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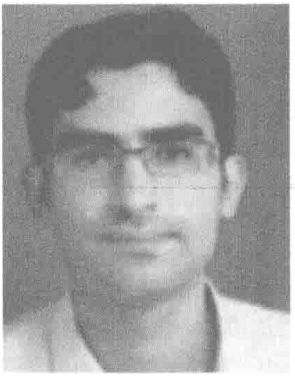

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Dr. Noorul Hassan Zardari works as Senior Lecturer at Institute of Environmental and Water Resources Management (IPASA), Universiti Teknologi Malaysia (UTM), Skudai, Malaysia. His areas of expertise include water resources management, irrigation, groundwater hydrology, decision-making and policy in water resources allocations, integration of land and water resources in watersheds, and urban water supply and management. He is author of over 40 publications.

Dr. Noorul has organized many publication workshops in which academicians, researchers, and postgraduate students from different faculties of the Universiti Teknologi Malaysia were trained on enhancing writing and publication skills. The major objectives of such workshops were to promote publication culture in the university and improve quality of the research. Dr. Noorul has reviewed about 50 journal articles which were submitted into indexed, non-indexed journals and conferences. He is also serving as Chairman of the Publication Committee, Water Research Alliance, Universiti Teknologi Malaysia where many students are assisted in their journal articles and theses write up.

Abstract

This book presents survey results on priority ranking of watershed management criteria. This survey was completed by 30 undergraduate and postgraduate students from Faculty of Civil Engineering, Universiti Teknologi Malaysia. The students were registered in various programs run by the Faculty in Semester 1, 2012. The applications of three weighting methods namely rating, ranking, and ratio are discussed in the book. We have also done data mining on some keywords using three popular scholar databases. These databases include *sciencedirect*, *scopus*, and *sciverse*. Four abbreviated keywords (MCDM, MCDA, MCA, MADM) used to represent multi-criteria decision-making were used and these three databases were searched for different popular weighting methods for a period of 13 years (2000–2012). The findings of data mining are presented in this book. Overall, this book presents a review of weighting methods applied in various multi-criteria decision-making (MCDM) methods.

Keywords Weighting methods · MCDM · Multi-criteria decision-making · Ranking · Water resources

Contents

Chapter 1
Introduction

1.1 Introduction

For last more than 20 years, multi-criteria decision making (MCDM) models have been applied to the field of natural resources management. In literature, eight areas of application of MCDM models are identified in water resources management: catchment management; ground water management; infrastructure selection; project appraisal; water allocation; water policy and the planning of supply; water quality management; and marine protected area management. MCDM models can provide solutions for complex water decision-making problems. In majority MCDM models, assigning weights to the evaluation criteria is an important step. For that, various weighting methods have been proposed in literature and applied for solving different MCDM problems. These weighting methods are classified in different ways: algebraic or statistical, decomposed or holistic, direct or indirect, and compensatory or non-compensatory. Compensatory weighting methods are used in Multi Attribute Utility (MAU) methods and non-compensatory weighting methods are used mainly in outranking methods (e.g. ELECTRE and PROMETHEE). Point allocation, ranking methods, rating methods, pairwise comparison, and trade-off analysis are some popular weighting methods. Each weighting method, however, differs in terms of accuracy, ease of use, complexity for users, and theoretical foundations and produce different sets of criteria weights. The decision for selection of a proper weighting method is a crucial step in solving a multi-criteria decision problem. Many researchers have dismissed the difficulty in measuring and meaning the criteria weights and assumes that the meaning of criteria importance is well understood by all decision makers. However, true meaning and the validity of criteria weights obtained by using different weighting procedures are important for avoiding any misuse of the MCDM models and getting reliable model results.

The main objective of the project is to evaluate different weighting methods based on their subjective and objective inputs and their influence on the model results. For that, we have hypothesized a watershed for which management plan is

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need to be developed. A priority ranking of environmental and socio-economic criteria are intend to be developed from the survey participants' preferences on various watershed management criteria and weights for criteria are elicited for further usage in MCDM models. In this study, a questionnaire was designed and administered to the undergraduate and postgraduate students of Faculty of Civil Engineering, Universiti Teknologi Malaysia. In the survey, the participants were asked to answer the question "Rank the decision criteria according to their importance (most important to least important) for a watershed management problem". The participants were asked to show their preferences by using three different weighting methods i.e. ranking, rating, and ratio weighting methods.

1.2 Problem Background

Multi-criteria decision making (MCDM) models have been applied to decisions on the management of natural resources over the last 20 years or so (Hajkowicz and Higgins 2008). As for water resources management, Hajkowicz and Collins (2007) identified eight areas of application: catchment management; ground water management; infrastructure selection; project appraisal; water allocation; water policy and the planning of supply; water quality management; and marine protected area management. Multi-criteria decision making models provide solutions for complex water decision-making problems (Goncalves and Pereira 2009; Silva et al. 2010). MCDM models are used to evaluate a finite set of alternatives with respect to multiple criteria. Alternatives are first evaluated with respect to each of the criteria to obtain criterion priority scores which are then aggregated into overall preference values (Choo et al. 1999). These scores and overall preference values may be in ordinal, interval or ratio scales. Many different methods have been proposed for assessing criteria weights which are then used to aggregate criterion priority scores. Thus, the true meaning and the validity of these criteria weights are important for avoiding misuse of the MCDM models. Unfortunately, criteria weights are often misunderstood and misused (Zhang and Wang 1992).

There are various methods to determine criteria weights, which can be classified in different ways: algebraic or statistical, decomposed or holistic, direct or indirect, and compensatory or non-compensatory. Direct methods require the respondents to compare two criteria in terms of ratio judgments and indirect procedures ask them to express preference judgments to derive criteria weights. Compensatory weighting techniques are used in Multi Attribute Utility (MAU) methods, while non-compensatory ones are used mainly in outranking methods (e.g. ELECTRE and PROMETHEE). Popular weighting methods include point allocation, ranking methods, rating methods, pairwise comparison, and trade-off analysis. Each weighting method differs in terms of accuracy, ease of use, complexity for users, and theoretical foundations and produce different sets of criteria weights. Weighting methods are either oversimplified, lacking any theoretical foundation (Hokkanen and Salminen 1997). The decision for selection of a proper weighting method is important in solving a particular multi-criteria decision making problem.

Many researchers, however, have dismissed the difficulty in measuring and meaning the criteria weights and assumes that the meaning of criteria importance is transparent and well understood by all decision makers (Choo et al. 1999).

In this study, we are providing a thorough discussion on advantages and disadvantages of some popular weighting methods. Issues like subjectivity and misuse of MCDM models in previous studies are also discussed in detail. Different non-compensatory weighting methods (i.e. direct point allocation, spontaneous ranking, and ratio methods) for eliciting criteria weights from decision makers and stakeholders are applied in a survey questionnaire in which a hypothetical watershed management problem was presented to the survey participants. The participants of the survey were asked to answer the question "Rank the decision criteria that are assumed to be important for managing any watershed". The participants arranged the watershed management criteria in order of their priority (most important to least important). After they listed them, they assigned weights to all criteria starting with a weight of 100 % for the most important criterion (Rank 1). Based on different effects of weighting methods on final results of a MCDM model and influence of subjectivity on model outcomes can be evaluated in future studies and a decision framework can be developed to assist decision makers in selecting most suitable weighting method for solving a watershed management problem.

1.3 Problem Statement

There are various methods to determine criteria weights, which can be classified in different ways: algebraic or statistical, decomposed or holistic, direct or indirect, and compensatory or non-compensatory. Direct methods require the respondents to compare two criteria in terms of ratio judgments and indirect procedures ask them to express preference judgments to derive criteria weights. Compensatory weighting techniques are used in Multi Attribute Utility (MAU) methods, while non-compensatory ones are used mainly in outranking methods (e.g. ELECTRE and PROMETHEE). Popular weighting methods include point allocation, ranking methods, rating methods, pairwise comparison, and trade-off analysis. Each weighting method differs in terms of accuracy, ease of use, complexity for users, and theoretical foundations and produce different sets of criteria weights. Weighting methods are either oversimplified, lacking any theoretical foundation (Hokkanen and Salminen 1997). The decision for selection of a proper weighting method is important in solving a particular multi-criteria decision making problem. Many researchers, however, have dismissed the difficulty in measuring and meaning the criteria weights and assumes that the meaning of criteria importance is transparent and well understood by all decision makers (Choo et al. 1999).

In this study, we have summarized all above issues related to the weighting methods and have illustrated how the selection of weighting method for a particular multi-criteria problem is important and how the final results of multi-criteria decision models were dependent on the use of different weighting method.

1.4 Objectives of the Study

The main objective of the study was to critically examine the properties of some popular weighting methods which are being currently used to establish relative importance of criteria/attributes in multi-criteria decision making (MCDM) methods to aid decision-makers in solving real-world problems. The specific objectives of the study are as follows:

- To investigate how different weighting methods affects the quality of decisions based on multi-criteria decision making models
- To develop a priority ranking of weighting methods based on their easiness, accuracy, and strong theoretical foundation
- To investigate how (and to what degree) the subjective weights affect the outcomes of the multi-criteria decision making models.

1.5 Scope of the Study

The study focuses on the weighting methods which have been frequently used to know the importance of multiple criteria in multi-criteria decision making methods. In this study, our more focus was on those weighting methods which were used in solving multi-criteria decision problems related to water resources and hydrology. The data was extracted from three popular online databases (sciencedirect, sciverse, and scopus) for a period of only 13 years (i.e. 2000–2012). A survey on three weighting methods (rating, ranking, and point allocation) was completed from small groups of undergraduate and postgraduate students registered at Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai campus.

1.6 Significance of the Study

Literature on weighting methods is very rich. However, summarizing them according to their effects on final model outputs is missing in the literature. We have attempted to quantify these effects through this study. The findings of the study could assist decision makers to select the best weighting method for their studies according to human resources, funds, and time availability factors. We emphasize that the weighting methods applied in solving multi-criteria problems in water resources and hydrology were only listed in this study. Weighting methods used in solving problems outside of water resources and hydrology are excluded from this study.

1.7 Chapter Summary

This chapter presents an overview of this study. It includes a brief introduction, background of the study, the problem statement, the study objectives, the scope of the study and its significance.

1.8 Report Organization

This report is organized into four chapters. This chapter presents an introduction and the background of the study, which is followed by the problem statement, scope of the study and the significance of the study. Chapter 2 is limited to literature review on weighting methods applied in multi-criteria decision making methods. A brief introduction of multi-criteria decision making methods is also provided in this chapter. Chapter 3 mostly discusses the methodological part of the study. Here we have given the procedure for extracting data using three main online databases. A framework of the applied methodology is also presented in this chapter. Results of data analysis and interpretation of data mining and survey results are also given in this chapter. Chapter 4 covers conclusions and main findings of the study. Recommendations for future work are also given in this chapter.