STAKEHOLDER PARTICIPATION AND MULTI-CRITERIA DECISION MAKING APPROACHES TO URBAN WATER SUPPLY PLANNING IN ISKANDAR MALAYSIA

NUR 'ASIKIN BINTI ROSLAN

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DEDICATION

Specially dedicated to myself

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ABSTRACT

Stakeholder participation is a process where the stakeholder's point of view is considered in the decision-making. The Multi-Criteria Decision-Making method (MCDM) is a technique in which all the decision criteria are weighted systematically and used to obtain the best result. This study applied stakeholder participation in complex decision-making of alternative urban water supply source using the MCDM technique. The alternative water resources considered in this study are desalination, reclaimed wastewater, groundwater and rainwater. The main objective of this study is to assign appropriate weightage to urban water supply management criteria through stakeholder participation and establish a priority ranking of different alternatives as the basis for developing an integrated urban water supply management guideline. From 200 criteria, initially listed from various literature, 100 criteria were selected and further reduced to six criteria and 59 Performance Measures by the stakeholders using Online Rating in Google Forms and Ranking by New Modified Graphical Innovative Method. The cost criteria score is the most unique as it gets the first importance in the Innovative method but scores the lowest in Online Rating. Criteria on environmental aspect score second in both questionnaires. Next, potential water supply alternatives were paired in different combinations and presented to the stakeholders in a hypothetical scenario and pairwise comparison were used for the evaluation. Most respondents ranked quality as the most important criteria, followed by hydrology and environment. Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) which uses D-Sight Software was applied to get the final weightage of the alternative water supply. The pairwise comparison of hypothetical scenario result shows that rainwater harvesting and surface water score the highest preferences with a score of 20.12. However, rainwater harvesting had more potential with a medium score level compared to low surface water. This is followed by recycled wastewater, 20.01, groundwater, 19.92, and desalination falls last with 19.84, although the potential is high for the study area. However, the results obtained from the PROMETHEE method show that groundwater scored the highest (57.86), followed by desalination (54.74), rainwater harvesting (50.07), storage augmentation, 47.05 (business as usual) and recycling of wastewater (40.30). Even when the result is inconsistent, reflecting different opinions of stakeholders, the decision maker does not prefer business as usual and it is crucial to explore alternative water resources for better future water security. An integrated guideline which combines MCDM and stakeholder participation method was also successfully established through this research.

ABSTRAK

Penyertaan pemegang taruh adalah proses di mana pandangan mereka diambil kira dalam membuat keputusan. Pembuatan Keputusan Berbilang Kriteria (MCDM) adalah teknik membuat keputusan di mana semua kriteria yang berkaitan diberi nilai pemberat secara sistematik dan digunakan untuk mendapatkan keputusan terbaik. Dalam kajian ini, penyertaan pemegang taruh diambil kira dalam membuat keputusan yang kompleks tentang sumber alternatif pembekalan air bandar menggunakan teknik MCDM. Bekalan air alternatif merangkumi sumber-sumber yang bukan konvensional iaitu penyahgaraman, air kumbahan, air bawah tanah dan air hujan. Objektif utama kajian ini adalah untuk menentukan nilai pemberat yang sesuai ke atas kriteria bekalan air perbandaran melalui penyertaan pemegang taruh dan menetapkan pangkat keutamaan ke atas pelbagai alternatif sebagai asas untuk membangunkan garis panduan pengurusan bekalan air perbandaran yang bersepadu. Di peringkat awal, sebanyak 200 kriteria telah disenaraikan berdasarkan kajian literatur. Bilangan kriteria kemudian telah dikurangkan kepada 100 dan akhirnya 6 kriteria dan 59 petunjuk prestasi, yang dipilih oleh pemegang taruh dengan Penskoran Dalam Talian menggunakan Google Forms dan kaedah Inovatif Grafik Terubah. Skor bagi kos adalah paling unik kerana mendapat tertinggi dengan Kaedah Inovatif tetapi mendapat skor terendah dengan kaedah Dalam Talian. Kriteria aspek persekitaran mendapat tempat kedua untuk kedua-dua kaedah bancian. Seterusnya, potensi bekalan air alternatif digabungkan dalam senario yang berbeza dan dikemukakan kepada pemegang taruh dalam senario hipotetikal dan di nilai menggunakan kaedah Perbandingan Berpasangan. Kebanyakan responden meletakkan kualiti sebagai kriteria yang paling penting diikuti hidrologi dan alam sekitar. Pilihan Penskoran Organisasi bagi Kaedah Penilaian Pengayaan (PROMETHEE) melalui Perisian D-Sight digunakan untuk mendapatkan pemberat akhir bekalan air alternatif. Keputusan daripada perbandingan pasangan bagi senario hipotetikal menunjukkan bahawa penuaian air hujan dan air permukaan mendapat pangkat tertinggi dengan skor yang sama iaitu 20.12. Walau bagaimanapun, penuaian air hujan lebih berpotensi dengan peringkat skor sederhana berbanding air permukaan. Ini diikuti dengan kitar semula air buangan dengan skor 20.01, skor air bawah tanah, 19.92 dan penyahgaraman di tempat terakhir, 19.84 walaupun potensinya tinggi untuk kawasan kajian. Walau bagaimanapun, keputusan PROMETHEE menunjukkan skoran tertinggi untuk air bawah tanah (57.86) diikuti oleh penyahgaraman (54.74), penuaian air hujan (50.07), penambahan simpanan (perniagaan seperti biasa) (47.05), dan kitar semula air kumbahan (40.30). Meskipun terdapat keputusan yang tidak konsisten disebabkan perbezaan pendapat antara pemegang taruh, senario biasa tidak dipilih oleh pembuat dasar dan sangat penting untuk meneroka sumber air alternatif bagi memastikan keselamatan air masa depan yang lebih terjamin. Garis panduan bersepadu yang menggabungkan kaedah MCDM dan penyertaan pihak berkepentingan juga berjaya dirangka melalui kajian ini.

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LIST OF ABBREVIATIONS

GDP	-	Gross Domestic Product
MCDM	-	Multi Criteria Decision Making
NRW	-	Non Revenue Water
UN	-	United Nations
G20	-	Group of Twenty (Group of 19 countries and the EU)
UTM	-	Universiti Teknologi Malaysia
NAHRIM	-	National Hydraulic Research Institute of Malaysia
US	-	United States
SWTR	-	Surface Water Treatment
PM	-	Performance Measure
USEPA	-	United State Environment Protection Agency
SAJ	-	Syarikat Air Johor
JMS	-	Job Management System
CCM	-	Call Center Management
BIS	-	Billing Information System
RMS	-	Remote Monitoring System
SPAN	-	Suruhanjaya Perkhidmatan Air Negara
NPV	-	Net Present Value
EIA	-	Environmental Impact Assessment
SMART	-	Simple Multi Attribute Rating Technique
SMARTER	-	SMART Exploiting Ranks
AHP	-	Analytical Hierarchy Process
PATTERN	-	Planning Assistance through Technical Evaluation of Relevance Number
TOPSIS	-	Technique for Order of Preference by Similarity to Ideal Solution
MCDA	-	Multi Criteria Decision Analysis
MCA	-	Multi Criteria Analysis
MADM	-	Multi Attribute Decision Making

PROMETHEE	-	Preference Ranking Organization Method for Enrichment of Evaluations
MAVT	-	Multi-attribute value theory
GMAA	-	General Multi Attribute Analysis
MDSS	-	Mulino Decision Support System
MACBETH	-	Measuring Attractiveness through Categorical Based Evaluation Technique
LCA	-	Life Cycle Analysis
VIP	-	Variable Interdependent Parameter
ELECTRE	-	Eliminating and Choice Expressing Reality
SDI	-	Sustainable Development Indicator
TNS	-	The Natural Step
DID	-	Department of Irrigation and Drainage
DOE	-	Department of Environment
IRDA	-	Iskandar Region Development Authority
BAKAJ	-	Badan Kawalselia Air Johor
SPSS	-	Statistical Package for Social Sciences
GAIA	-	Geometrical Analysis for Interactive Aid
IWRM	-	Integrated Water Resource Management
IRBM	-	Integrated River Basin Management
MPJB	-	Majlis Perbandaran Johor Bahru
MBIP	-	Majlis Bandaraya Iskandar Puteri
MPK	-	Majlis Perbandaran Kulai
MPPG	-	Majlis Perbandaran Pasir Gudang
MPPG(PG)	-	Majlis Perbandaran Pasir Gudang (Pasir Gudang)
MPPG(T)	-	Majlis Perbandaran Pasir Gudang (Tebrau)
PVC	-	Polyvinyl Chloride
MED	-	Multiple Effect Distillation
MVC	-	Mechanical Vapour Compression
UPVC	-	Unplasticized Polyvinyl Chloride
ABS	-	Acrylonitrile Butadiene Styrene
UV	-	Ultra Violet
RBF	-	River Bank Filtration
RC	-	Running Cost

CC	-	Construction Cost
HI	-	Health Impacts
WSQ	-	Water Supply Quality
CWS	-	Continuity of Water Supply
WCDS	-	Water Consumption Demand and Supply
RI	-	Risk of Infection
ACW	-	Availability to Clean Water
IC	-	Investment Cost
TC	-	Total Cost
MC	-	Maintenance Cost
ERCC	-	Efficiency in Redresses of Customer Complaints
MWC	-	Metering of Water Connection
HCL	-	Household Coverage Level
CuC	-	Customer Complaints
ENRW	-	Extent of Non-Revenue Water

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water supply had become major challenges in many countries and cities due to the high growth rate and climate change. The extreme weather condition with prolonged drought and intense rainfall had severely affected cities which dependent on rain-fed surface water (Kaniewski et al., 2017; Tsheko, 2003). Such example can be seen where prolonged El-Nino had affected their water supply mainly obtained from dam causing several cities to enforce water rationing. This problem mainly rooted in the government inability to foresee the high population growth of their countries despite all the measures taken to mitigate the drought effect. It is crucial to consider alternative supply such as desalination, wastewater recycling, rainwater harvesting groundwater etc. At the same time, it's necessary to strengthen water related policy and management in order to increase water use efficiency in various sectors.

Water supply problem can also be seen locally in Malaysia, with primary water resource which account for 97% surface water sourced from river and dam (Chin & Ng, 2015; Kailasam, 2011), water in Malaysia had experience many instability when prolonged drought occur with effect can be seen when water rationing were enforced.

In Johor, Iskandar Malaysia which is located in southern of Johor had account most of the Johor Gross Domestic Product (GDP) with high population number and high population growth rate (Rizzo & Khan, 2013). The population growth mainly contributed to immigration of people into the area due to better work opportunity and state government initiatives to increase foreign professional to migrate into the area by providing tax incentives (Jayaraman, Khu, & Kiumarsi). The region population is estimated to be 1.3 million (Rizzo & Khan, 2013) which is 43 % from 3.17 million the total population of Johor. With fast increasing population, Johor state needs to cope up

with providing them utilities such as power and water supply not only for the well-being of the community but also for the economic to prosper (Sabri & Yaakup, 2008).

Urban water supply in Iskandar Malaysia is predicted to be insufficient by year 2025 with shortages of approximately 100 million litre per day (Khazanah Nasional, 2006). This amount is very huge since Malaysia is blessed with high average annual rainfall of 2500 mm/yr left only the possibility of the problem to be based on the inefficient planning and water usages. Many measures to improvise urban water supply system had been planned such as erecting new treatment plants, building of trenches, concrete water tank, construction and repairing of existing pipeline, reducing non-revenue water and etc. with estimated cost of RM769 million (Khazanah Nasional, 2006). With identification of new source and infrastructure improvement, supply plans still need to be reformed to ensure supply sustainability and to cope with external factors.

1.2 Problem Statement

The alternative water supply and management systems can be adopted by the current decision makers in the area of case study and also be extended to other main river basins which supply water to urban area. It is important especially in developing countries to have some guideline and contingency plan on the urban water supply system and for them to revise the current operation systems to meet the growing population demand in fast changing environment where lots of factors and wrong decision can deteriorate our water resources.

As Malaysia is blessed with abundant of rainfall, the remaining problems that often cause water shortages are related to inefficient planning and water usages. Planning has to take into account the other stakeholder preferences to achieve fair operation that can benefit all stakeholders (Hall, Gilbertz, Anderson, & Ward, 2016). Achieving one goal (objectives) by sacrificing all other objectives is not an option to be taken especially when the risk involve is high such as water shortages (Alexander, Moglia, & Miller, 2010; Ivey, Smithers, De Loë, & Kreutzwiser, 2004). Decision by

intuition is outdated and of high risks. Thus, there should be a call for systematic ways in making decision by leveraging on reliable softwares and methods so that the best decision can be made.

By integrating stakeholder participation into decision making process and aided with MCDM method, a solid and reliable decision can be made which benefit not only the decision makers, but also all the stakeholders and for the sustainable use of water resources for future generations.

Integration of MCDM and stakeholder participation will create a new perspective on water resource planning and management. Integrated water resource planning nowadays has considered inclusion of all stakeholders to achieve mutual benefit in the ecology, social as well as the economy (Barbosa, Mushtaq, & Alam, 2017; Brombal et al., 2018; Højberg, Troldborg, Stisen, Christensen, & Henriksen, 2013; Llopis-Albert, Palacios-Marques, & Soto-Acosta, 2015). The new integration of stakeholder participation will further strengthen these stakeholders understanding on the water resource management and options and can be used to project outcomes of the implementation of the alternative water supply and management systems. The integration seems necessary to nurture right behaviour amongst water users and stakeholders apart from adopting the best available technologies to achieve desired goal (Masimbe, 2018).

1.3 Objectives of the study

Objectives of the study is as follows:

a) To assign appropriate weightage to urban water supply management criteria through stakeholder participation.

b) To develop a priority ranking of different alternatives in urban water supply using MCDM method by taking stakeholders' preferences in decision making process

c) To establish an integrated guideline framework for urban water supply management by using stakeholder participation and MCDM method.

1.4 Scope of Study

The scope of the study includes developing water supply management plan in integrated manners by considering multi criteria methods and stakeholder involvement in decision making. Detail analysis of this method leads to experimentation with various methods and improvisation to better reflect stakeholder preferences. Multiple criteria related to urban water supply planning were outlined and used for measuring the suitability of alternative water supply options. Comparison of various alternative water supply options then follows. Special emphasis were given to the participation method which considered the community perception on the potential alternative water supply source chosen for water supply augmentation.

1.5 Importance of the Study

Integration of stakeholder participation as well as MCDM method will create a strong decision-making tool. Integrated water resource planning nowadays has taken into account inclusion of all stakeholders to achieve mutual benefit in the ecology, social and also the economy (Aliewi, El-Sayed, Akbar, Hadi, & Al-Rashed, 2017; Dandy et al., 2019; Molinos-Senante et al., 2016; Molinos-Senante, Muñoz, & Chamorro, 2019; Pathak, Garg, Jato-Espino, Lakshmi, & Ojha, 2019). Integration give stakeholder and the public sense of ownership which is important in water supply management (Masimbe, 2018). The integrated decision making will be able to address urban water management issues in current social situation.

As Malaysia is blessed with high rainfall every year, the remaining problems that often cause water shortages are associated with inefficient planning and water usages. Planning has to consider other stakeholders' preferences to achieve fair decision making that can benefit all stakeholders. Achieving one goal (objectives) by

sacrificing all other objectives is not an option especially when the risks involve is high. Decisions by intuition were also outdated and of high risks. There should be a call for systematic ways in making decision, aided by reliable software and programme so that best decision can be made.

Thus, the aim of this study is that by integrating stakeholder participation into decision making process, a solid and reliable decision can be made which benefit not only the decision makers, but also all stakeholders in ensuring sustainability of water resources for future generations.

1.6 Structure of Thesis

This thesis presents extensive literature review on the study area which is Iskandar Malaysia as well as its current water supply status. The literature review explores on alternative water supply options available and success stories on utilization of alternative water supply in other countries.

The second part of the literature review explores the stakeholder participation process, starting from the participation level needed, planning process, selection of methods, to execution of the process. It then proceeds with few examples of utilization of popular methods in different countries.

Chapter three outlines the methodology which include the identification of suitable alternative source in specified study area, scenario building, criteria identification, participation method selection and data analysis technique.

Chapters 4, 5 and 6 present the findings and discussion based on the objectives outlined previously. Chapter 7 will conclude the whole thesis, recommend best solution to the problems and present future study opportunity.

1.7 Summary and Conclusion

Surface water might seem as cheapest source of water supply but reliability was affected by climate extremities. Alternative water supply which are more reliable and consistent are now available and with advancement of technology, these alternative supplies can be harvested at cheaper rate. Alternative supply is also suitable to be implemented at regions with high development rate where continuous water supply is important to ensure economic and agricultural growth as well as social well-being.

Selection of alternative water supply can be made through MCDM method with active stakeholder participation, elaborate weighting tools and innovative questionnaire construction which can tackle the complex cognition of decision maker and stakeholder alike.

Iskandar Malaysia, being rapidly developed is seen suitable as candidate for MCDM implementation. Alternative water supply decision making will gain advantage through the objectives of this thesis.

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