

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

Thanippuli Appuhamillage Amal Indika Jayaranga

179237 T

Degree of Master of Science

Department of Civil Engineering

University of Moratuwa

Sri Lanka

July 2020

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

Thanippuli Appuhamillage Amal Indika Jayaranga

179237 T

Supervised by

Professor N.T.S. Wijsekera

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

UNESCO Madanjeet Centre for
South Asia Water Management (UMCSAWM)
Department of Civil Engineering

University of Moratuwa

Sri Lanka

July 2020

DECLARATION

I declare that this is my own work and thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other university or institute of higher learning and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as article or books)

.....

T.A.A.I.Jayaranga

.....

Date:

The above candidate has carried out research for the Masters thesis under my supervision.

.....

Professor N.T.S. Wijesekera

.....

Date:

ACKNOWLEDGEMENTS

My sincere gratitude and thanks to the people who have contributed their valuable support and encouragement to complete this study and I extend my appreciation to National Water Supply & Drainage Board and UNESCO Madanjeet Singh Center for giving me this great opportunity.

Firstly I would like to thank my supervisor, Professor N.T.S.Wijesekera, who offers guidance, valuable advice, endless support and encouragement throughout the study. Further I extend my thanks to Dr. R.L.H Lalith Rajapakse, the course coordinator of UNESCO Madanjeet Singh Center for South Asia Water management for his guidance and advice.

Secondly, I offer my sincere gratitude to Eng. Mrs. A.Kaluarachchi (AGM –P&D), Eng. B.A. Fernando (Chief Engineer –P&D) and other staff members of the National Water Supply Drainage Board who supported my research. And I also wish to special thanks to Eng .G.J Prasad (Area Engineer-Ja Ela) to his valuable support.

Finally, I would like to thank my friends & family members for their continuous support and special thanks to my wife and children for their endless support for this achievement.

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

Abstract

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

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

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

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

Key Words:

Water Supply System, MCDA, Organizational Objectives, Stakeholder Survey,

Table of Contents

DECLARATION	i
ACKNOWLEDGEMENTS	ii
Abstract	iii
Table of Contents	iv
List of Tables.....	ix
List of Abbreviations.....	xi
1 INTRODUCTION	1
1.1 General.....	1
1.2 Water Supply in Sri Lanka.....	1
1.3 Management of water supply schemes	3
1.4 Study Area	5
1.5 Objectives	7
1.5.1 Overall Objectives	7
1.5.2 Specific Objectives	7
2 LITERATURE REVIEW	8
2.1 Objectives of water supply and water supply institutions	8
2.2 Criteria used to measure the achievement of objective	10
2.3 Field Level measurement Parameters to Evaluate the Criteria.....	11
2.4 Mathematical Models Used	11
2.5 Summary of Management Criteria.....	12
2.6 Review of Current State of Art	15
3 METHODOLOGY	16
3.1 General.....	16
3.2 Methodology Flow Chart.....	18
4 DATA COLLECTION	19
4.1 Study Area	19
4.2 Data Collection	21
4.2.1 Data Collection on Study area	21
4.2.2 Stakeholder Survey	23
4.2.2.1 Preparing Questionnaire.....	24
4.2.3 Collection of Respondent data.....	27

4.3	Data Checking.....	29
4.3.1	Collected Field Data	29
4.3.2	Stakeholder Response –Management View.....	29
4.3.3	Comparison of data	29
5	ANALYSIS AND RESULTS.....	33
5.1	MCDA model conceptualization	33
5.2	Criteria Identification.....	35
5.2.1	Survey Sample	35
5.2.2	Identification of Main criteria.....	36
5.2.3	Identification Sub Criteria.....	41
5.2.3.1	Income Generation.....	41
5.2.3.2	System Sustainability.....	42
5.2.3.3	System losses	43
5.2.3.4	System Reliability.....	44
5.3	Alternatives	49
5.3.1	Management Zones.....	49
5.3.2	Income Generation.....	50
5.3.2.1	New Connection.....	50
5.3.2.2	Bill Collection.....	51
5.3.3	System Sustainability.....	51
5.3.3.1	Operation & Maintenance Cost	52
5.3.3.2	Staff salaries.....	52
5.3.4	System Losses.....	53
5.3.5	System Reliability.....	54
5.4	MDCA Model framework.....	55
5.4.1	Main Criteria.....	55
5.4.1.1	Pairwise matrix- Main Criteria	55
5.4.1.2	Ranking Main Criteria	58
5.4.2	Sub Parameter	58
5.4.2.1	Pairwise Comparison	59
5.4.2.2	Pairwise matrix- Sub criteria	61
5.4.2.3	Ranking sub criteria	62

5.4.3	Alternative Priority	63
5.4.3.1	New Connection.....	63
5.4.3.2	Bill Collection.....	64
5.4.3.3	O&M Expenditure	65
5.4.3.4	Staff Salaries	66
5.4.3.5	Non-Revenue Water.....	67
5.4.3.6	System Reliability.....	67
5.4.3.7	No water.....	68
5.4.3.8	Main Leak.....	69
5.4.3.9	Connection Leak.....	69
5.4.3.10	Defective meter.....	70
5.4.3.11	Low Pressure.....	70
5.4.3.12	Night Time Leak.....	71
5.4.3.13	Water Quality.....	71
5.4.4.1	Ranking Alternatives.....	72
5.5	Consistency check.....	75
5.5.1	Main Criteria.....	75
5.5.2	Sub Criteria	76
5.5.3	Alternatives.....	76
5.6	Model Calibration Results	79
5.7	Model Verification.....	80
6	DISCUSSION	82
6.1	MCDA model framework.....	82
6.2	Stakeholder survey.....	82
6.3	Data Checking.....	82
6.4	Main Criteria.....	83
6.5	Sub Criteria	83
6.6	Alternatives.....	84
6.7	Verification of model.....	84
6.8	MCDA models for Water Supply	86
6.9	Results.....	86
7	CONCLUSION.....	88

8 RECOMMENDATIONS 89
9 REFERENCES 90

APPENDIX B –STAKEHOLDER SURVEY 92
APPENDIX C- PROBABILITY CURVES..... 123

List of Figures

Figure 1.1: Study Area	6
Figure 3.1: Methodology Flow Chart	18
Figure 4.1: Ja Ela Distribution System	20
Figure 4.2 : Spatial Variation of OIC Boundaries	22
Figure 4.3 : Priority Scores vs. Main Parameters for Working Sections	27
Figure 4.4 : Comparison of stakeholder data -Income Generation	30
Figure 4.5 : Comparison of stakeholder data- System Sustainability	30
Figure 4.6 : Comparison of stakeholder data -System Losses	31
Figure 4.7 : Comparison of stakeholder data-System Reliability	31
Figure 5.1 : MCDA Frame work.....	34
Figure 5.2 : Probability of Exceedance for main criteria	36
Figure 5.3 : probability of Exceedance curve-Income Generation - Selected Combi.	38
Figure 5.4 : probability of Exceedance curve-System Sustainability - Selected Combi .	39
Figure 5.5 : probability of Exceedance curve-System Losses - Selected Combi.....	39
Figure 5.6: probability of Exceedance curve-System Reliability - Selected Combi.....	40
Figure 5.7 : Identified sub-parameters - Income Generation	42
Figure 5.8 : Identified sub-parameters - System Sustainability	43
Figure 5.9 : Identified sub parameters - System Losses	44
Figure 5.10: Identified sub parameters - System Reliability.....	45
Figure 5.11: Probability of Exceedance - sub parameters- Income Generation	46
Figure 5.12: Probability of Exceedance -sub parameters – System Sustainability.....	46
Figure 5.13: Probability of Exceedance - sub parameters -NRW	47
Figure 5.14: Probability of Exceedance - sub parameters – System Reliability	47
Figure 5.15 : MCDA Frame work.....	48
Figure 5.16 : Results for MCDA Model	78
Figure 5.17 : Results –Model Prioritization vs Field Prioritization	81

List of Tables

Table 2-1: Main and Sub Criteria of Water Supply Management from Literature.....	12
Table 4-1 : Data Collection for Ja Ela.....	21
Table 4-2 : Preliminary Discussion Group.....	25
Table 4-3 : Initially Identified Main & Sub parameters.....	25
Table 4-4 : Summary of data collection.....	27
Table 4-5 : Summary of additional sub-parameters.....	28
Table 4-6 : percentage of respondent and main criteria.....	32
Table 5-1 : Designation of Stakeholders.....	35
Table 5-2 Work Experience of Survey Sample.....	35
Table 5-3 : Summarized the Main Criteria Values	37
Table 5-4 : Selected Combinations	37
Table 5-5: Final Combinations	40
Table 5-6: Summary of zone Arrangement in Ja Ela Area	49
Table 5-7 : Number of connection for each management Zone.....	50
Table 5-8: Bill Collection for Study Area.....	51
Table 5-9: O&M Cost for Study Area.....	52
Table 5-10: Staff salary for Study Area	53
Table 5-11: NRW for Study Area	53
Table 5-12: Total Number of Complaints for Study Area	54
Table 5-13: Pairwise comparison of main criteria	55
Table 5-14: Pairwise comparison for main criteria -Saaty scale	56
Table 5-15: Pairwise preferences -Combination 1	56
Table 5-16: Pairwise preferences -Combination 2.....	57
Table 5-17: Pairwise preferences -Combination 3.....	57
Table 5-18: Pairwise preferences -Combination 4.....	57
Table 5-19: Relative importance of main criteria	58
Table 5-20: Summary of classification values for sub parameter.....	59
Table 5-21: pairwise comparison for the sub parameters	60
Table 5-22: pairwise matrix of sub parameter - Income Generation	61
Table 5-23: pairwise matrix of sub parameter -System Sustainability	61
Table 5-24: pairwise matrix of sub parameter -System Reliability	61
Table 5-25: Relative Importance -Income Generation.....	62
Table 5-26: Relative Importance - System Sustainability	62
Table 5-27: Relative Importance -System Reliability.....	62
Table 5-28: Relative weights for New Connections	63
Table 5-29: Pairwise preferences converted to saaty scale- New Connection.....	63
Table 5-30: Relative weights for Bill Collections.....	64
Table 5-31: Pairwise preferences converted to saaty scale-Bill Collection	64
Table 5-32: Relative weights for O & M Expenditure.....	65
Table 5-33: Pairwise preferences converted to saaty scale- O & M Expenditure.....	65
Table 5-34: Relative weights for Staff Salaries	66

Table 5-35: Pairwise preferences converted to saaty scale- Staff Salaries	66
Table 5-36: Relative weights for NRW	67
Table 5-37: Pairwise preferences converted to saaty scale- NRW	67
Table 5-38: Relative weights for Customer Complaints.....	68
Table 5-39 : Pairwise preferences converted to saaty scale- No water.....	68
Table 5-40: Pairwise preferences converted to saaty scale- Main Leak	69
Table 5-41: Pairwise preferences converted to saaty scale- Connection Leak	69
Table 5-42: Pairwise preferences converted to saaty scale- Defective Meters	70
Table 5-43: Pairwise preferences converted to saaty scale- Low Pressure.....	70
Table 5-44: Pairwise preferences converted to saaty scale- Night Time Leak	71
Table 5-45: Pairwise preferences converted to saaty scale- Water Quality.....	71
Table 5-46 : Consistency Ratios – Main Criteria.....	75
Table 5-47 : Consistency Ratio for Sub parameter	76
Table 5-48 : Consistency Ratio for Sub parameters	76
Table 5-49 : Consistency Ratios for Sub parameters	76
Table 5-50 : Consistency Ratios for Alternatives	76
Table 5-51 : Prioritized zones for combination 1 and combination 3.....	79
Table 5-52: Difference between combination 1 and combination 3	80
Table 5-53: Model Prioritization vs Field Prioritization.....	81
Table 6-1 Comparison of Consistent Weight Combinations1 & 3	84
Table 6-2 Model Prioritization and Field Prioritization.....	85

List of Abbreviations

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