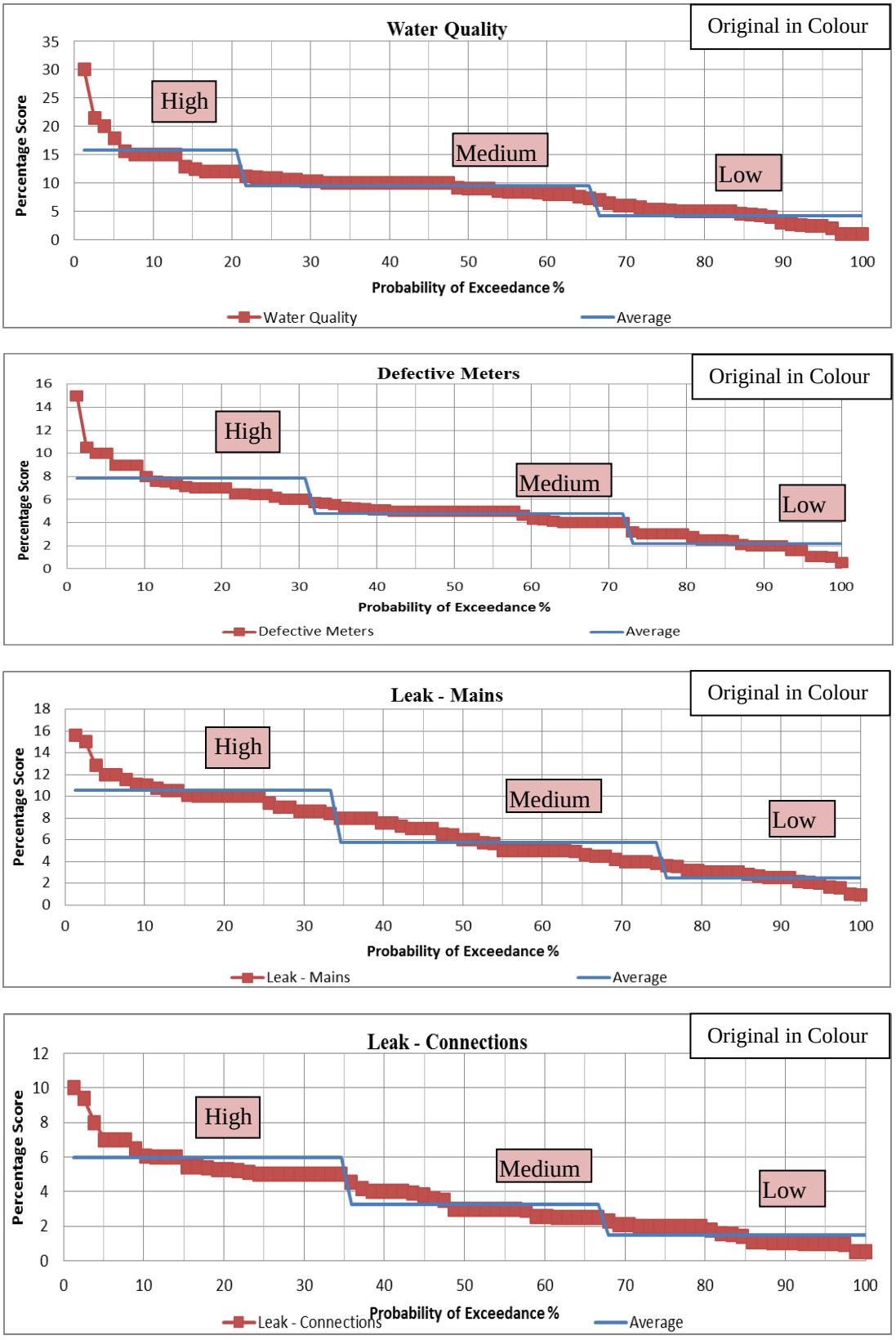

Figure C.5: Probability of Exceedance Curves for Sub Criteria

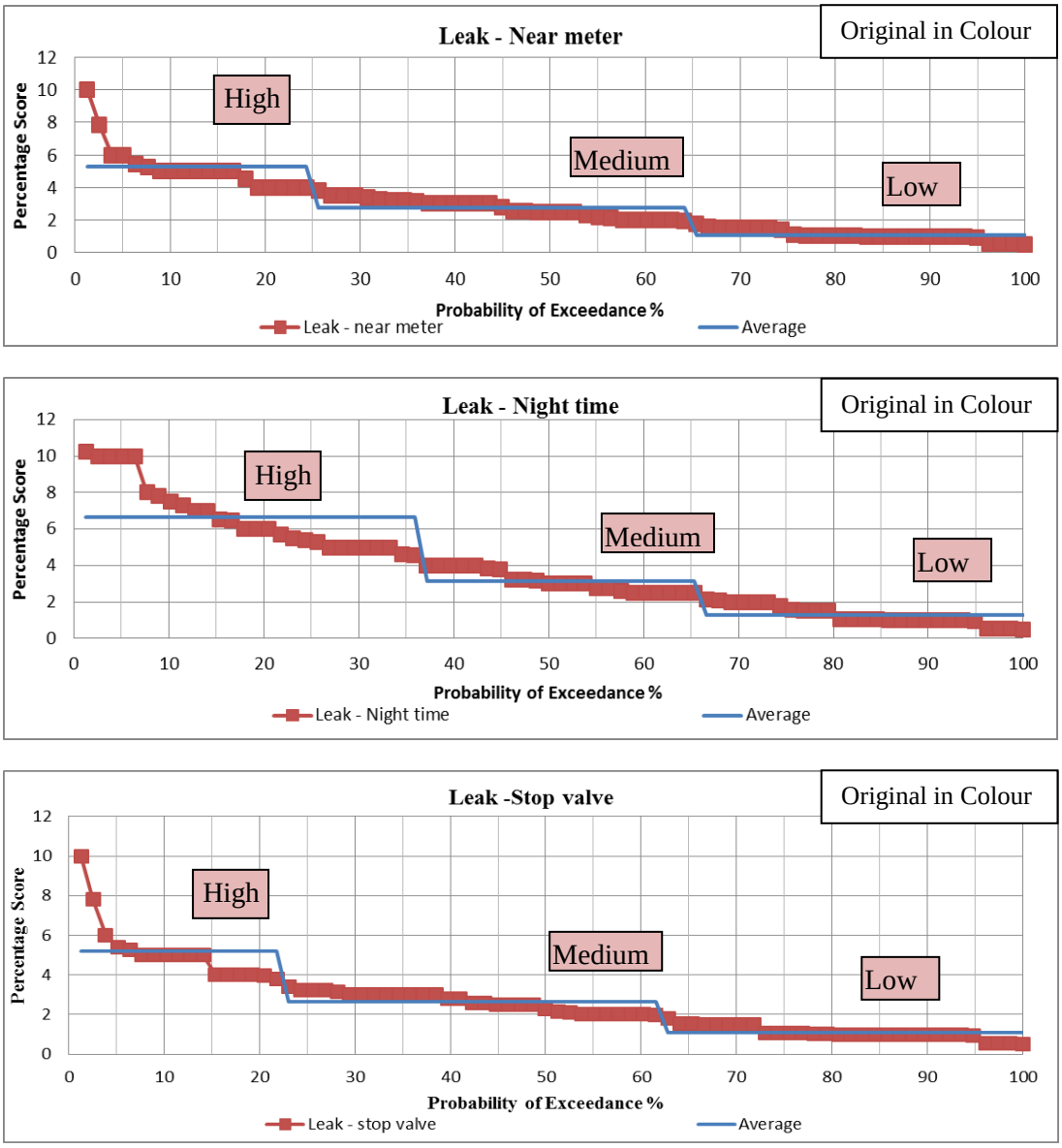

Figure C 6: Probability of Exceedance Curves for Sub Criteria

Table C.1: Pairwise Preferences for Alternatives for Sub Criterion – New Connections

Mgt Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.00	1.19	5.15	4.58	2.50	1.60	1.78	3.25	5.81	2.84	2.99	2.13	5.68	1.77	5.34	3.34	1.67	7.00	3.03	6.86	3.74	3.22
2	0.84	1.00	4.32	3.84	2.10	1.34	1.49	2.72	4.87	2.38	2.51	1.79	4.76	1.48	4.48	2.80	1.40	5.87	2.54	5.75	3.14	2.70
3	0.19	0.23	1.00	0.89	0.49	0.31	0.35	0.63	1.13	0.55	0.58	0.41	1.10	0.34	1.04	0.65	0.33	1.36	0.59	1.33	0.73	0.59
4	0.22	0.26	1.13	1.00	0.55	0.35	0.39	0.71	1.27	0.62	0.65	0.47	1.24	0.39	1.17	0.73	0.37	1.53	0.66	1.50	0.82	0.66
5	0.40	0.48	2.06	1.83	1.00	0.64	0.71	1.30	2.32	1.14	1.19	0.85	2.27	0.71	2.13	1.33	0.67	2.79	1.21	2.74	1.49	1.29
6	0.62	0.74	3.21	2.85	1.56	1.00	1.11	2.02	3.63	1.77	1.86	1.33	3.54	1.10	3.33	2.08	1.04	4.36	1.89	4.28	2.33	2.01
7	0.56	0.67	2.89	2.57	1.40	0.90	1.00	1.82	3.26	1.59	1.68	1.19	3.18	0.99	3.00	1.87	0.94	3.92	1.70	3.84	2.10	1.81
8	0.31	0.37	1.59	1.41	0.77	0.49	0.55	1.00	1.79	0.88	0.92	0.66	1.75	0.54	1.65	1.03	0.52	2.16	0.93	2.11	1.15	0.99
9	0.17	0.21	0.89	0.79	0.43	0.28	0.31	0.56	1.00	0.49	0.51	0.37	0.98	0.30	0.92	0.57	0.29	1.20	0.52	1.18	0.64	0.52
10	0.35	0.42	1.81	1.61	0.88	0.56	0.63	1.14	2.05	1.00	1.05	0.75	2.00	0.62	1.88	1.17	0.59	2.46	1.06	2.41	1.32	1.13
11	0.33	0.40	1.72	1.53	0.84	0.54	0.60	1.09	1.94	0.95	1.00	0.71	1.90	0.59	1.79	1.12	0.56	2.34	1.01	2.29	1.25	1.08
12	0.47	0.56	2.42	2.15	1.18	0.75	0.84	1.52	2.73	1.33	1.40	1.00	2.66	0.83	2.51	1.57	0.79	3.28	1.42	3.22	1.76	1.51
13	0.18	0.21	0.91	0.81	0.44	0.28	0.31	0.57	1.02	0.50	0.53	0.38	1.00	0.31	0.94	0.59	0.29	1.23	0.53	1.21	0.66	0.53
14	0.57	0.68	2.91	2.59	1.42	0.91	1.01	1.84	3.29	1.61	1.69	1.21	3.21	1.00	3.02	1.89	0.95	3.96	1.71	3.88	2.12	1.83
15	0.19	0.22	0.96	0.86	0.47	0.30	0.33	0.61	1.09	0.53	0.56	0.40	1.06	0.33	1.00	0.62	0.31	1.31	0.57	1.28	0.70	0.57
16	0.30	0.36	1.54	1.37	0.75	0.48	0.53	0.97	1.74	0.85	0.90	0.64	1.70	0.53	1.60	1.00	0.50	2.10	0.91	2.05	1.12	0.97
17	0.60	0.71	3.08	2.73	1.50	0.96	1.07	1.94	3.47	1.70	1.79	1.27	3.39	1.06	3.19	1.99	1.00	4.18	1.81	4.10	2.24	1.93
18	0.14	0.17	0.74	0.65	0.36	0.23	0.25	0.46	0.83	0.41	0.43	0.30	0.81	0.25	0.76	0.48	0.24	1.00	0.43	0.98	0.53	0.43
19	0.33	0.39	1.70	1.51	0.83	0.53	0.59	1.07	1.92	0.94	0.99	0.70	1.88	0.58	1.77	1.10	0.55	2.31	1.00	2.27	1.24	1.07
20	0.15	0.17	0.75	0.67	0.37	0.23	0.26	0.47	0.85	0.41	0.44	0.31	0.83	0.26	0.78	0.49	0.24	1.02	0.44	1.00	0.55	0.44
21	0.27	0.32	1.38	1.22	0.67	0.43	0.48	0.87	1.55	0.76	0.80	0.57	1.52	0.47	1.43	0.89	0.45	1.87	0.81	1.83	1.00	0.86
22	0.31	0.37	1.70	1.51	0.78	0.50	0.55	1.01	1.92	0.88	0.93	0.66	1.88	0.55	1.77	1.03	0.52	2.31	0.94	2.27	1.16	1.00

Table C.2: Pairwise Preferences for Alternatives for Sub Criterion – Bill Collection

Mgt Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	1.00	0.74	17.00	0.65	0.64	1.02	0.59	0.28	0.34	0.21	0.31	0.64	0.67	0.95	0.14	0.26	0.57	0.21	0.73	0.77	0.33	0.59
2	1.34	1.00	5.00	0.88	0.86	1.38	0.80	0.38	0.46	0.28	0.41	0.86	0.90	1.28	0.19	0.35	0.76	0.29	0.98	1.03	0.44	0.80
3	0.06	0.20	1.00	0.05	0.05	7.40	0.06	0.08	0.50	0.33	0.09	0.05	0.17	0.25	1.00	0.05	0.13	0.10	0.06	0.11	0.07	0.08
4	1.53	1.14	21.00	1.00	0.98	1.57	0.94	0.43	0.52	0.32	0.47	0.98	1.02	1.46	0.21	0.40	0.87	0.33	1.12	1.17	0.50	0.91
5	1.57	1.17	20.00	1.03	1.00	1.61	0.97	0.44	0.53	0.33	0.48	1.00	1.05	1.50	0.22	0.41	0.89	0.34	1.15	1.20	0.52	0.93
6	0.98	0.73	0.14	0.64	0.62	1.00	0.58	0.28	0.33	0.21	0.30	0.62	0.65	0.93	0.14	0.26	0.55	0.21	0.71	0.75	0.32	0.58
7	1.68	1.25	18.00	1.06	1.04	1.72	1.00	0.46	0.55	0.34	0.50	1.04	1.13	1.61	0.23	0.43	0.92	0.35	1.23	1.29	0.54	0.97
8	3.55	2.64	13.00	2.32	2.26	3.63	2.18	1.00	1.21	0.75	1.09	2.26	2.38	3.39	0.49	0.93	2.01	0.76	2.59	2.71	1.17	2.11
9	2.94	2.19	2.00	1.92	1.87	3.01	1.81	0.83	1.00	0.62	0.91	1.88	1.97	2.81	0.41	0.77	1.67	0.63	2.15	2.25	0.97	1.75
10	4.73	3.52	3.00	3.09	3.01	4.84	2.91	1.33	1.61	1.00	1.46	3.02	3.17	4.52	0.66	1.24	2.69	1.01	3.46	3.62	1.56	2.81
11	3.25	2.42	11.00	2.12	2.07	3.33	2.00	0.92	1.10	0.69	1.00	2.07	2.18	3.10	0.45	0.85	1.84	0.70	2.37	2.49	1.07	1.93
12	1.57	1.17	22.00	1.02	1.00	1.60	0.96	0.44	0.53	0.33	0.48	1.00	1.05	1.50	0.22	0.41	0.89	0.34	1.15	1.20	0.52	0.93
13	1.49	1.11	6.00	0.98	0.95	1.53	0.89	0.42	0.51	0.32	0.46	0.95	1.00	1.43	0.21	0.39	0.85	0.32	1.09	1.14	0.49	0.89
14	1.05	0.78	4.00	0.68	0.67	1.07	0.62	0.30	0.36	0.22	0.32	0.67	0.70	1.00	0.15	0.28	0.59	0.22	0.77	0.80	0.35	0.62
15	7.20	5.36	1.00	4.71	4.59	7.38	4.43	2.03	2.45	1.52	2.22	4.60	4.82	6.88	1.00	1.89	4.09	1.54	5.27	5.51	2.38	4.28
16	3.80	2.83	19.00	2.48	2.42	3.89	2.34	1.07	1.29	0.80	1.17	2.43	2.55	3.63	0.53	1.00	2.16	0.81	2.78	2.91	1.25	2.26
17	1.76	1.31	8.00	1.15	1.12	1.80	1.08	0.50	0.60	0.37	0.54	1.12	1.18	1.68	0.24	0.46	1.00	0.38	1.29	1.35	0.58	1.05
18	4.67	3.48	10.00	3.05	2.98	4.79	2.88	1.32	1.59	0.99	1.44	2.98	3.13	4.46	0.65	1.23	2.65	1.00	3.42	3.58	1.54	2.78
19	1.37	1.02	16.00	0.89	0.87	1.40	0.81	0.39	0.47	0.29	0.42	0.87	0.92	1.31	0.19	0.36	0.78	0.29	1.00	1.05	0.45	0.81
20	1.31	0.97	9.00	0.85	0.83	1.34	0.78	0.37	0.44	0.28	0.40	0.83	0.88	1.25	0.18	0.34	0.74	0.28	0.96	1.00	0.43	0.78
21	3.03	2.26	14.00	1.98	1.93	3.10	1.87	0.85	1.03	0.64	0.93	1.93	2.03	2.89	0.42	0.80	1.72	0.65	2.22	2.32	1.00	1.80
22	1.68	1.25	12.00	1.10	1.07	1.72	1.03	0.47	0.57	0.36	0.52	1.07	1.13	1.61	0.23	0.44	0.95	0.36	1.23	1.29	0.55	1.00

Table C.3: Pairwise Preferences for Alternatives for Sub Criterion – Operation and Maintenance Cost

Mgt zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.00	1.69	1.03	321.00	11.07	3.91	0.83	1.56	4.46	0.95	1.69	2.38	2.18	2.01	0.60	2.82	160.50	1.49	1.47	3.69	2.74	5.63
2	0.59	1.00	0.61	190.00	6.55	2.32	0.49	0.92	2.64	0.56	1.00	1.41	1.29	1.19	0.35	1.67	95.00	0.88	0.87	2.18	1.62	3.33
3	0.98	1.65	1.00	313.00	10.79	3.82	0.81	1.52	4.35	0.92	1.65	2.32	2.13	1.96	0.58	2.75	156.50	1.45	1.43	3.60	2.68	5.49
4	0.00	0.01	0.00	1.00	0.03	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.50	0.00	0.00	0.01	0.01	0.02
5	0.09	0.15	0.09	29.00	1.00	0.35	0.07	0.14	0.40	0.09	0.15	0.21	0.18	0.18	0.05	0.25	14.50	0.13	0.13	0.33	0.25	0.51
6	0.26	0.43	0.26	82.00	2.83	1.00	0.21	0.40	1.14	0.24	0.43	0.61	0.51	0.51	0.15	0.72	41.00	0.38	0.37	0.94	0.70	1.44
7	1.21	2.04	1.24	388.00	13.38	4.73	1.00	1.88	5.39	1.14	2.04	2.87	2.64	2.43	0.72	3.40	194.00	1.80	1.77	4.46	3.32	6.81
8	0.64	1.08	0.66	206.00	7.10	2.51	0.53	1.00	2.86	0.61	1.08	1.53	1.40	1.29	0.38	1.81	103.00	0.95	0.94	2.37	1.76	3.61
9	0.22	0.38	0.23	72.00	2.48	0.88	0.19	0.35	1.00	0.21	0.38	0.53	0.45	0.45	0.13	0.63	36.00	0.33	0.33	0.83	0.62	1.26
10	1.06	1.78	1.08	339.00	11.69	4.13	0.87	1.65	4.71	1.00	1.78	2.51	2.31	2.12	0.63	2.97	169.50	1.57	1.55	3.90	2.90	5.95
11	0.59	1.00	0.61	190.00	6.55	2.32	0.49	0.92	2.64	0.56	1.00	1.41	1.29	1.19	0.35	1.67	95.00	0.88	0.87	2.18	1.62	3.33
12	0.42	0.71	0.43	135.00	4.66	1.65	0.35	0.66	1.88	0.40	0.71	1.00	0.92	0.84	0.25	1.18	67.50	0.63	0.62	1.55	1.15	2.37
13	0.46	0.77	0.47	160.00	5.52	1.95	0.38	0.71	2.22	0.43	0.77	1.09	1.00	0.92	0.27	1.29	80.00	0.68	0.67	1.84	1.26	2.81
14	0.50	0.84	0.51	160.00	5.52	1.95	0.41	0.78	2.22	0.47	0.84	1.19	1.09	1.00	0.30	1.40	80.00	0.74	0.73	1.84	1.37	2.81
15	1.68	2.84	1.72	539.00	18.59	6.57	1.39	2.62	7.49	1.59	2.84	3.99	3.67	3.37	1.00	4.73	269.50	2.50	2.46	6.20	4.61	9.46
16	0.36	0.60	0.36	114.00	3.93	1.39	0.29	0.55	1.58	0.34	0.60	0.84	0.78	0.71	0.21	1.00	57.00	0.53	0.52	1.31	0.97	2.00
17	0.01	0.01	0.01	2.00	0.07	0.02	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.00	0.02	1.00	0.01	0.01	0.02	0.02	0.04
18	0.67	1.14	0.69	216.00	7.45	2.63	0.56	1.05	3.00	0.64	1.14	1.60	1.47	1.35	0.40	1.89	108.00	1.00	0.99	2.48	1.85	3.79
19	0.68	1.15	0.70	219.00	7.55	2.67	0.56	1.06	3.04	0.65	1.15	1.62	1.49	1.37	0.41	1.92	109.50	1.01	1.00	2.52	1.87	3.84
20	0.27	0.46	0.28	87.00	3.00	1.06	0.22	0.42	1.21	0.26	0.46	0.64	0.54	0.54	0.16	0.76	43.50	0.40	0.40	1.00	0.74	1.53
21	0.36	0.62	0.37	117.00	4.03	1.43	0.30	0.57	1.63	0.35	0.62	0.87	0.80	0.73	0.22	1.03	58.50	0.54	0.53	1.34	1.00	2.05
22	0.18	0.30	0.18	57.00	1.97	0.70	0.15	0.28	0.79	0.17	0.30	0.42	0.36	0.36	0.11	0.50	28.50	0.26	0.26	0.66	0.49	1.00

Table C.4: Pairwise Preferences for Alternatives for Sub Criterion – Salaries and Overtime Cost

Mgt zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	1.00	0.76	17.00	0.65	0.64	1.03	0.55	0.34	0.35	0.22	0.36	0.63	0.67	0.89	0.15	0.25	0.51	0.22	0.70	0.76	0.33	0.55
2	1.31	1.00	5.00	0.86	0.84	1.34	0.72	0.45	0.46	0.28	0.47	0.83	0.88	1.16	0.19	0.33	0.67	0.29	0.92	1.00	0.43	0.72
3	0.06	0.20	1.00	0.05	0.05	7.18	0.06	0.09	0.07	0.33	0.50	0.05	0.17	0.25	1.00	0.05	0.13	0.10	0.06	0.11	0.08	0.08
4	1.53	1.17	21.00	1.00	0.98	1.57	0.93	0.52	0.54	0.33	0.55	0.97	1.03	1.36	0.22	0.38	0.78	0.34	1.08	1.17	0.50	0.84
5	1.57	1.20	22.00	1.02	1.00	1.61	0.96	0.53	0.55	0.34	0.56	0.99	1.06	1.39	0.23	0.39	0.80	0.35	1.10	1.20	0.52	0.86
6	0.97	0.74	0.14	0.64	0.62	1.00	0.54	0.33	0.34	0.21	0.35	0.62	0.66	0.86	0.14	0.24	0.50	0.22	0.69	0.74	0.32	0.54
7	1.82	1.39	18.00	1.07	1.05	1.86	1.00	0.56	0.58	0.36	0.59	1.04	1.22	1.61	0.24	0.41	0.84	0.37	1.28	1.39	0.54	0.90
8	2.93	2.24	11.00	1.92	1.87	3.01	1.79	1.00	1.03	0.64	1.06	1.86	1.97	2.60	0.43	0.74	1.50	0.65	2.07	2.24	0.97	1.61
9	2.84	2.17	14.00	1.86	1.81	2.92	1.73	0.97	1.00	0.62	1.02	1.80	1.91	2.52	0.42	0.71	1.45	0.63	2.00	2.17	0.93	1.56
10	4.61	3.52	3.00	3.01	2.94	4.73	2.81	1.57	1.62	1.00	1.66	2.92	3.10	4.08	0.68	1.16	2.36	1.03	3.25	3.52	1.52	2.54
11	2.77	2.12	2.00	1.81	1.77	2.85	1.69	0.95	0.98	0.60	1.00	1.76	1.87	2.46	0.41	0.70	1.42	0.62	1.95	2.12	0.91	1.53
12	1.58	1.21	20.00	1.03	1.01	1.62	0.96	0.54	0.56	0.34	0.57	1.00	1.06	1.40	0.23	0.40	0.81	0.35	1.11	1.21	0.52	0.87
13	1.48	1.13	6.00	0.97	0.95	1.52	0.82	0.51	0.52	0.32	0.54	0.94	1.00	1.32	0.22	0.37	0.76	0.33	1.05	1.13	0.49	0.82
14	1.13	0.86	4.00	0.74	0.72	1.16	0.62	0.38	0.40	0.24	0.41	0.72	0.76	1.00	0.17	0.28	0.58	0.25	0.80	0.86	0.37	0.62
15	6.80	5.20	1.00	4.45	4.34	6.98	4.15	2.32	2.39	1.48	2.45	4.31	4.58	6.03	1.00	1.71	3.48	1.52	4.79	5.20	2.24	3.74
16	3.98	3.04	19.00	2.60	2.54	4.08	2.43	1.36	1.40	0.86	1.43	2.52	2.68	3.52	0.58	1.00	2.03	0.89	2.80	3.04	1.31	2.19
17	1.96	1.49	8.00	1.28	1.25	2.01	1.19	0.67	0.69	0.42	0.71	1.24	1.32	1.73	0.29	0.49	1.00	0.44	1.38	1.49	0.64	1.08
18	4.49	3.43	10.00	2.93	2.86	4.61	2.74	1.53	1.58	0.97	1.62	2.84	3.02	3.98	0.66	1.13	2.29	1.00	3.16	3.43	1.48	2.47
19	1.42	1.08	16.00	0.93	0.91	1.46	0.78	0.48	0.50	0.31	0.51	0.90	0.96	1.26	0.21	0.36	0.73	0.32	1.00	1.08	0.47	0.78
20	1.31	1.00	9.00	0.86	0.84	1.34	0.72	0.45	0.46	0.28	0.47	0.83	0.88	1.16	0.19	0.33	0.67	0.29	0.92	1.00	0.43	0.72
21	3.04	2.32	13.00	1.99	1.94	3.12	1.85	1.04	1.07	0.66	1.10	1.93	2.05	2.69	0.45	0.76	1.55	0.68	2.14	2.32	1.00	1.67
22	1.82	1.39	12.00	1.19	1.16	1.86	1.11	0.62	0.64	0.39	0.65	1.15	1.22	1.61	0.27	0.46	0.93	0.40	1.28	1.39	0.60	1.00

Table C.5: Pairwise Preferences for Alternatives for Sub Criterion – Transport Cost

Mgt zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.00	2.46	2.69	4.63	3.14	1.05	6.13	1.68	1.19	1.08	1.13	1.11	2.79	1.48	0.68	1.20	3.00	1.05	1.09	1.76	1.04	2.84
2	0.41	1.00	1.09	1.88	1.27	0.43	2.49	0.68	0.48	0.44	0.46	0.45	1.13	0.60	0.28	0.48	6.00	0.42	0.44	0.72	0.42	1.15
3	0.37	0.92	1.00	1.72	1.17	0.39	2.28	0.63	0.44	0.40	0.42	0.41	1.04	0.55	0.25	0.44	16.00	0.39	0.41	0.66	0.39	1.06
4	0.22	0.53	0.58	1.00	0.68	0.23	1.32	0.36	0.26	0.23	0.24	0.24	0.60	0.32	0.15	0.26	17.00	0.23	0.24	0.38	0.22	0.61
5	0.32	0.78	0.86	1.48	1.00	0.33	1.95	0.53	0.38	0.34	0.36	0.35	0.89	0.47	0.22	0.38	4.00	0.33	0.35	0.56	0.33	0.90
6	0.95	2.35	2.56	4.42	2.99	1.00	5.84	1.60	1.14	1.03	1.08	1.06	2.66	1.42	0.65	1.14	13.00	1.00	1.04	1.68	0.99	2.71
7	0.16	0.40	0.44	0.76	0.51	0.17	1.00	0.27	0.19	0.18	0.18	0.18	0.46	0.24	0.11	0.19	0.10	0.17	0.18	0.29	0.17	0.46
8	0.60	1.47	1.60	2.76	1.87	0.62	3.65	1.00	0.71	0.64	0.67	0.66	1.66	0.88	0.41	0.71	22.00	0.62	0.65	1.05	0.62	1.69
9	0.84	2.07	2.25	3.89	2.64	0.88	5.14	1.41	1.00	0.90	0.95	0.93	2.34	1.25	0.57	1.01	12.00	0.88	0.92	1.48	0.87	2.38
10	0.93	2.29	2.49	4.30	2.91	0.97	5.69	1.56	1.11	1.00	1.05	1.03	2.59	1.38	0.63	1.11	11.00	0.97	1.02	1.64	0.96	2.63
11	0.88	2.18	2.37	4.09	2.77	0.93	5.41	1.48	1.05	0.95	1.00	0.98	2.46	1.31	0.60	1.06	8.00	0.92	0.97	1.56	0.91	2.51
12	0.90	2.23	2.43	4.19	2.84	0.95	5.54	1.52	1.08	0.97	1.02	1.00	2.52	1.34	0.62	1.08	2.00	0.95	0.99	1.59	0.94	2.57
13	0.36	0.88	0.96	1.66	1.13	0.38	2.20	0.60	0.43	0.39	0.41	0.40	1.00	0.53	0.24	0.43	5.00	0.37	0.39	0.63	0.37	1.02
14	0.67	1.66	1.81	3.12	2.11	0.71	4.13	1.13	0.80	0.73	0.76	0.75	1.88	1.00	0.46	0.81	20.00	0.70	0.74	1.19	0.70	1.91
15	1.47	3.61	3.93	6.79	4.60	1.54	8.98	2.46	1.75	1.58	1.66	1.62	4.09	2.18	1.00	1.75	1.00	1.53	1.60	2.59	1.52	4.16
16	0.83	2.07	2.25	3.89	2.64	0.88	5.14	1.40	0.99	0.90	0.95	0.92	2.34	1.24	0.57	1.00	18.00	0.87	0.91	1.47	0.86	2.38
17	0.33	0.17	0.06	0.06	0.25	0.08	9.68	0.05	0.08	0.09	0.13	0.50	0.20	0.05	1.00	0.06	7.00	0.05	0.07	0.05	0.10	0.11
18	0.96	2.36	2.57	4.43	3.00	1.00	5.86	1.61	1.14	1.03	1.08	1.06	2.67	1.42	0.65	1.15	19.00	1.00	1.05	1.69	0.99	2.71
19	0.91	2.25	2.45	4.23	2.87	0.96	5.60	1.54	1.09	0.98	1.04	1.01	2.55	1.36	0.62	1.10	14.00	0.96	1.00	1.61	0.95	2.60
20	0.57	1.40	1.52	2.62	1.78	0.59	3.47	0.95	0.68	0.61	0.64	0.63	1.58	0.84	0.39	0.68	21.00	0.59	0.62	1.00	0.59	1.61
21	0.97	2.38	2.59	4.47	3.03	1.01	5.92	1.62	1.15	1.04	1.09	1.07	2.69	1.43	0.66	1.16	10.00	1.01	1.06	1.70	1.00	2.74
22	0.35	0.87	0.95	1.63	1.11	0.37	2.16	0.59	0.42	0.38	0.40	0.39	0.98	0.52	0.24	0.42	9.00	0.37	0.39	0.62	0.36	1.00

Table C.6: Pairwise Preferences for Alternatives for Sub Criterion – Non Revenue Water

Mgt Zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.00	0.65	0.73	0.59	0.71	0.60	0.61	1.47	0.78	0.70	1.01	0.61	0.65	0.50	0.82	0.55	0.53	0.70	0.60	0.65	0.68	0.59
2	1.53	1.00	1.11	0.89	1.09	0.90	0.92	2.25	1.19	1.06	1.55	0.92	0.97	0.75	1.25	0.83	0.80	1.05	0.90	0.98	1.02	0.89
3	1.38	0.90	1.00	0.81	0.98	0.82	0.84	2.02	1.07	0.97	1.39	0.84	0.89	0.69	1.13	0.76	0.73	0.96	0.82	0.90	0.93	0.82
4	1.69	1.12	1.23	1.00	1.21	1.01	1.03	2.48	1.31	1.19	1.71	1.03	1.09	0.84	1.39	0.93	0.90	1.18	1.01	1.10	1.14	1.00
5	1.40	0.92	1.02	0.83	1.00	0.84	0.86	2.06	1.09	0.99	1.42	0.86	0.91	0.70	1.15	0.77	0.75	0.98	0.84	0.92	0.95	0.83
6	1.67	1.11	1.21	0.99	1.19	1.00	1.02	2.45	1.30	1.18	1.69	1.02	1.08	0.83	1.37	0.92	0.89	1.16	1.00	1.09	1.13	0.99
7	1.64	1.09	1.19	0.97	1.17	0.98	1.00	2.40	1.27	1.15	1.65	1.00	1.06	0.82	1.34	0.90	0.87	1.14	0.98	1.07	1.11	0.97
8	0.68	0.45	0.49	0.40	0.49	0.41	0.42	1.00	0.53	0.48	0.69	0.42	0.44	0.34	0.56	0.38	0.36	0.48	0.41	0.45	0.46	0.40
9	1.28	0.84	0.93	0.76	0.92	0.77	0.79	1.89	1.00	0.90	1.30	0.79	0.83	0.64	1.05	0.71	0.69	0.90	0.77	0.84	0.87	0.76
10	1.42	0.94	1.03	0.84	1.01	0.85	0.87	2.09	1.11	1.00	1.43	0.87	0.92	0.71	1.16	0.78	0.76	0.99	0.85	0.93	0.96	0.84
11	0.99	0.65	0.72	0.59	0.71	0.59	0.61	1.45	0.77	0.70	1.00	0.61	0.64	0.49	0.81	0.55	0.53	0.69	0.59	0.65	0.67	0.59
12	1.63	1.08	1.19	0.97	1.16	0.98	1.00	2.40	1.27	1.15	1.65	1.00	1.06	0.82	1.34	0.90	0.87	1.14	0.98	1.07	1.10	0.97
13	1.55	1.03	1.12	0.91	1.10	0.93	0.94	2.27	1.20	1.09	1.56	0.95	1.00	0.77	1.27	0.85	0.82	1.08	0.92	1.01	1.04	0.92
14	2.00	1.33	1.45	1.18	1.43	1.20	1.22	2.94	1.56	1.41	2.02	1.23	1.29	1.00	1.64	1.10	1.07	1.40	1.20	1.31	1.35	1.19
15	1.22	0.80	0.89	0.72	0.87	0.73	0.75	1.79	0.95	0.86	1.23	0.75	0.79	0.61	1.00	0.67	0.65	0.85	0.73	0.80	0.82	0.72
16	1.81	1.20	1.32	1.07	1.29	1.09	1.11	2.66	1.41	1.28	1.83	1.11	1.17	0.91	1.49	1.00	0.97	1.27	1.08	1.19	1.23	1.08
17	1.87	1.24	1.36	1.11	1.34	1.12	1.15	2.75	1.46	1.32	1.89	1.15	1.21	0.94	1.54	1.03	1.00	1.31	1.12	1.22	1.27	1.11
18	1.43	0.95	1.04	0.85	1.02	0.86	0.88	2.10	1.12	1.01	1.45	0.88	0.93	0.72	1.17	0.79	0.76	1.00	0.86	0.94	0.97	0.85
19	1.67	1.11	1.22	0.99	1.19	1.00	1.02	2.46	1.30	1.18	1.69	1.03	1.08	0.84	1.37	0.92	0.89	1.17	1.00	1.09	1.13	0.99
20	1.53	1.02	1.11	0.91	1.09	0.92	0.94	2.25	1.19	1.08	1.55	0.94	0.99	0.76	1.25	0.84	0.82	1.07	0.91	1.00	1.03	0.91
21	1.48	0.98	1.08	0.88	1.06	0.89	0.90	2.17	1.15	1.04	1.49	0.91	0.96	0.74	1.21	0.82	0.79	1.03	0.88	0.97	1.00	0.88
22	1.68	1.12	1.22	1.00	1.20	1.01	1.03	2.47	1.31	1.19	1.70	1.03	1.09	0.84	1.38	0.93	0.90	1.18	1.01	1.10	1.14	1.00

Table C.7: Pairwise Preferences for Alternatives for Sub Criterion – Low Pressure

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0
2	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0
3	40.0	40.0	1.0	40.0	40.0	4.0	0.8	2.0	4.0	0.6	2.0	4.0	2.0	4.0	0.6	40.0	40.0	4.0	2.0	40.0	4.0	40.0
4	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0
5	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0
6	10.0	10.0	0.3	10.0	10.0	1.0	0.2	0.5	1.0	0.1	0.5	1.0	0.5	1.0	0.1	10.0	10.0	1.0	0.5	10.0	1.0	10.0
7	50.0	50.0	1.3	50.0	50.0	5.0	1.0	2.5	5.0	0.7	2.5	5.0	2.5	5.0	0.7	50.0	50.0	5.0	2.5	50.0	5.0	50.0
8	20.0	20.0	0.5	20.0	20.0	2.0	0.4	1.0	2.0	0.3	1.0	2.0	1.0	2.0	0.3	20.0	20.0	2.0	1.0	20.0	2.0	20.0
9	10.0	10.0	0.3	10.0	10.0	1.0	0.2	0.5	1.0	0.1	0.5	1.0	0.5	1.0	0.1	10.0	10.0	1.0	0.5	10.0	1.0	10.0
10	70.0	70.0	1.8	70.0	70.0	7.0	1.4	3.5	7.0	1.0	3.5	7.0	3.5	7.0	1.0	70.0	70.0	7.0	3.5	70.0	7.0	70.0
11	20.0	20.0	0.5	20.0	20.0	2.0	0.4	1.0	2.0	0.3	1.0	2.0	1.0	2.0	0.3	20.0	20.0	2.0	1.0	20.0	2.0	20.0
12	10.0	10.0	0.3	10.0	10.0	1.0	0.2	0.5	1.0	0.1	0.5	1.0	0.5	1.0	0.1	10.0	10.0	1.0	0.5	10.0	1.0	10.0
13	20.0	20.0	0.5	20.0	20.0	2.0	0.4	1.0	2.0	0.3	1.0	2.0	1.0	2.0	0.3	20.0	20.0	2.0	1.0	20.0	2.0	20.0
14	10.0	10.0	0.3	10.0	10.0	1.0	0.2	0.5	1.0	0.1	0.5	1.0	0.5	1.0	0.1	10.0	10.0	1.0	0.5	10.0	1.0	10.0
15	70.0	70.0	1.8	70.0	70.0	7.0	1.4	3.5	7.0	1.0	3.5	7.0	3.5	7.0	1.0	70.0	70.0	7.0	3.5	70.0	7.0	70.0
16	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0
17	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0
18	10.0	10.0	0.3	10.0	10.0	1.0	0.2	0.5	1.0	0.1	0.5	1.0	0.5	1.0	0.1	10.0	10.0	1.0	0.5	10.0	1.0	10.0
19	20.0	20.0	0.5	20.0	20.0	2.0	0.4	1.0	2.0	0.3	1.0	2.0	1.0	2.0	0.3	20.0	20.0	2.0	1.0	20.0	2.0	20.0
20	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0
21	10.0	10.0	0.3	10.0	10.0	1.0	0.2	0.5	1.0	0.1	0.5	1.0	0.5	1.0	0.1	10.0	10.0	1.0	0.5	10.0	1.0	10.0
22	1.0	1.0	0.0	1.0	1.0	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	1.0	1.0	0.1	0.1	1.0	0.1	1.0

Table C.8: Pairwise Preferences for Alternatives for Sub Criterion – No Water

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.0	2.0	1.2	1120.0	1120.0	1120.0	0.9	2.1	1120.0	1.2	1.9	2.6	1.6	2.0	3.0	1120.0	1120.0	2.6	1.4	4.5	1120.0	1120.0
2	0.5	1.0	0.6	550.0	550.0	550.0	0.5	1.0	550.0	0.6	0.9	1.3	0.8	1.0	8.0	550.0	550.0	1.3	0.7	2.2	550.0	550.0
3	0.9	1.7	1.0	950.0	950.0	950.0	0.8	1.8	950.0	1.0	1.6	2.2	1.3	1.7	10.0	950.0	950.0	2.2	1.2	3.8	950.0	950.0
4	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	17.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0
5	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	9.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0
6	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	16.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0
7	1.1	2.2	1.3	1200.0	1200.0	1200.0	1.0	2.2	1200.0	1.3	2.0	2.8	1.7	2.1	1.0	1200.0	1200.0	2.8	1.5	4.8	1200.0	1200.0
8	0.5	1.0	0.6	540.0	540.0	540.0	0.5	1.0	540.0	0.6	0.9	1.3	0.8	1.0	12.0	540.0	540.0	1.3	0.7	2.2	540.0	540.0
9	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0
10	0.8	1.7	1.0	940.0	940.0	940.0	0.8	1.7	940.0	1.0	1.6	2.2	1.3	1.7	19.0	940.0	940.0	2.2	1.2	3.8	940.0	940.0
11	0.5	1.1	0.6	590.0	590.0	590.0	0.5	1.1	590.0	0.6	1.0	1.4	0.8	1.0	14.0	590.0	590.0	1.4	0.8	2.4	590.0	590.0
12	0.4	0.8	0.5	540.0	540.0	540.0	0.4	0.8	540.0	0.5	0.7	1.0	0.6	0.8	18.0	540.0	540.0	1.0	0.5	1.7	540.0	430.0
13	0.6	1.3	0.8	720.0	720.0	720.0	0.6	1.3	720.0	0.8	1.2	1.7	1.0	1.3	11.0	720.0	720.0	1.7	0.9	2.9	720.0	720.0
14	0.5	1.0	0.6	570.0	570.0	570.0	0.5	1.1	570.0	0.6	1.0	1.3	0.8	1.0	2.0	570.0	570.0	1.3	0.7	2.3	570.0	570.0
15	0.3	0.1	0.1	0.1	0.1	0.1	1.0	0.1	0.3	0.1	0.1	0.1	0.1	0.5	1.0	0.2	1820.0	0.1	0.1	0.1	0.2	0.1
16	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	5.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0
17	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0
18	0.4	0.8	0.5	430.0	430.0	430.0	0.4	0.8	430.0	0.5	0.7	1.0	0.6	0.8	20.0	430.0	430.0	1.0	0.5	1.7	430.0	430.0
19	0.7	1.4	0.8	790.0	790.0	790.0	0.7	1.5	790.0	0.8	1.3	1.8	1.1	1.4	13.0	790.0	790.0	1.8	1.0	3.2	790.0	790.0
20	0.2	0.5	0.3	250.0	250.0	250.0	0.2	0.5	250.0	0.3	0.4	0.6	0.4	0.4	22.0	250.0	250.0	0.6	0.3	1.0	250.0	250.0
21	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	6.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0
22	0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	21.0	1.0	1.0	0.0	0.0	0.0	1.0	1.0

Table C.9: Pairwise Preferences for Alternatives for Sub Criterion – Water Quality

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	0.8	1	40	40	40	1	40	40	4	4	40	4	40	3	40	40	1.33	40	4	2	40
2	1.25	1	1.25	50	50	50	1.3	50	50	5	5	50	5	50	1	50	50	1.67	50	5	2.5	50
3	1	0.8	1	40	40	40	1	40	40	4	4	40	4	40	10	40	40	1.33	40	4	2	40
4	0.03	0	0.03	1	1	1	0	1	10	0.1	0.1	10	0.1	10	18	10	10	0.03	10	0.1	0.05	10
5	0.03	0	0.03	1	1	1	0	1	1	0.1	0.1	1	0.1	1	20	1	1	0.03	1	0.1	0.05	1
6	0.03	0	0.03	1	1	1	0	1	1	0.1	0.1	1	0.1	1	22	1	1	0.03	1	0.1	0.05	1
7	1	0.8	1	40	40	40	1	40	40	4	4	40	4	40	19	40	40	1.33	40	4	2	40
8	0.03	0	0.03	1	1	1	0	1	1	0.1	0.1	1	0.1	1	21	1	1	0.03	1	0.1	0.05	1
9	0.03	0	0.03	0.1	1	1	0	1	1	0.1	0.1	1	0.1	1	6	1	1	0.03	1	0.1	0.05	1
10	0.25	0.2	0.25	10	10	10	0.3	10	10	1	1	10	1	10	14	10	10	0.33	10	1	0.5	10
11	0.25	0.2	0.25	10	10	10	0.3	10	10	1	1	10	1	10	2	10	10	0.33	10	1	0.5	10
12	0.03	0	0.03	0.1	1	1	0	1	1	0.1	0.1	1	0.1	1	16	1	1	0.03	1	0.1	0.05	1
13	0.25	0.2	0.25	10	10	10	0.3	10	10	1	1	10	1	10	8	10	10	0.33	10	1	0.5	10
14	0.03	0	0.03	0.1	1	1	0	1	1	0.1	0.1	1	0.1	1	5	1	1	0.03	1	0.1	0.05	1
15	0.33	1	0.1	0.06	0.05	0.05	0.1	0.05	0.17	0.07	0.5	0.1	0.13	0.2	7	0.11	0.25	0.08	0.06	0.08	0.09	90
16	0.03	0	0.03	0.1	1	1	0	1	1	0.1	0.1	1	0.1	1	9	1	1	0.03	1	0.1	0.05	1
17	0.03	0	0.03	0.1	1	1	0	1	1	0.1	0.1	1	0.1	1	4	1	1	0.03	1	0.1	0.05	1
18	0.75	0.6	0.75	30	30	30	0.8	30	30	3	3	30	3	30	13	30	30	1	30	3	1.5	30
19	0.03	0	0.03	0.1	1	1	0	1	1	0.1	0.1	1	0.1	1	17	1	1	0.03	1	0.1	0.05	1
20	0.25	0.2	0.25	10	10	10	0.3	10	10	1	1	10	1	10	12	10	10	0.33	10	1	0.5	10
21	0.5	0.4	0.5	20	20	20	0.5	20	20	2	2	20	2	20	11	20	20	0.67	20	2	1	20
22	0.03	0	0.03	0.1	1	1	0	1	1	0.1	0.1	1	0.1	1	0	1	1	0.03	1	0.1	0.05	1

Table C.10: Pairwise Preferences for Alternatives for Sub Criterion – Defective Meters

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	2	0.67	60	60	1.2	1.5	3	1	3	6	2	0.86	0.86	13	2	60	60	0.75	2	1.5	6
2	0.5	1	0.33	30	30	0.6	0.75	1.5	0.5	1.5	3	1	0.43	0.43	12	1	30	30	0.38	1	0.75	3
3	1.5	3	1	90	90	1.8	2.25	4.5	1.5	4.5	9	3	1.29	1.29	1	3	90	90	1.13	3	2.25	9
4	0.02	0.03	0.01	1	1	0.02	0.03	0.05	0.02	0.05	0.1	0	0.01	0.01	9	0.03	1	1	0.01	0.03	0.03	0.1
5	0.02	0.03	0.01	1	1	0.02	0.03	0.05	0.02	0.05	0.1	0	0.01	0.01	4	0.03	1	1	0.01	0.03	0.03	0.1
6	0.83	1.67	0.56	50	50	1	1.25	2.5	0.83	2.5	5	1.7	0.71	0.71	14	1.67	50	50	0.63	1.67	1.25	5
7	0.67	1.33	0.44	40	40	0.8	1	2	0.67	2	4	1.3	0.57	0.57	2	1.33	40	40	0.5	1.33	1	4
8	0.33	0.67	0.22	20	20	0.4	0.5	1	0.33	1	2	0.7	0.29	0.29	21	0.67	20	20	0.25	0.67	0.5	2
9	1	2	0.67	60	60	1.2	1.5	3	1	3	6	2	0.86	0.86	11	2	60	60	0.75	2	1.5	6
10	0.33	0.67	0.22	20	20	0.4	0.5	1	0.33	1	2	0.7	0.29	0.29	6	0.67	20	20	0.25	0.67	0.5	2
11	0.17	0.33	0.11	10	10	0.2	0.25	0.5	0.17	0.5	1	0.3	0.14	0.14	16	0.33	10	10	0.13	0.33	0.25	1
12	0.5	1	0.33	30	30	0.6	0.75	1.5	0.5	1.5	3	1	0.43	0.43	18	1	30	30	0.38	1	0.75	3
13	1.17	2.33	0.78	70	70	1.4	1.75	3.5	1.17	3.5	7	2.3	1	1	10	2.33	70	70	0.88	2.33	1.75	7
14	1.17	2.33	0.78	70	70	1.4	1.75	3.5	1.17	3.5	7	2.3	1	1	19	2.33	70	70	0.88	2.33	1.75	7
15	0.08	0.08	1	0.11	0.25	0.07	0.5	0.05	0.09	0.17	0.06	0.1	0.1	0.05	7	0.05	0.06	120	0.33	0.05	0.13	0.2
16	0.5	1	0.33	30	30	0.6	0.75	1.5	0.5	1.5	3	1	0.43	0.43	20	1	30	30	0.38	1	0.75	3
17	0.02	0.03	0.01	1	1	0.02	0.03	0.05	0.02	0.05	0.1	0	0.01	0.01	17	0.03	1	1	0.01	0.03	0.03	0.1
18	0.02	0.03	0.01	1	1	0.02	0.03	0.05	0.02	0.05	0.1	0	0.01	0.01	0	0.03	1	1	0.01	0.03	0.03	0.1
19	1.33	2.67	0.89	80	80	1.6	2	4	1.33	4	8	2.7	1.14	1.14	3	2.67	80	80	1	2.67	2	8
20	0.5	1	0.33	30	30	0.6	0.75	1.5	0.5	1.5	3	1	0.43	0.43	22	1	30	30	0.38	1	0.75	3
21	0.67	1.33	0.44	40	40	0.8	1	2	0.67	2	4	1.3	0.57	0.57	8	1.33	40	40	0.5	1.33	1	4
22	0.17	0.33	0.11	10	10	0.2	0.25	0.5	0.17	0.5	1	0.3	0.14	0.14	5	0.33	10	10	0.13	0.33	0.25	1

Table C.11: Pairwise Preferences for Alternatives for Sub Criterion – Water Supply Mains Leak

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	0.9	1.07	440	11	2.095	0.6	0.79	2.444	0.69	1.19	1.9	3.667	2.44	0.3	1.05	22	0.55	2	2.75	1.76	2.75
2	1.114	1	1.2	490	12.25	2.333	0.7	0.88	2.722	0.77	1.32	2.1	4.083	2.72	0.4	1.17	24.5	0.61	2.23	3.06	1.96	3.063
3	0.932	0.8	1	410	10.25	1.952	0.6	0.73	2.278	0.64	1.11	1.8	3.417	2.28	0.3	0.98	20.5	0.51	1.86	2.56	1.64	2.563
4	0.002	0	0	1	0.025	0.005	0	0	0.006	0	0	0	0.008	0.01	0	0	0.05	0	0.01	0.01	0.004	0.006
5	0.091	0.1	0.1	40	1	0.19	0.1	0.07	0.222	0.06	0.11	0.2	0.333	0.22	0	0.1	2	0.05	0.18	0.25	0.16	0.25
6	0.477	0.4	0.51	210	5.25	1	0.3	0.38	1.167	0.33	0.57	0.9	1.75	1.17	0.2	0.5	10.5	0.26	0.96	1.31	0.84	1.313
7	1.614	1.4	1.73	710	17.75	3.381	1	1.27	3.944	1.11	1.92	3.1	5.917	3.94	0.6	1.69	35.5	0.89	3.23	4.44	2.84	4.438
8	1.273	1.1	1.37	560	14	2.667	0.8	1	3.111	0.88	1.51	2.4	4.667	3.11	0.4	1.33	28	0.7	2.55	3.5	2.24	3.5
9	0.409	0.4	0.44	180	4.5	0.857	0.3	0.32	1	0.28	0.49	0.8	1.5	1	0.1	0.43	9	0.23	0.82	1.13	0.72	1.125
10	1.455	1.3	1.56	640	16	3.048	0.9	1.14	3.556	1	1.73	2.8	5.333	3.56	0.5	1.52	32	0.8	2.91	4	2.56	4
11	0.841	0.8	0.9	370	9.25	1.762	0.5	0.66	2.056	0.58	1	1.6	3.083	2.06	0.3	0.88	18.5	0.46	1.68	2.31	1.48	2.313
12	0.523	0.5	0.56	250	6.25	1.095	0.3	0.41	1.278	0.36	0.62	1	2.083	1.39	0.2	0.55	12.5	0.29	1.05	1.56	0.92	1.563
13	0.273	0.2	0.29	120	3	0.571	0.2	0.21	0.667	0.19	0.32	0.5	1	0.67	0.1	0.29	6	0.15	0.55	0.75	0.48	0.75
14	0.409	0.4	0.44	180	4.5	0.857	0.3	0.32	1	0.28	0.49	0.7	1.5	1	0.1	0.43	9	0.23	0.82	1.13	0.72	1.125
15	2.909	2.6	3.12	1280	32	6.095	1.8	2.29	7.111	2	3.46	5.6	10.67	7.11	1	3.05	64	1.6	5.82	8	5.12	8
16	0.955	0.9	1.02	420	10.5	2	0.6	0.75	2.333	0.66	1.14	1.8	3.5	2.33	0.3	1	21	0.53	1.91	2.63	1.68	2.625
17	0.045	0	0.05	20	0.5	0.095	0	0.04	0.111	0.03	0.05	0.1	0.167	0.11	0	0.05	1	0.03	0.09	0.13	0.08	0.125
18	1.818	1.6	1.95	800	20	3.81	1.1	1.43	4.444	1.25	2.16	3.5	6.667	4.44	0.6	1.91	40	1	3.64	5	3.2	5
19	0.5	0.4	0.54	220	5.5	1.048	0.3	0.39	1.222	0.34	0.6	1	1.833	1.22	0.2	0.52	11	0.28	1	1.38	0.88	1.375
20	0.364	0.3	0.39	160	4	0.762	0.2	0.29	0.889	0.25	0.43	0.6	1.333	0.89	0.1	0.38	8	0.2	0.73	1	0.64	1
21	0.568	0.5	0.61	250	6.25	1.19	0.4	0.45	1.389	0.39	0.68	1.1	2.083	1.39	0.2	0.6	12.5	0.31	1.14	1.56	1	1.563
22	0.364	0.3	0.39	160	4	0.762	0.2	0.29	0.889	0.25	0.43	0.6	1.333	0.89	0.1	0.38	8	0.2	0.73	1	0.64	1

Table C.12: Pairwise Preferences for Alternatives for Sub Criterion – Water Connections Leak

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.00	2.33	0.97	1070.00	13.38	5.10	0.91	2.10	5.10	0.91	1.47	2.33	3.82	2.10	0.68	3.06	1070.00	1.65	1.53	4.12	2.49	9.73
2	0.43	1.00	0.42	460.00	5.75	2.19	0.39	0.90	2.19	0.39	0.63	1.00	1.64	0.90	0.29	1.31	460.00	0.71	0.66	1.77	1.07	4.18
3	1.03	2.39	1.00	1100.00	13.75	5.24	0.93	2.16	5.24	0.94	1.51	2.39	3.93	2.16	0.70	3.14	1100.00	1.69	1.57	4.23	2.56	10.00
4	0.00	0.00	0.00	1.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.01
5	0.07	0.17	0.07	80.00	1.00	0.38	0.07	0.16	0.38	0.07	0.11	0.17	0.29	0.16	0.05	0.23	80.00	0.12	0.11	0.31	0.19	0.73
6	0.20	0.46	0.19	210.00	2.63	1.00	0.18	0.41	1.00	0.18	0.29	0.46	0.75	0.41	0.13	0.60	210.00	0.32	0.30	0.81	0.49	1.91
7	1.10	2.57	1.07	1180.00	14.75	5.62	1.00	2.31	5.62	1.01	1.62	2.57	4.21	2.31	0.75	3.37	1180.00	1.82	1.69	4.54	2.74	10.73
8	0.48	1.11	0.46	510.00	6.38	2.43	0.43	1.00	2.43	0.44	0.70	1.11	1.82	1.00	0.32	1.46	510.00	0.78	0.73	1.96	1.19	4.64
9	0.20	0.46	0.19	210.00	2.63	1.00	0.18	0.41	1.00	0.18	0.29	0.46	0.75	0.41	0.13	0.60	210.00	0.32	0.30	0.81	0.49	1.91
10	1.09	2.54	1.06	1170.00	14.63	5.57	0.99	2.29	5.57	1.00	1.60	2.54	4.18	2.29	0.75	3.34	1170.00	1.80	1.67	4.50	2.72	10.64
11	0.68	1.59	0.66	730.00	9.13	3.48	0.62	1.43	3.48	0.62	1.00	1.59	2.61	1.43	0.46	2.09	730.00	1.12	1.04	2.81	1.70	6.64
12	0.43	1.00	0.42	460.00	5.75	2.19	0.39	0.90	2.19	0.39	0.63	1.00	1.64	0.90	0.29	1.31	460.00	0.71	0.66	1.77	1.07	4.18
13	0.26	0.61	0.25	280.00	3.50	1.33	0.24	0.55	1.33	0.24	0.38	0.61	1.00	0.55	0.18	0.80	280.00	0.43	0.40	1.08	0.65	2.55
14	0.48	1.11	0.46	510.00	6.38	2.43	0.43	1.00	2.43	0.44	0.70	1.11	1.82	1.00	0.32	1.46	510.00	0.78	0.73	1.96	1.19	4.64
15	1.47	3.41	1.43	1570.00	19.63	7.48	1.33	3.08	7.48	1.34	2.15	3.41	5.61	3.08	1.00	4.49	1570.00	2.42	2.24	6.04	3.65	14.27
16	0.33	0.76	0.32	350.00	4.38	1.67	0.30	0.69	1.67	0.30	0.48	0.76	1.25	0.69	0.22	1.00	350.00	0.54	0.50	1.35	0.81	3.18
17	0.00	0.00	0.00	1.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.01
18	0.61	1.41	0.59	650.00	8.13	3.10	0.55	1.27	3.10	0.56	0.89	1.41	2.32	1.27	0.41	1.86	650.00	1.00	0.93	2.50	1.51	5.91
19	0.65	1.52	0.64	700.00	8.75	3.33	0.59	1.37	3.33	0.60	0.96	1.52	2.50	1.37	0.45	2.00	700.00	1.08	1.00	2.69	1.63	6.36
20	0.24	0.57	0.24	260.00	3.25	1.24	0.22	0.51	1.24	0.22	0.36	0.57	0.93	0.51	0.17	0.74	260.00	0.40	0.37	1.00	0.60	2.36
21	0.40	0.93	0.39	430.00	5.38	2.05	0.36	0.84	2.05	0.37	0.59	0.93	1.54	0.84	0.27	1.23	430.00	0.66	0.61	1.65	1.00	3.91
22	0.10	0.24	0.10	110.00	1.38	0.52	0.09	0.22	0.52	0.09	0.15	0.24	0.39	0.22	0.07	0.31	110.00	0.17	0.16	0.42	0.26	1.00

Table C.13: Pairwise Preferences for Alternatives for Sub Criterion – Leaks near Meter

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.0	1.6	0.9	350.0	17.5	2.7	0.7	1.1	2.3	0.7	2.7	2.7	1.6	2.1	1.2	2.2	350.0	1.9	1.1	3.5	2.1	11.7
2	0.6	1.0	0.6	220.0	11.0	1.7	0.4	0.7	1.5	0.5	1.7	1.7	1.0	1.3	0.8	1.4	220.0	1.2	0.7	2.2	1.3	7.3
3	1.1	1.8	1.0	390.0	19.5	3.0	0.7	1.2	2.6	0.8	3.0	3.0	1.8	2.3	1.3	2.4	390.0	2.2	1.2	3.9	2.3	13.0
4	0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
5	0.1	0.1	0.1	20.0	1.0	0.2	0.0	0.1	0.1	0.0	0.2	0.2	0.1	0.1	0.1	0.1	20.0	0.1	0.1	0.2	0.1	0.7
6	0.4	0.6	0.3	130.0	6.5	1.0	0.2	0.4	0.9	0.3	1.0	1.0	0.6	0.8	0.4	0.8	130.0	0.7	0.4	1.3	0.8	4.3
7	1.5	2.4	1.4	530.0	26.5	4.1	1.0	1.6	3.5	1.1	4.1	4.1	2.4	3.1	1.8	3.3	530.0	2.9	1.6	5.3	3.1	17.7
8	0.9	1.5	0.8	330.0	16.5	2.5	0.6	1.0	2.2	0.7	2.5	2.5	1.5	1.9	1.1	2.1	330.0	1.8	1.0	3.3	1.9	11.0
9	0.4	0.7	0.4	150.0	7.5	1.2	0.3	0.5	1.0	0.3	1.2	1.2	0.7	0.9	0.5	0.9	150.0	0.8	0.5	1.5	0.9	5.0
10	1.3	2.1	1.2	470.0	23.5	3.6	0.9	1.4	3.1	1.0	3.6	3.6	2.1	2.8	1.6	2.9	470.0	2.6	1.4	4.7	2.8	15.7
11	0.4	0.6	0.3	130.0	6.5	1.0	0.2	0.4	0.9	0.3	1.0	1.0	0.6	0.8	0.4	0.8	130.0	0.7	0.4	1.3	0.8	4.3
12	0.4	0.6	0.3	130.0	6.5	1.0	0.2	0.4	0.9	0.3	1.0	1.0	0.6	0.8	0.4	0.8	130.0	0.7	0.4	1.3	0.8	4.3
13	0.6	1.0	0.6	220.0	11.0	1.7	0.4	0.7	1.5	0.5	1.7	1.7	1.0	1.3	0.8	1.4	220.0	1.2	0.7	2.2	1.3	7.3
14	0.5	0.8	0.4	170.0	8.5	1.3	0.3	0.5	1.1	0.4	1.3	1.3	0.8	1.0	0.6	1.1	170.0	0.9	0.5	1.7	1.0	5.7
15	0.8	1.3	0.7	290.0	14.5	2.2	0.5	0.9	1.9	0.6	2.2	2.2	1.3	1.7	1.0	1.8	290.0	1.6	0.9	2.9	1.7	9.7
16	0.5	0.7	0.4	160.0	8.0	1.2	0.3	0.5	1.1	0.3	1.2	1.2	0.7	0.9	0.6	1.0	160.0	0.9	0.5	1.6	0.9	5.3
17	0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
18	0.5	0.8	0.5	180.0	9.0	1.4	0.3	0.5	1.2	0.4	1.4	1.4	0.8	1.1	0.6	1.1	180.0	1.0	0.5	1.8	1.1	6.0
19	0.9	1.5	0.8	330.0	16.5	2.5	0.6	1.0	2.2	0.7	2.5	2.5	1.5	1.9	1.1	2.1	330.0	1.8	1.0	3.3	1.9	11.0
20	0.3	0.5	0.3	100.0	5.0	0.8	0.2	0.3	0.7	0.2	0.8	0.8	0.5	0.6	0.3	0.6	100.0	0.6	0.3	1.0	0.6	3.3
21	0.5	0.8	0.4	170.0	8.5	1.3	0.3	0.5	1.1	0.4	1.3	1.3	0.8	1.0	0.6	1.1	170.0	0.9	0.5	1.7	1.0	5.7
22	0.1	0.1	0.1	30.0	1.5	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.2	30.0	0.2	0.1	0.3	0.2	1.0

Table C.14: Pairwise Preferences for Alternatives for Sub Criterion – Night time Leaks

Mgt zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table C.15: Pairwise Preferences for Alternatives for Sub Criterion – Leaks at Stop Valve

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	1	0.89	80	4	2.67	0.7	1	4	1.14	8	2	4	0.89	0.89	8	80	1.6	1.6	2	2.67	8
2	1	1	0.89	80	4	2.67	0.7	1	4	1.14	8	2	4	0.89	0.89	8	80	1.6	1.6	2	2.67	8
3	1.13	1.1	1	90	4.5	3	0.8	1.13	4.5	1.29	9	2.25	4.5	1	1	9	90	1.8	1.8	2.25	3	9
4	0.01	0	0.01	1	0.05	0.03	0	0.01	0.05	0.01	0.1	0.03	0.05	0.01	0.01	0.1	1	0.02	0.02	0.03	0.03	0.1
5	0.25	0.3	0.22	20	1	0.67	0.2	0.25	1	0.29	2	0.5	1	0.22	0.22	2	20	0.4	0.4	0.5	0.67	2
6	0.38	0.4	0.33	30	1.5	1	0.3	0.38	1.5	0.43	3	0.75	1.5	0.33	0.33	3	30	0.6	0.6	0.75	1	3
7	1.5	1.5	1.33	120	6	4	1	1.5	6	1.71	12	3	6	1.33	1.33	12	120	2.4	2.4	3	4	12
8	1	1	0.89	80	4	2.67	0.7	1	4	1.14	8	2	4	0.89	0.89	8	80	1.6	1.6	2	2.67	8
9	0.25	0.3	0.22	20	1	0.67	0.2	0.25	1	0.29	2	0.5	1	0.22	0.22	2	20	0.4	0.4	0.5	0.67	2
10	0.88	0.9	0.78	70	3.5	2.33	0.6	0.88	3.5	1	7	1.75	3.5	0.78	0.78	7	70	1.4	1.4	1.75	2.33	7
11	0.13	0.1	0.11	10	0.5	0.33	0.1	0.13	0.5	0.14	1	0.25	0.5	0.11	0.11	1	10	0.2	0.2	0.25	0.33	1
12	0.5	0.5	0.44	40	2	1.33	0.3	0.5	2	0.57	4	1	2	0.44	0.44	4	40	0.8	0.8	1	1.33	4
13	0.25	0.3	0.22	20	1	0.67	0.2	0.25	1	0.29	2	0.5	1	0.22	0.22	2	20	0.4	0.4	0.5	0.67	2
14	1.13	1.1	1	90	4.5	3	0.8	1.13	4.5	1.29	9	2.25	4.5	1	1	9	90	1.8	1.8	2.25	3	9
15	1.13	1.1	1	90	4.5	3	0.8	1.13	4.5	1.29	9	2.25	4.5	1	1	9	90	1.8	1.8	2.25	3	9
16	0.13	0.1	0.11	10	0.5	0.33	0.1	0.13	0.5	0.14	1	0.25	0.5	0.11	0.11	1	10	0.2	0.2	0.25	0.33	1
17	0.01	0	0.01	1	0.05	0.03	0	0.01	0.05	0.01	0.1	0.03	0.05	0.01	0.01	0.1	1	0.02	0.02	0.03	0.03	0.1
18	0.63	0.6	0.56	50	2.5	1.67	0.4	0.63	2.5	0.71	5	1.25	2.5	0.56	0.56	5	50	1	1	1.25	1.67	5
19	0.63	0.6	0.56	50	2.5	1.67	0.4	0.63	2.5	0.71	5	1.25	2.5	0.56	0.56	5	50	1	1	1.25	1.67	5
20	0.5	0.5	0.44	40	2	1.33	0.3	0.5	2	0.57	4	1	2	0.44	0.44	4	40	0.8	0.8	1	1.33	4
21	0.38	0.4	0.33	30	1.5	1	0.3	0.38	1.5	0.43	3	0.75	1.5	0.33	0.33	3	30	0.6	0.6	0.75	1	3
22	0.13	0.1	0.11	10	0.5	0.33	0.1	0.13	0.5	0.14	1	0.25	0.5	0.11	0.11	1	10	0.2	0.2	0.25	0.33	1

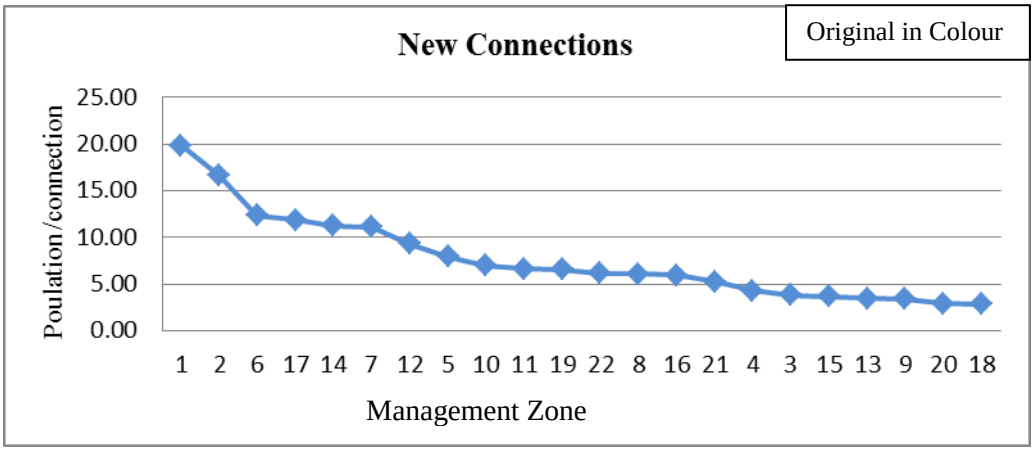

Figure C.7: Probability of Exceedance Curves for Sub Criteria – New Connection

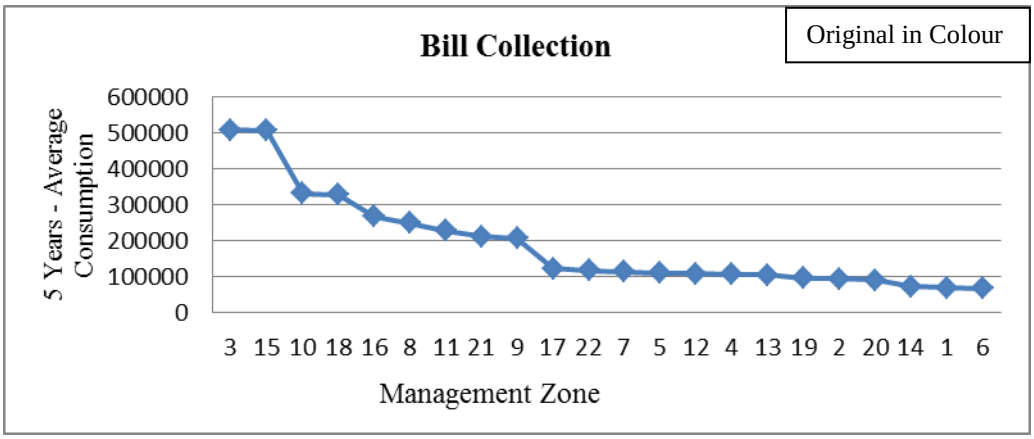

Figure C.8: Probability of Exceedance Curves for Sub Criteria – Bill Collection

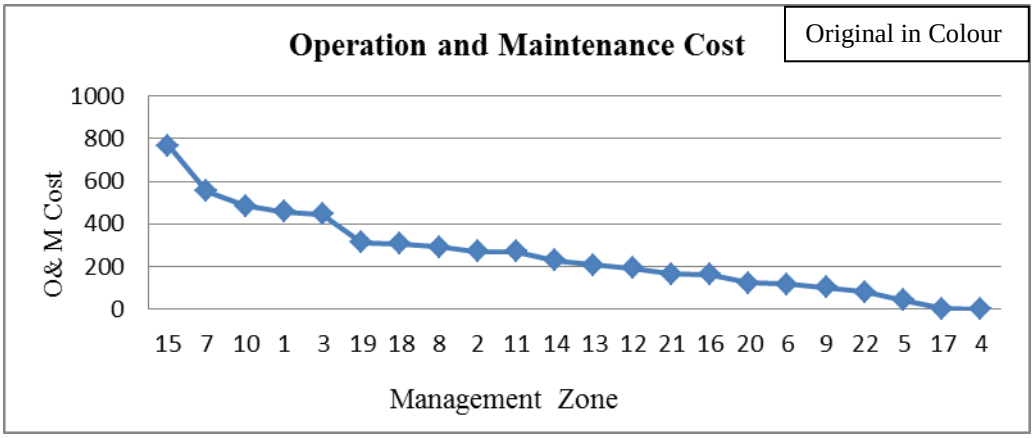

Figure C.9: Probability of Exceedance Curves for Sub Criteria – O&M Cost

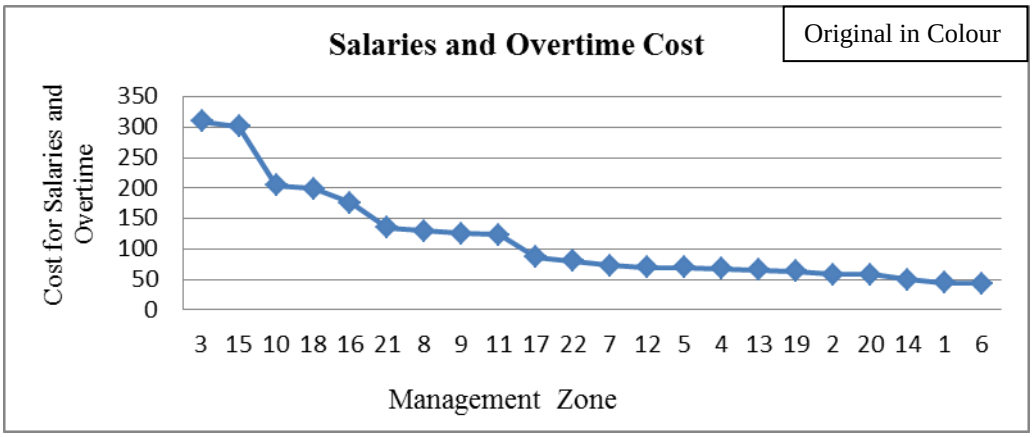

Figure C.10: Probability of Exceedance Curves for Sub Criteria – Salaries and Overtime Cost

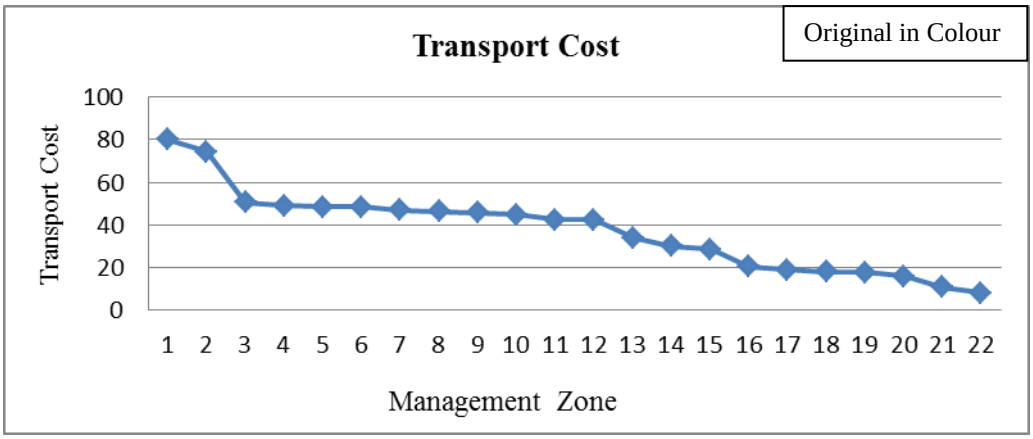

Figure C.11: Probability of Exceedance Curves for Sub Criteria – Transport Cost

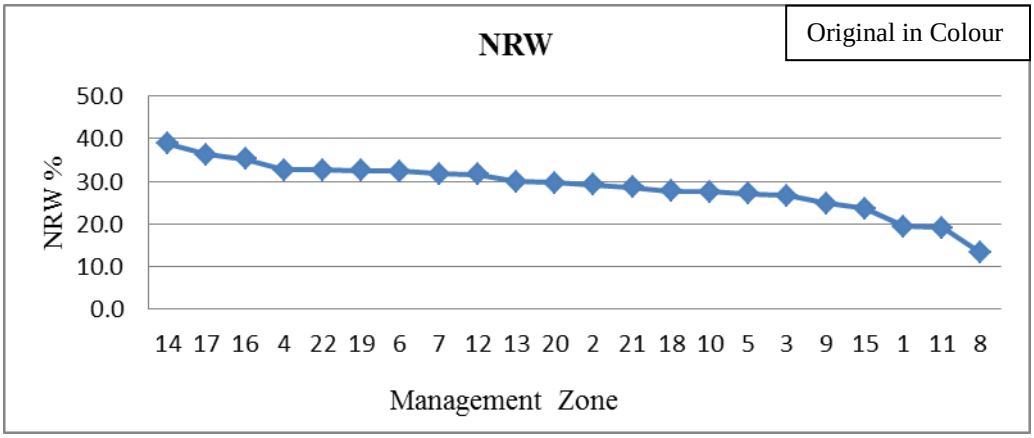

Figure C.12: Probability of Exceedance Curves for Sub Criteria -NRW

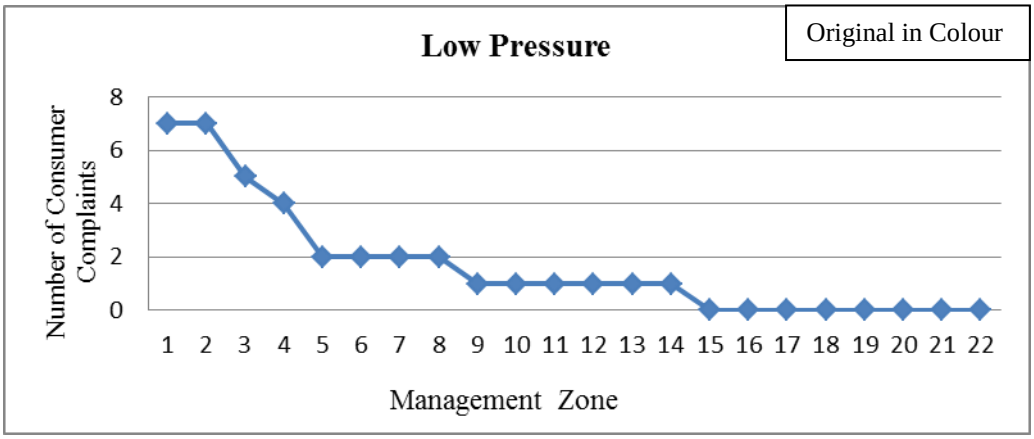

Figure C.13: Probability of Exceedance Curves for Sub Criteria – Low Pressure

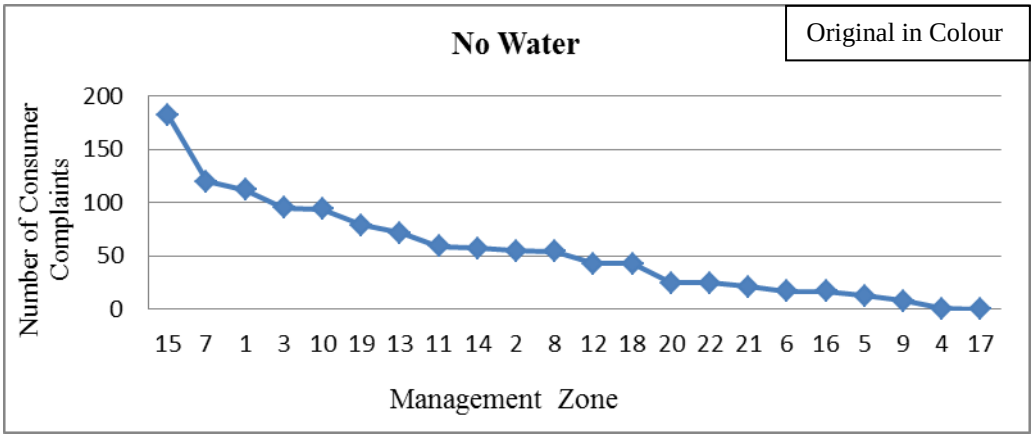

Figure C.14: Probability of Exceedance Curves for Sub Criteria – No Water

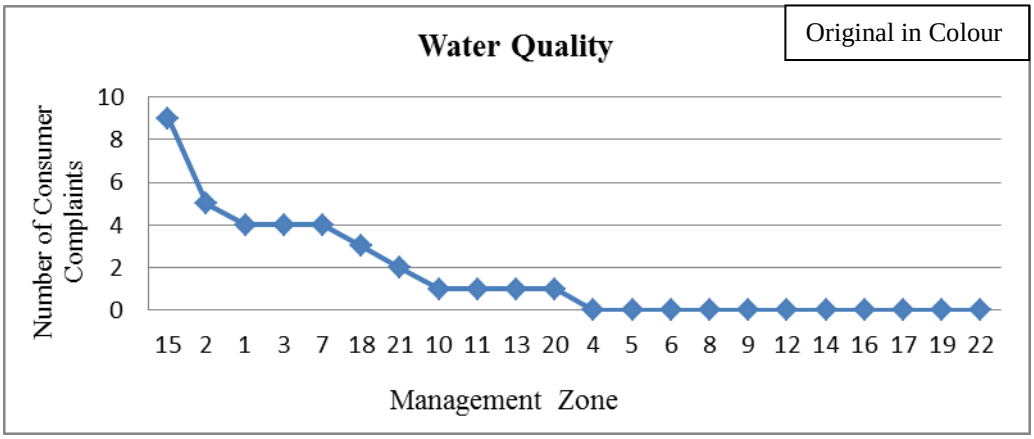

Figure C.15: Probability of Exceedance Curves for Sub Criteria – Water Quality

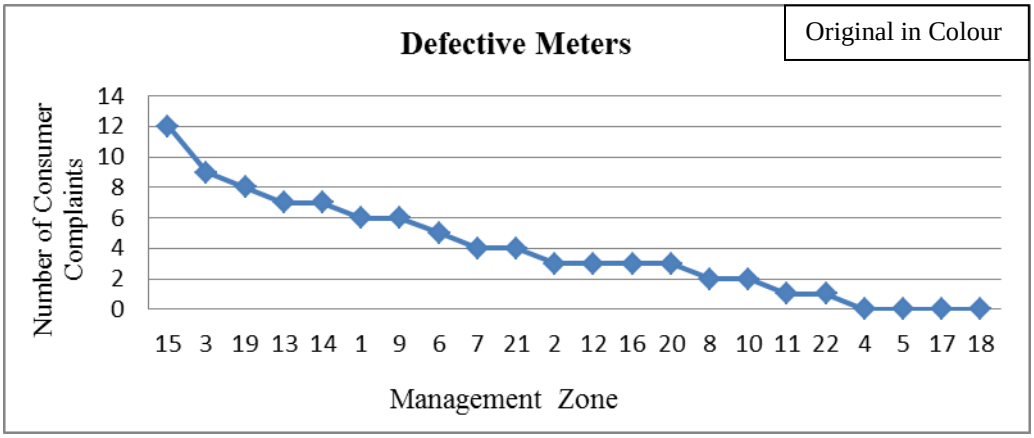

Figure C.16: Probability of Exceedance Curves for Sub Criteria –Defective Meters

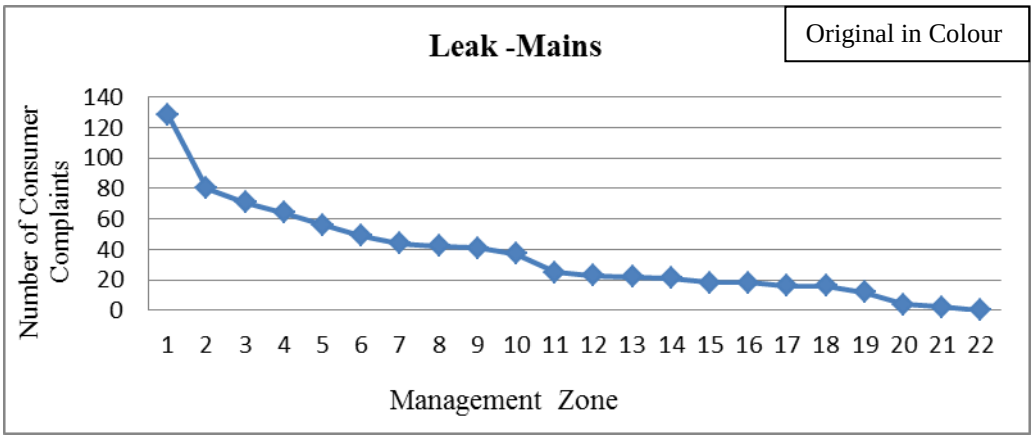

Figure C.17: Probability of Exceedance Curves for Sub Criteria – Leak Mains

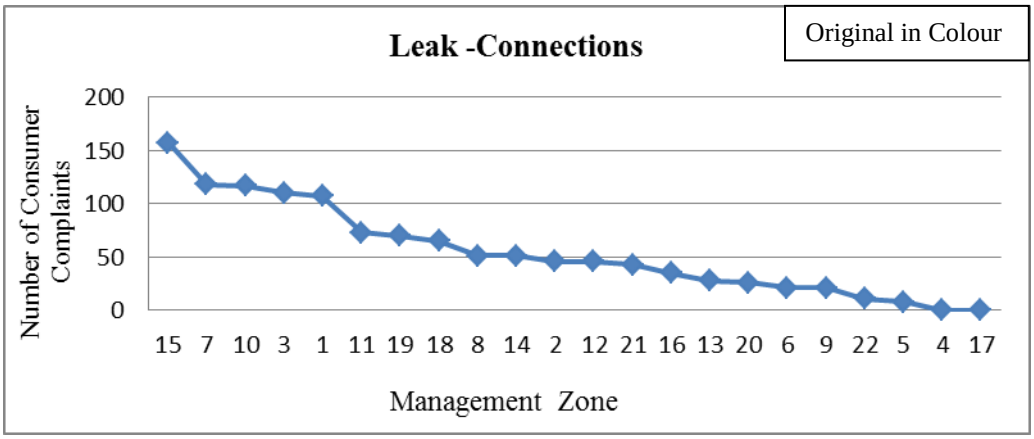

Figure C.18: Probability of Exceedance Curves for Sub Criteria - Connections Leak

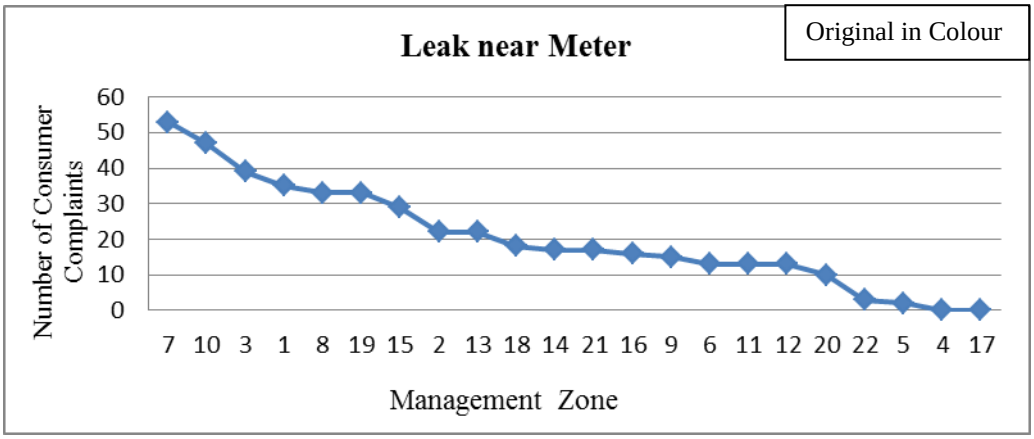

Figure C.19: Probability of Exceedance Curves for Sub Criteria –Leak near Meter

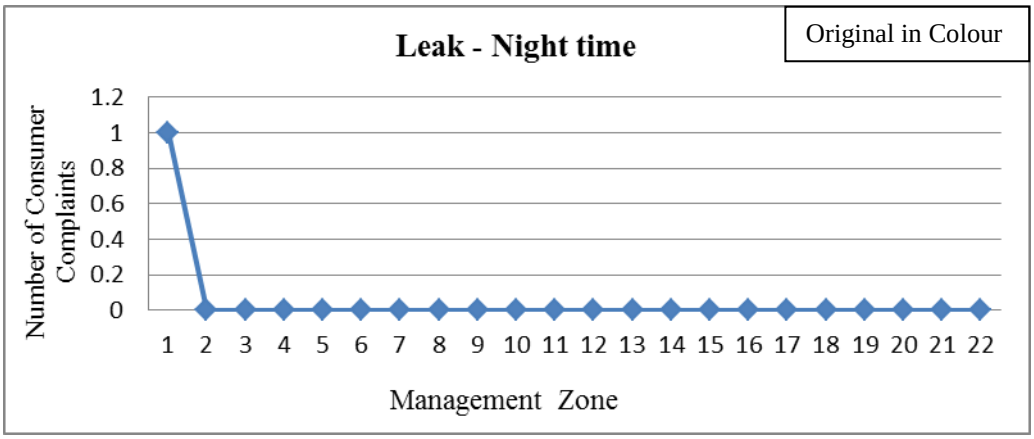

Figure C.20: Probability of Exceedance Curves for Sub Criteria – Night time Leak

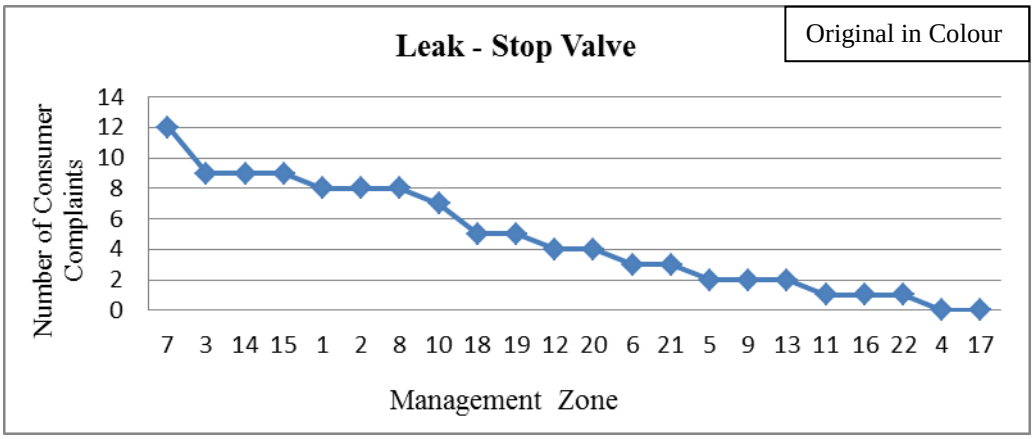

Figure C.21: Probability of Exceedance Curves for Sub Criteria – Leak at stop valve